Spectral opportunity analysis of the terrestrial television frequency bands in South Africa

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Abstract

The sharing of the terrestrial TV frequency spectrum with Secondary Users (SUs) is presently the focus point of numerous research efforts worldwide. In many regulatory domains, contiguous blocks of VHF and UHF spectrum are available for exclusive use by the terrestrial TV broadcasting incumbents. However, this notion is currently challenged by the spectrum management paradigm of Dynamic Spectrum Access (DSA), advocating that this spectrum may be shared on a dynamic basis with SUs.

The migration of analogue terrestrial TV to Digital Terrestrial Television (DTT) has also catalysed the notion that the terrestrial TV frequency spectrum will no longer be exclusively used for terrestrial broadcasting. Some administrations have already embraced this technology, reforming spectrum policy to allow unlicensed secondary access to the Spectral Opportunities (SOs) present in the terrestrial TV frequency bands. The Independent Communications Authority of South Africa (ICASA) has expressed early interest in the possibilities of TV white space technology and its possible utility in exploiting the SOs that exist in the terrestrial TV frequency bands.

Core to the issues mentioned above is the quantification of the Spectral Opportunity (SO) available. To this end, the work presented in this thesis gives a quantified estimate of the SO available in South Africa. This work is the first of its kind for the South African environment and uncovers new knowledge regarding SO in South Africa.

SO is analysed and quantified on provincial and national level for three discrete points in time: before the start of dual-illumination, during dual illumination and after analogue switch-off.

A system model that is able to produce the required geo-referenced field strength coverage and SO maps is conceptualised and implemented. A complete standards compliant model is implemented from scratch, verified and validated, with design decisions specific to the South African context. The analysis methodology is developed with rigour. The construction of the TV transmitter database, definition of incumbent protection criteria and development of the required analysis metrics to quantify SO are presented.

SO in the VHF and UHF terrestrial TV frequency bands is quantified by expressing SO in terms of the number of available channels, weighted respectively by land area and population density. The analysis results indicate that significant SO is available for exploitation by TV white space devices in the terrestrial TV spectrum in South Africa.

The effects of radio astronomy advantage areas on the SO available are also investigated. The probability of finding contiguous channels in the Very High Frequency (VHF) and Ultra High Frequency (UHF) bands is also quantified. A comparative study, comparing the SO for South Africa with related work in Europe and the United States of America (USA), is also performed. Finally, maps that visualise the SO available are constructed for the three discrete time periods evaluated.

Keywords: *Analogue switch-off, Dynamic Spectrum Access (DSA), Digital dividend, Secondary Access, Spectral Opportunity (SO), TV white space*

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List of Acronyms

AGL Above Ground Level

AMSL Above Mean Sea Level

BER Bit Error Rate

CAA Civil Aviation Authority

CAGR Compound Annual Growth Rate

CCDF Complementary Cumulative Distribution Function

CDF Cumulative Distribution Function

CD:NGI Chief Directorate: National Geospatial Information

CEPT European Conference of Postal and Telecommunications Administrations

C/N Carrier to Noise Ratio

CR Cognitive Radio

DAB Digital Audio Broadcast

DoC Department of Communications

DECT Digital Electronic Cordless Telephone

DEM Digital Elevation Model

DSA Dynamic Spectrum Access

DSM Dynamic Spectrum Management

DTT Digital Terrestrial Television

DVB-T Digital Video Broadcast-Terrestrial

DVB-T2 Digital Video Broadcast-Terrestrial version 2

DVB-H Digital Video Broadcast-Handheld

EA Enumeration Area

ECC European Communications Committee

ERP Effective Radiated Power

EIRP Effective Isotropic Radiated Power

FCC Federal Communications Commission

GE-06 Geneva 2006

GIS Geographical Information System

GPS Global Positioning System

GSM Global System for Mobile Communications

ICASA Independent Communications Authority of South Africa

ICT Information and Communications Technology

IMT International Mobile Telecommunications

ISM Industrial, Scientific and Medical

ITM Irregular Terrain Model

ITU International Telecommunication Union

ITU-R International Telecommunication Union Radiocommunications Sector

LTE Long Term Evolution

MFN Multi-Frequency Network

OSA Opportunistic Spectrum Access

PU Primary User

PMSE Programme Making and Special Events

QEF Quasi Error Free

QoS Quality of Service

RAM Random Access Memory

RF Radio Frequency

RFI Radio Frequency Interference

RRC-06 Regional Radio Conference 2006

SU Secondary User

SABC South African Broadcasting Corporation

SDR Software-Defined Radio

SFN Single-Frequency Network

SKA Square Kilometre Array

SO Spectral Opportunity

SRTM Shuttle Radar Topography Mission

TCA terrain clearance angle

TV television

UHF Ultra High Frequency

UK United Kingdom

UMTS Universal Mobile Telecommunications System

USA United States of America

VHF Very High Frequency

WLAN Wireless Local Area Network

WRAN Wireless Regional Access Network

WRC-07 World Radio Conference of 2007

List of Symbols

t_A	Time before dual illumination
t_{DU}	Time during dual illumination
t_D	Time after dual illumination
E_{min_a}	Minimum electrical field strength for the analogue TV service
E_{min_f}	Minimum electrical field strength for the fixed mode digital TV service
E_{min_p}	Minimum electrical field strength for the mobile mode digital TV service
ψ	Erosion margin
$E_{protect}$	Field strength at the co-channel protected contour
$E^{'}_{protect}$	Field strength at the adjacent channel protected contour
$x_i(c,t)$	Co-channel availability decision for grid cell i, channel c and time t
$x^{'}_i(c,t)$	Adjacent channel availability decision for grid cell i, channel c and time t
$\bar{s}_a$	Mean available channels weighted by area for the co-channel availability decision
$\bar{s}^{'}_a$	Mean available channels weighted by area for the adjacent channel availability decision
$\bar{s}_p$	Mean available channels weighted by population for the co-channel availability decision
$\bar{s}^{'}_p$	Mean available channels weighted by population for the adjacent channel availability decision

Chapter 1

Introduction

Chapter 1 serves as an introduction to the research work. A brief contextualisation of the research problem is given to motivate the relevance and originality of the envisaged contribution. The research goal is then formulated, the methodology of the study is discussed and an overview of the thesis is provided in conclusion.

1.1 Contextualisation

The sharing of the terrestrial television (TV) frequency spectrum with Secondary Users (SUs) is the focus point of numerous present research efforts worldwide. Presently, in many regulatory domains, contiguous blocks of Very High Frequency (VHF) and Ultra High Frequency (UHF) spectrum are available for exclusive use by the terrestrial TV broadcasting incumbents. However, this notion is currently challenged by the spectrum management paradigm of Dynamic Spectrum Access (DSA), advocating that this spectrum may be shared on a dynamic basis with SUs for communication and other purposes.

Some administrations, such as the United States of America (USA), have already embraced this technology reforming their spectrum policy to allow for unlicensed secondary access to the terrestrial TV frequency bands [11]. Other administrations are still weighing up the benefits or are in the process of determining the regulatory framework under which DSA capable devices will be allowed to function. The Independent Communications Authority of South Africa (ICASA) has expressed early interest in the possibilities of this technology and its possible utility in exploiting the terrestrial TV frequency spectrum [12], [13].

The migration of analogue terrestrial TV broadcasting to Digital Terrestrial Television (DTT) has also catalysed the notion that the terrestrial TV frequency spectrum will no longer be exclusively used for terrestrial broadcasting. After analogue switch-off, the digital dividend will be released (790-862 MHz), currently earmarked for the International Mobile Telecommunications (IMT) service [5].

Technological advances in the fields of Software-Defined Radio (SDR) and Cognitive Radio (CR) make it possible for secondary communication networks to co-exist in the same spatial, temporal and frequency domains as the terrestrial TV spectrum incumbent. Furthermore, the UHF and higher VHF spectrum has favourable propagation characteristics, such as good penetration through walls, buildings and foliage. These characteristics are also beneficial for data communication networks [14].

Many researchers and industry professionals share the view that spectrum management and regulatory policy are the cause of an artificial spectrum scarcity. Spectrum that is not efficiently utilised is in many cases tied up in exclusive use licenses. The licensing regime prohibits the utility of the spectrum to be maximised. Radio spectrum is therefore not a scarce resource; it is just inefficiently allocated by the spectrum management paradigm in use. Aforementioned statement is quantified by the numerous spectrum occupancy measurement studies that have been performed at various locations across the world [15].

1.1.1 Demand for increasing data rates

Worldwide, wireless communication systems are put under more and more pressure to cope with the growing data requirements of current and future wireless devices and services. The Cisco Visual Networking Index forecasts for the period 2009 to 2014 give some perspective on the bandwidth requirements that mobile devices will place on radio spectrum resources in the years to come [16]:

- Data traffic is expected to double every year from 2009 through to 2014, increasing a total of 39 times in this time period. This translates into a Compound Annual Growth Rate (CAGR) of 108% over the six-year period.
- By 2014, 66% of the mobile data traffic will be video. This translates into a CAGR of 131%, showing the highest growth figures of all mobile application categories for the forecast period.

The latest Cisco Visual Networking Index Mobile forecast estimates South Africa's mobile data traffic growth at 132% for 2011. Furthermore, it is forecast that mobile data traffic will grow 49-fold from 2011 to 2016 [17].

These forecasts highlight the fact that the use of wireless devices and accompanying wireless services will continue to proliferate, placing immense demands on the amount of bandwidth required. As mobile data is transmitted via the wireless medium, the increase in data bandwidth requirements translate into an increase in spectrum bandwidth required. Furthermore, the type of data traffic also places increasing Quality of Service (QoS) requirements on the underlying wireless infrastructure.

1.1.2 Radio frequency spectrum regulation

Currently, three approaches to Radio Frequency (RF) spectrum regulation exist [18,19]:

- Licensed spectrum for exclusive use
- Licensed spectrum for shared use
- Unlicensed spectrum

In licensed spectrum for exclusive use a licensee obtains exclusive rights for a specific spectrum. The licensee's rights are protected and enforced by the regulator. Examples are the licenses awarded to Global System for Mobile Communications (GSM) network operators.

The licensed spectrum for shared use is spectrum that is restricted for use to a specific technology. Examples are the bands for ship-to-shore communication and Digital Electronic Cordless Telephone (DECT) systems.

Unlicensed spectrum is available for use to all radio systems conforming to the relevant regulatory standards. Typical regulations include restrictions on the maximum power at which a transmitter may transmit. The regulator offers or enforces no protection from interference in the unlicensed bands. Examples are devices which operate in 2.4 GHz Industrial, Scientific and Medical (ISM) band such as Wireless Local Area Network (WLAN) clients and access points.

Historically, regulators worldwide have made use of the abovementioned three approaches to regulate spectrum. A fourth spectrum management paradigm, namely open spectrum, defines a minimum set of rules and etiquettes under which users of the spectrum are allowed to utilise the spectrum [18, 19]. The rules and etiquettes are in place to merely promote sharing, and not police the spectrum. This approach does however have many technical challenges for the devices that will operate in the RF spectrum. This approach is also not favourable for the protection of legacy services, and therefore remains an idealistic paradigm.

1.1.3 Dynamic Spectrum Access

Dynamic Spectrum Access (DSA) is defined as "The real-time adjustment of spectrum utilisation in response to changing circumstances and objectives" [20]. A device capable of DSA needs to be aware of the radio spectrum environment and make decisions about when and where in the spectrum to transmit or receive, in order to meet the required objectives, which in the case of DSA are:

- Efficient spectrum utilisation.
- Not cause harmful interference to incumbents of the spectrum.

Core to the functionality of DSA is the concept of spectrum sharing in order to increase the efficiency with which devices use and access spectrum. Spectrum can be shared horizontally between users with similar regulatory rights. For example, this is employed in current regulatory regimes through the unlicensed spectrum use model [18], [21]. Vertical or hierarchical spectrum sharing is also possible, and refers to a type of spectrum sharing where some radios have higher precedence in certain spectrum than others [18]. This type of spectrum sharing distinguishes between Primary Users (PUs) and SUs of the spectrum. A further taxonomy of the different DSA paradigms proposed is presented in [21].

The PU or incumbent has preferential access to an allocated part of the spectrum and must be protected against interference from other users of this spectrum. Some bands, however, show low spectrum occupancy rates for PUs. These bands can be utilised by SUs when not in use by the PU. This approach of DSA is termed Opportunistic Spectrum Access (OSA). Spectrum is opportunistically exploited by SUs until the required spectrum is required by the PU again. A key concern with this approach is incumbent interference protection.

For the purposes of this work, the hierarchical access model is considered, making use of spectrum overlay as originally proposed by Mitola [22]. In this model, the spectrum incumbent is also called the PU. An SU may use the PU's spectrum when the PU is not utilising the spectrum. However, the SU may only use the PU's spectrum subject to fulfilment of the following conditions:

- The SU must accept harmful interference from the PU.
- The SU may not cause harmful interference to the PU.

In this context Dynamic Spectrum Management (DSM) is also of importance, as new ways of accessing and utilising spectrum necessitate the need for new ways of dealing with spectrum policy. Some of the concepts that have been explored include spectrum commons, markets and trading [23], [15].

1.1.4 Definition of Spectral Opportunity (SO)

A Spectral Opportunity (SO) can be defined as the existence of a frequency band segment, satisfying an availability criterion, that DSA or OSA capable devices can exploit for their communications purposes [20]. In terms of DSA, the availability criteria are typically as follows:

- The SU must not cause harmful interference to the PU (incumbent) transmitters or receivers.
- The SU must accept interference from the PU (incumbent) transmitters and receivers.

To complete the definition of an SO, a definition of what constitutes harmful interference is required. Furthermore, the availability criterion needs to be expressed in a quantitative manner. These topics will be elaborated upon in chapter 2.

Currently, the main techniques for determining and exploiting SOs are spectrum sensing, geolocation databases and beacons [24]. In spectrum sensing, the spectrum is sensed to determine whether a PU is using a given part of the spectrum. From the sensed samples it is determined whether the specified criterion holds for an SO to exist. Geolocation databases use knowledge about the geographical location of PU and SU devices in conjunction with a Geographical Information System (GIS) to determine where in the frequency band and at what geographical location SOs exist. The beacon technique allows SUs to transmit only under the receipt of a control signal or beacon that identifies available channels in the SU's service area.

1.1.5 Spectrum occupancy measurements

Spectrum occupancy measurements provide an answer to the question of whether there is actually spectrum available on a temporal basis at a given location. Numerous spectrum occupancy studies have been carried out in various locations around the world. It is an important first step towards the deployment of DSA-capable systems, as temporal spectrum occupancy characteristics differ greatly between measurement sites. This is expected, however, because spectrum occupancy is currently understood to be a function of geographic location, time, user profile and population density [25], [26], [27]. These relevant spectrum occupancy studies and their results will be elaborated upon in chapter 2.

However, all the studies suggest that, on average, most parts of the spectrum are unoccupied. Spectrum is not heavily used; it is inefficiently allocated. Unfortunately, there is no mechanism in current regulatory policies that allows for the dynamic or opportunistic use of underutilised spectrum, and therefore an artificial spectrum scarcity exists.

1.1.6 Spectral Opportunity (SO) modelling

An alternative approach to quantify the amount of spectrum available for secondary reuse is through SO modelling and analysis. Spectrum occupancy measurement campaigns are very useful for obtaining real world results of spectrum utilisation. However, because of the costs and specialised equipment involved in performing these measurements, the geographic region studied is usually limited to a few measurement sites.

Spectrum occupancy measurement studies in general therefore fail to capture or quantify the amount of spectrum available on national or provincial level. To this end, SO modelling provides an attractive alternative. Data availability about the location of PU transmitters and receivers, in combination with a valid propagation model, can be used to predict the coverage areas of the PU service. By applying the availability criterion of an SO to the predictions, an SO map can be derived for the region of interest. This approach makes it feasible to quantify the amount of available spectrum over a larger geographic extent than what is possible with spectrum occupancy measurement studies.

The modelling approach has been applied in related work to quantify the SO available in the terrestrial TV frequency bands for the USA, Europe and Germany and other administrations [1], [10], [28]. The SOs in the terrestrial TV frequency bands are also referred to as TV white space. The quantification of TV white space or SOs in general are an important and relevant research topic. It provides an answer to whether it is viable and necessary for policy makers to amend the current regulatory framework to allow DSA technologies to penetrate the market and utilise some parts of the RF spectrum.

Secondary access to the terrestrial TV frequency bands is especially relevant, as standardisation initiatives such as IEEE 802.22 [29] are already in place, and deployed networks using these devices are already operational in some administrations [11]. In South Africa, ICASA has expressed early interest in the possibilities of this technology and its possible utility in exploiting the terrestrial TV frequency spectrum [12], [13].

However, to the best of the author's knowledge, a quantitative estimate of the SO available in South Africa has not been presented, and this is supported by the literature presented in chapter 2 of this thesis.

1.2 Research goal

The goal of the research conducted in this thesis is to provide a quantitative estimate of the SO available in the terrestrial TV frequency bands of South Africa on provincial and national level for the following three discrete time periods:

- The SO before the start of the dual illumination period, i.e. when only the analogue service was operational.
- The SO available during the dual illumination period.
- The SO available after analogue switch-off, i.e. the digital service only.

1.3 Research contributions

The way in which a unique contribution to knowledge is made in this study is through the critical analysis of existing information in a new way. New facts, information and insight on Spectral Opportunity (SO) are obtained through the critical analysis of information available from the Final Terrestrial Broadcasting Plan of 2008 [5] and the ICASA TV transmitter database.

This work is the first of its kind for the South African environment and uncovers new knowledge regarding Spectral Opportunity (SO) in South Africa. Furthermore, the work presented gives a quantified estimate of SO available for the whole of South Africa. More specifically the following contributions are made:

1. A geographically referenced field strength coverage map for every terrestrial TV channel in South Africa is produced.
2. From the field strength coverage map, a geographically referenced SO map for every terrestrial TV channel in South Africa is produced.

3. A quantification of the available SO on provincial and national level weighted respectively by land area and population density is presented.

Note that in order to do this, a complete standards compliant model is implemented and validated, with design decisions taken specific to the South African context.

1.4 Issues addressed and methodology

To work towards the research goal, an outline of the issues that need to be addressed is required. Together with the outline, the methodology for executing each of these issues is also discussed.

Study of the relevant literature: The case for an original contribution to knowledge has to be supported by factual evidence from the literature. The necessary background information pertaining to SO modelling, the digital dividend and analogue switch-off also needs to be elaborated upon.

Development of the system model: This entails the development of a conceptual model of the target system. The reasons for design decisions taken must be motivated or investigated. A propagation model needs to be incorporated into the system model to facilitate field strength predictions. The system model implementation particulars needs to be discussed. To this end the system model presented in this thesis incorporates the International Telecommunication Union Radiocommunications Sector (ITU-R) P.1546 propagation model, compliant with version 4 of ITU-R P.1546 [30].

Verification and validation of the system model: The constituting elements of the system model need to be verified to ensure that the output provided by the model can be deemed correct. The output of the system model must be shown to be valid and fit for the purpose for which the system model will be used.

Method of analysis: The experiments that need to be performed to analyse the SO in a required frequency band need to be designed and formulated. Motivations for the system parameters chosen need to be given. Furthermore, the metrics required to fully analyse the required properties of the system under study need to be developed.

Analysis of results: The results obtained by following the method of analysis need to be critically evaluated according to the required analysis metrics. The evaluation of these metrics will allow for the quantification of SO on provincial and national level in South Africa.

Reflect on the research goal: The results obtained by addressing the aforementioned list of issues must be compared to the goals of the original research question. The manner in which the work presented addressed the research goal must be evaluated and stated.

1.5 Thesis overview

The rest of the thesis is organised as follows: Chapter 2 details the literature studied. Chapter 3 describes the conceptual design and implementation details of the system model. Chapter 4 details the verification and validation of the system model. Chapter 5 elaborates on the methodology followed to analyse the SOs. The analysis metrics and methods are also developed in this chapter.

In chapter 6, the SO analysis results of South Africa on provincial and national level are presented. Finally, chapter 7 provides concluding remarks and recommendations for future research.

Chapter 2

Literature study

This chapter provides a overview of the literature applicable to the research problem. A brief overview of how administrations are exploiting the digital dividend is provided. Special attention is given to factors influencing SO availability in South Africa. Relevant spectrum occupancy studies in the international and local context are discussed. Related work in the field of SO modelling is critically evaluated. Finally, the case for a unique contribution, as evident from the literature, is made.

2.1 SO in the terrestrial TV frequency spectrum

The migration from analogue TV to DTT has opened the possibility to reuse previously underutilised spectrum in the terrestrial TV frequency bands for many countries around the world. The migration to DTT brings about the opportunity to share the terrestrial TV spectrum with other secondary services, be it through the digital dividend or TV white spaces.

2.1.1 Digital dividend

DTT can accommodate the same number of channels in less spectrum than is possible with analogue TV due to the better spectral efficiency of DTT. After digital migration has been completed and all analogue transmitters have been switched off, spectrum previously used for analogue terrestrial TV will be released. This release of spectrum is referred to as the digital dividend. With DTT channel reshuffling and spectrum re-farming practices, the digital dividend can be released as a contiguous block of spectrum, which can be utilised for other purposes.

The first digital dividend (790-862 MHz or channel 61-69) is currently earmarked for the IMT service [5], [31]. Digital dividend 1 will be allocated to IMT services from 17 June 2015, when International Telecommunication Union (ITU) region 1 countries should have complied with the requirements of the Geneva 2006 (GE-06) agreement [4]. GE-06 requires region 1 members to complete the migration to DTT and switch-off analogue transmitters before the due date mentioned above. Member countries may still continue to operate analogue transmitters after this date; however, these analogue transmissions will no longer be afforded protection from harmful interference after the set date.

Future channel reshuffling of the DTT service to below channel 49 will see the release of the so-called digital dividend 2 (694-790 MHz or channel 49-60), which is also earmarked to be re-purposed for IMT [32], [13].

2.1.2 TV white space

TV white space is defined in [33] as ``a label indicating a part of the spectrum, which is available for a radiocommunication application (service, system) at a given time in a given geographical area on a non-interfering/non-protected basis with regard to other services with a higher priority on a national basis.˝

Traditionally, terrestrial TV broadcast networks have been planned as Multi-Frequency Networks (MFNs). This is done to facilitate the international coordination of frequencies across the physical borders of administrations. This has the effect that certain TV channels are not used in certain geographical areas so as to avoid interference with terrestrial broadcast services in adjacent regions. These unused channels or SOs are also known as TV white space, and can be reused by secondary services in the given geographical area.

For the purposes of this thesis an explicit differentiation between the spectrum destined for the digital dividend and the TV white space is not made. The digital dividend and TV white space offer the ability to reuse previously unavailable spectrum for purposes other than broadcasting, and are therefore considered SOs.

2.2 Overview of DSA to terrestrial TV frequency bands

In this section a brief overview is given of the administration's status regarding utilisation of the digital dividend and the regulatory approach to secondary access of the terrestrial TV spectrum. The USA, Europe and South Africa are discussed. The discussion is by no means exhaustive, and additional context regarding other administrations can be found in [34] and [2].

2.2.1 USA

The USA falls under ITU region 2, and completed digital migration from analogue NTSC to digital ATSC on 23:59, June 12, 2009. The legacy UHF TV frequency channel numbers and frequency ranges are shown in table 2.1. Channels have a bandwidth of 6 MHz each.

During digital migration, all DTT channels were moved to channels 14-51. Channels 52-62 (65 MHz in total) form part of the digital dividend and have been auctioned off for fixed/mobile use. Channels 52-69 still contain low power TV repeater stations, and are in the process of being migrated to digital. The FCC intends to relocate the remaining channels as well, which will result in a total digital dividend of 108 MHz [35].

Table 2.1: Legacy UHF TV channel assignments for the USA [3]

Channel number	14-51	52-62	63-69
Frequency range (MHz)	470-698	698-763	763-806

The Federal Communications Commission (FCC) passed a ruling on November 14, 2008, to allow unlicensed access to TV white space for CR devices. The initial ruling called for CR devices to be able to either sense or make use of a geolocation database to determine white spaces in their region. The Second Memorandum Opinion and Order of 23 September 2010 changed this requirement so that a device with geolocation and database access capability need not implement spectrum sensing [11].

The FCC is, under this ruling, currently allowing for unlicensed secondary access to the entire frequency band shown in table 2.1. Furthermore, secondary access is also allowed to VHF channels 2, 5, 6 and 7-13 [36].

The FCC's drive for spectrum liberalisation, which is fuelled by the strategic objectives of America's broadband plan [37], has spurred the development of technical standards for TV white space devices, which is the focus of the IEEE 802.22 standard for cognitive Wireless Regional Access Networks (WRANs) [29].

2.2.2 Europe

Countries in Europe fall under ITU Region 1 together with the Middle East, Parts of Asia and Africa. The broadcast frequency assignments for greater Europe are shown in table 2.2, with channel bandwidths of 8 MHz each in UHF and 7 MHz in VHF. Of the 26 European countries, 22 have already switched analogue broadcasts off in compliance with GE-06 [38].

As discussed in section 2.1.1, it was decided at the World Radio Conference of 2007 (WRC-07) that digital dividend 1 will be allocated to IMT services from 17 June 2015, when digital migration should be completed by all member countries.

Table 2.2: Terrestrial TV channel assignments for Europe [4]

Band	Channel number	Frequency range (MHz)	Range designation
III	5-12	174-230, 246-254	VHF
IV	21-34	470-582	UHF
V	35-69	582-862	UHF

The harmonisation of frequency arrangements and least restrictive technical parameters for the use of digital dividend 1 is the focus of the CEPT 30 and CEPT 31 reports [39], [40]. A detailed discussion of the proposed allocation is presented in [41]. The digital dividend 1 will be auctioned off.

With regard to secondary access, the United Kingdom (UK) regulator, Ofcom, has developed a different regulatory framework for determining TV white space [42]. Currently, the approach of requiring geolocation capability from the CR device is favoured. This approach also forms the basis of the methodology that will be used for the larger European regulatory framework [43].

2.2.3 South Africa

South Africa also falls under ITU region 1. The terrestrial TV channel assignments with their corresponding frequency ranges and ITU band allocation for South Africa are shown in table 2.3. All channels have a bandwidth of 8 MHz each. The South African assignment differs a bit from the European assignments for band III, as an additional channel 13 is added. Furthermore, channel 69 is not in use in South Africa for terrestrial TV, as those frequency allocations are currently used for fixed links [44].

The signal distributor Sentech has reported that at the end of March 2012, 60% of the population was covered by a digital TV signal [45]. The signal distribution roll-out target is to have 80% of the population covered by end of March 2013.

Digital migration is now to the Digital Video Broadcast-Terrestrial version 2 (DVB-T2) standard, instead of Digital Video Broadcast-Terrestrial (DVB-T), for which the Regional Radio Conference 2006 (RRC-06) channel assignment plans were originally made. The mobile DTT service uses the Digital Video Broadcast-Handheld (DVB-H) standard. In the strategic plan for 2011-2014 [46], issued by the Department of Communications (DoC), it is set forth that the government will provide assistance to poor households through subsidising set-top-boxes as part of the digital migration process.

Table 2.3: Terrestrial TV channel assignments for South Africa [5]

Band	Channel number	Frequency range (MHz)	Range designation
III	4-11, 13	174-238, 246-254	VHF
IV	21-34	470-582	UHF
V	35-68	582-854	UHF

The final Digital Migration Regulations of 2012 [47] has also been published to enforce the migration process from analogue to digital. The switch-over period will be referred to as the performance period. During this time all licensees will simulcast all channels provided by them in digital and analogue formats. South Africa is following a dual-illumination approach to phase out the analogue service.

The Digital Migration Regulations of 2012 provide the following roll-out targets for the public broadcaster, i.e. the SABC, for population penetration from the start of the performance or switch-over period:

- 74% in 6 months.
- 95% at the end of the performance period.

The roll-out targets for other broadcasters will be subject to their license conditions with ICASA [47].

The Final Terrestrial Broadcast Plan [5] details the frequency assignments that will be used during the performance period. All analogue channels remain on their designated frequencies. This has the implication that band III is nearly fully utilised on all transmitter stations and therefore DTT channels are assigned in band IV and V. The fixed DTT service will be assigned to multiplex 1 and 2, whilst the mobile DTT service will assigned to multiplex 3 and 4 [48]. A multiplex refers to group of video streams that are multiplexed to be transmitted within a single DVB-T channel. Streams are demultiplexed again at the receiver.

After the performance period, dual illumination will cease and all the analogue channels will be switched off. The remaining transmitters in channel 61-68 will be relocated to lower channels, so that digital dividend 1 can be released for IMT [5]. ICASA estimates that 300 MHz will be made available after the dual illumination period ceases [5]. Furthermore, all spectrum freed up after the analogue switch-off will be forfeited to ICASA [47].

Note that whilst many administrations had to do a hard or phased soft switch-over from analogue to digital, South Africa has enough spare spectrum in the terrestrial TV bands to implement dual illumination followed by a soft analogue switch-off. This points to the promise that South Africa may have numerous SOs available for secondary access.

In the Final Terrestrial Broadcasting Plan of 2008, the date originally set for the analogue switch-off was November 2011 [5]. However, at the time of writing, the performance period has yet to commence. With the Digital Migration Regulations finalised, it is expected that the performance period will commence somewhere in 2013.

With regard to the digital dividend, the DoC has published draft policy directions on exploitation of the digital dividend for public consultation in December 2011 [12]. The two-page document outlines that digital dividend 1 will be allocated to IMT, as was agreed upon at WRC-07 and is being done in Europe and other Region 2 countries.

Furthermore, an inquiry into rational and efficient exploitation of the remaining spectrum and future digital dividend 2 is called for. The ``possible use of white space technologies´´ is also listed as an agenda point. It is envisaged that the digital dividend debate will gain momentum once the performance period has commenced, as this will give a better indication of a realistic analogue switch-off date.

Secondary access to the terrestrial TV frequency bands is gaining increased attention and awareness in South Africa. As discussed in section 1.1.6, ICASA has expressed early interest in the possible utility of DSA in exploiting the terrestrial TV frequency spectrum [12], [13]. To this end, ICASA is working in collaboration with key stakeholders on the launch of a white space trail network in the greater Cape Town area [49]. At the time of writing the network equipment was in the process of being installed and configured [50].

2.3 Factors affecting SO in South Africa

In addition to the terrestrial TV transmitters and receivers, there are other devices also operating in the terrestrial TV frequency bands that warrant protection. The radio astronomy service also operates in the same frequency bands. Wireless microphones and other services ancillary to programme making and broadcasting may also use some parts of the same frequency band [44]. Abovementioned services are also referred to as Programme Making and Special Events (PMSE) equipment.

Firstly, channel 38 (604-616 MHz) is reserved for radio astronomy use in certain geographical areas [44]. Secondly, PMSE equipment may use 173.7-175.1 MHz (lower band edge of channel 4), albeit these activities must be coordinated and licensed [44].

South Africa and Australia have recently been jointly awarded the bid to host the Square Kilometre Array (SKA). The SKA is afforded protection from harmful Radio Frequency Interference (RFI) by other services through the Astronomy Geographic Advantage Act [51]. Section 22 of the act deals with restrictions on radio frequency interference in core and central astronomy advantage areas. This is likely to affect terrestrial broadcast services and users of wireless spectrum in astronomy advantage areas. Users of radio spectrum will be bound by law to comply with section 22 of the act. These regulations will also have an influence on the SO available in the terrestrial

TV bands pending to the outcome of regulatory decisions made in line the with the act.

Some of the legislation which will be enforced by the Astronomy Geographic Advantage Act is still under development. In February 2010, the whole territory of the Northern Cape Province, excluding Sol Plaatje Municipality, was declared an astronomy advantage area [52]. This advantage area is subdivided into a core, central and coordinated advantage area. The expanse of the central and coordinated areas depends on the frequency range.

In August 2010, a total geographical area of 13406.8099 hectares on and around the core site for the SKA radio telescope was declared a core radio astronomy advantage area by the act [53]. Regulations are now in place that prohibit the use of any RF equipment without the necessary permissions in the core radio astronomy advantage area [54]. Furthermore, the protection criteria for the RFI levels to the radio astronomy service have also been established [55]. The interference level is measured at the reference point within the core advantage area, at 30.7148° S and 21.388° E.

Regulations on acceptable RFI in the central and coordinated astronomy advantage areas were at the time of writing not yet in effect [56], [57]. The proposed Karoo central radio astronomy advantage area is divided into areas 1, 2 and 3 for frequency bands 70-1710 MHz, 1.71-6 GHz and 6-25.5 GHz respectively. Of interest to our work is the proposed central advantage area 1 and coordinated advantage area 1. These areas, together with the core radio astronomy advantage area, are shown in figure 2.1.

The draft regulations stipulate that any transmissions within the central advantage area may not cause RFI at the core radio astronomy advantage area exceeding the threshold level prescribed in [55], unless exemption or concession has been granted by the managing authority. Furthermore, transmitters that exceed an Effective Radiated Power (ERP) of 60 dBm or 1 kW from within the coordinated radio astronomy advantage area will require additional coordination. Coordination of high power TV transmitters will therefore be required.

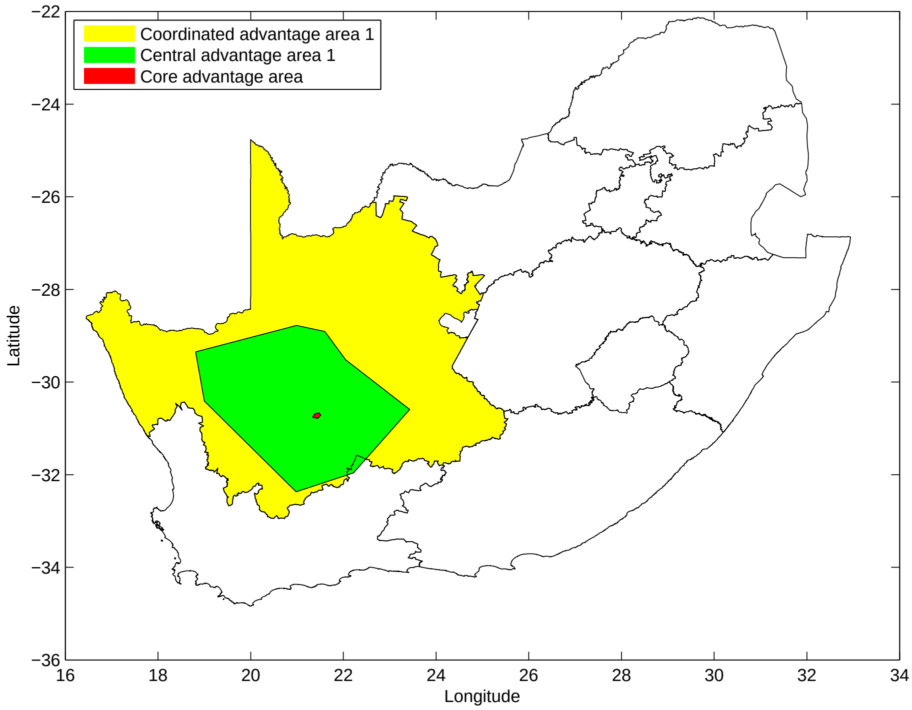


Figure 2.1: Astronomy advantage areas

2.4 Spectrum occupancy measurements

Recall from section 1.1.5 that spectrum occupancy measurement studies provide an answer to the question of whether there is actually spectrum available on a temporal basis at a given location. In this section, a few noteworthy spectrum occupancy studies and their results are presented to support the relevance of investigating the occurrence and nature of SOs in the RF spectrum. A few international studies and their findings are highlighted, after which the local studies already performed are discussed.

2.4.1 International studies

In [58] spectrum occupancy measurements were made at an indoor and outdoor measurement site in urban Auckland, New Zealand. Measurements were taken in the 806 MHz - 2750 MHz band. The study reports an average outdoor spectrum occupancy of 6.2% whilst the average indoor spectrum occupancy is 5,7%. The authors categorise the GSM bands as black spaces due to the heavy utilisation of spectrum, and therefore little possibility for SO in these bands exists.

In [25] outdoor spectrum occupancy measurements were made in Singapore in the 80 MHz - 5.85 GHz band. The average occupancy was found to be 4.54%, with high occupancy levels in the broadcasting and 900 MHz GSM bands. Radar and the 1.8 GHz UMTS bands showed moderate occupancy, whilst all other bands showed low levels of occupancy.

In [59] outdoor measurements were made in Chicago, Illinois, in the 30 MHz - 3 GHz band. The average spectrum occupancy was found to be 17.4%. The study found that considerable parts of the spectrum were unoccupied for extended periods of time, most notably spectrum bands used for broadcasting services. Furthermore, the temporal nature of the spectrum occupancy in these bands suggests that a DSA device need not be highly frequency agile to exploit the SOs that exist.

In [60] the authors report on the long-term spectrum occupancy statistics that have been recorded at their spectrum observatory in Chicago, Illinois, in the 30 MHz - 3 GHz band. They report the average occupancy for the band of interest at 18%, 15% and 14% respectively for 2008, 2009 and 2010. The time versus spectrum occupancy plots (waterfall plots) also highlight the SO that exists in the frequency bands used for the broadcasting service.

In [26] spectrum occupancy measurements were made at an indoor and outdoor measurement site in Aachen, Germany in the 20 MHz - 6 GHz band. It was found that the 3 GHz - 6 GHz band was rarely occupied at both measurement sites. Very high levels of ambient and man-made noise were detected at the outdoor measurement site between 20 MHz and 3 GHz, resulting in a spectrum occupancy of almost 100%. However, the indoor measurement site showed considerable SO in the 1 GHz - 3 GHz band, with an average occupancy of 32%.

2.4.2 Local studies

In South Africa, an extensive RFI survey was conducted as part of the bid to host the SKA telescope [61, 62]. The survey was conducted over 12 months and focused on interference measurements for radio astronomy purposes. The results indicate that spectrum is most heavily utilised in the 900 MHz GSM band, 1.8 GHz UMTS band, 2.4 GHz ISM band and point-to-point links at 4, 5, 6 and 7 GHz respectively.

In [63], Masonta et al. spectrum occupancy measurements are reported for a rural (Philipstown) and urban (Pretoria) location in South Africa and a rural (Macha) location in Zambia. Measurements were taken in the 50 MHz - 1 GHz band. The results indicate medium occupancy at the urban measurement site and low occupancy at the rural measurement sites. It is also noted that there were frequency bands at all three measurement sites that had 0% occupancy over the measurement period.

In [64], Lysko et al. measured the amount of TV white space available in the UHF terrestrial TV frequency band at a measurement site in the suburb of Bergvliet, Cape town, South Africa. The measurement results are compared with the predicted white space results, obtained by means of the free space loss propagation model. The authors report that the white space or SO in the UHF band can be between 16 and 100 MHz at the time of measurement, depending on the availability criterion used.

In [6], ICASA reports on the results of a spectrum occupancy measurement campaign conducted for seven continuous days in the 450-470 MHz band. Measurement sites were located in the cities of Johannesburg, Bloemfontein, Port Elizabeth, Cape Town and Durban. The band of interest was subdivided into 1600 measurement channels of 12.5 kHz each and the detection threshold was set to -106 dBm. Table 2.4 reports the percentage of channels in the band that showed 0% occupancy over the measurement period. In total, 97.26% of the channels measured had no activity during the measurement period. The duty cycle for each of the measurement channels that showed spectrum activity is furnished in the report [6].

The 450-470 MHz band is assigned for fixed links, low power mobile radio, single frequency mobile and trunked mobile applications in South Africa [44]. The investigation by ICASA is due to the international drive by the ITU to harmonise the frequency use of this band for IMT in the near future.

In [7], ICASA reports on the results of a spectrum occupancy measurement campaign conducted for seven continuous days in the 790-862 MHz band. Measurement sites were located in the cities of Johannesburg, Pretoria, Bloemfontein, Port Elizabeth, Cape Town and Durban. The band of interest was subdivided into 5760 measurement channels of 12.5 kHz each and the detection threshold was set to -106 dBm. Table 2.5 reports the percentage of channels in the band that showed 0% occupancy over the measurement period. In total, 99.35% of the channels measured had no activity during the measurement period. The duty cycle for each of the measurement channels that showed spectrum activity is furnished in the report [7].

Frequency assignments for this spectrum are for terrestrial broadcasting (790-854 MHz) and fixed links (856-864.1 MHz) [44]. The investigation by ICASA is due to the international drive by the ITU to harmonise the frequency use of this band for IMT. This will come into effect when analogue switch-off takes place and the digital dividend 1 is released.

Table 2.4: Spectrum occupancy statistics for 450-470 MHz [6]

City	Inactive Channels (%)
Port Elizabeth	98.12
Johannesburg	97.5
Bloemfontein	97.25
Durban	96.43
Cape Town	97

2.4.3 Spectrum occupancy measurement considerations

It must be noted that not all spectrum sensed as idle or not occupied can in fact be reused by an SU. In [65] Mitola warns against certain pitfalls when conducting spectrum occupancy measurements or when a DSA-capable device performs spectrum

Table 2.5: Spectrum occupancy statistics for 790-862 MHz [7]

City	Inactive Channels (%)
Port Elizabeth	99.74
Johannesburg	99.84
Bloemfontein	99.97
Durban	98.58
Cape Town	98.59
Pretoria	99.36

sensing. Current spectrum sensing techniques do not accurately detect pulsed radar systems (used for Aeronautical Navigation), deep space communications and GPS signals. This means that the measurements taken must take these pitfalls into account. Therefore, the availability of spectrum does not imply that the spectrum is exploitable for the use of data communications. As duly noted in [21] and [66], an SO does not necessarily constitute successful exploitation of the spectrum.

2.4.4 Remarks

The abovementioned measurement studies suggest that, on average, most parts of the spectrum are unoccupied. Spectrum is not heavily used and it is inefficiently allocated. Unfortunately there is no mechanism in current regulatory policies that allows for the dynamic or opportunistic use of underutilised spectrum. The spectrum occupancy measurement studies indicate that the spectrum scarcity is indeed artificial and due to the spectrum management paradigm in use.

2.5 From spectrum occupancy to SO

The spectrum occupancy measurement studies from section 2.4 suggest that many opportunities for the exploitation of unused spectrum exist. Recall from section 1.1.4 that an SO is defined as the existence of a frequency band segment, satisfying an availability criterion that DSA or OSA capable devices can exploit for communications purposes [20]. The main approaches for determining and exploiting SOs are briefly discussed, where after the availability criteria for the geolocation approach are described.

2.5.1 Beacons

The beacon technique allows SUs to transmit only under the receipt of a control signal or beacon that identifies available channels in the SUs service area. If the control signal is not received, no transmissions by the SUs are permitted. Typically, an infrastructure that can propagate the beacons or control signals is required. This approach is currently not favoured by any of the administrations considering DSA to the terrestrial TV bands [24], [2].

2.5.2 Spectrum sensing

In terms of the hierarchical access model (refer to section 1.1.3), the occupancy of the spectrum is considered to be due to the transmissions of the PU or incumbent [22]. The problem of determining whether a given band of spectrum is occupied or not is referred to as primary signal detection. The SO can then be expressed in terms of the complement of the spectrum occupancy, or as a binary hypothesis test.

Complement of spectrum occupancy

An SO can be formulated as the complement of the spectrum occupancy:

$$SO = 1 - OCC, \text{given } BW, \text{ subject to } T \tag{2.1}$$

where SO is the spectral opportunity, OCC is the spectrum occupancy, BW is the sensed spectrum bandwidth and T is decision threshold [67]. The decision threshold, T, will be determined by the type of primary service present in the channel.

Hypothesis test

An SO can also be formulated in terms of a binary hypothesis test. To formulate the hypothesis test we state that the null hypothesis is an idle channel, whilst the alternate is a busy channel as shown in (2.2):

$$H_0(idle) \text{ and } H_1(busy) \tag{2.2}$$

When the channel is idle, the channel will contain only the ambient noise in the RF environment. When the channel is busy, the channel will contain ambient noise as well as the PU signal. This can be modelled as respectively shown in (2.3) and (2.4):

$$H_0 : y(n) = w(n) \tag{2.3}$$

$$H_1 : y(n) = s(n) + w(n) \tag{2.4}$$

where $y(n)$ is the received signal, $w(n)$ is the ambient noise, $s(n)$ is the PU signal and n is the sample number. When the channel is busy, the channel will contain the PU signal and the ambient noise. The hypothesis test implies that the received signal will contain more energy when the channel is busy than when the channel is idle.

The simplest method to implement the hypothesis test is to use an energy detector. This is also how a spectrum analyser performs measurements. A power or energy detection threshold is typically set, and it acts as the determinant of the hypothesis test outcome. More advanced spectrum sensing techniques that use prior knowledge of the PU signal to facilitate detection also exist [68], but the fundamental hypothesis remains as given in (2.2).

However, sensing is not perfect due to dynamically changing channel conditions, additive noise and limited observations. Furthermore, detection accuracy may be compromised by the hidden node problem. Cooperative sensing strategies have been proposed to overcome this problem. However, practical issues such as the cost of calibrated sensors that can accurately sense to the required thresholds limit the current practical viability of a sensing only approach [68], [24].

This gives rise to the probability of making either a Type 1 or Type 2 statistical error, respectively denoted as the probability of a false alarm and the probability of a missed detection. A type 1 error results in an idle channel being detected as busy and therefore only represents a potentially missed opportunity for the SU, not causing any harm to the PU. However, a type 2 error or missed detection results in a busy channel being detected as idle and will therefore result in the SU causing harmful interference to the PU [3].

It is important to note that the absence of a primary user signal does not necessarily constitute an SO. This is because the SO needs to exist for a communication pair, i.e. the transmitting SU and the receiving SU. It also holds that an SO can in general be assumed to be asymmetric. These requirements place additional bounds on finding SOs that will lead to successful SO exploitation. Relevant work to this end is provided in [21] and [66].

2.5.3 Geolocation databases as an alternative

It follows from section 2.5.2 that spectrum sensing is currently still an imperfect technique. There will be sensing errors, either causing missed opportunities for the SU due to false alarms, or causing harmful interference for the PU due to missed detections. Very low detection thresholds are typically set to minimise the sensing errors incurred. The low thresholds result in underestimation of the SO available [69], [1].

The geolocation technique is currently the favoured approach by administrations considering DSA to the terrestrial TV frequency bands. This approach requires an SU to be able to determine its location. This could be done either locally with GPS, via the base station it associates with, or some other means. The SU queries a centralised geolocation database with its location and device specific parameters such as device type and antenna height. The geolocation database returns a list of channels available for use by the SU, accompanied by the maximum permissible transmit power and a time validity parameter for each channel [69].

The geolocation database is able to provide this information to the SU because it maintains a list of available channels for every location. This list is determined by using information about the PU transmitter locations, technical transmission parameters, frequencies in use and protection requirements to perform a set of propagation modelling calculations. The availability criterion is applied to determine where in the frequency, spatial and temporal domain SOs exist [19].

The geolocation approach has advantages from a policy and regulatory perspective. The regulator can specify the protection that needs to be afforded to the PUs. Policy can be enforced, and adapted as needed by simply updating the database. This approach does however require that the SUs are trustworthy.

Geolocation databases are useful for very specific DSA applications, where the temporal characteristics of the PU are static or vary slowly. Secondary access to the terrestrial TV frequency bands, also referred to as TV white space, is a good application for the geolocation approach. A geolocation-only approach would not work so well in frequency bands where the temporal behaviour of the PUs is more dynamic [24].

2.6 Availability criterion

Section 1.1.4 pointed out that to complete the definition of an SO, a definition of what constitutes harmful interference is required. The availability criterion can then be formulated, taking the definition of harmful interference into account. In this section the basis used to determine harmful interference is discussed, after which a conceptual overview of the FCC and SE43 methodology for calculating an SO is given.

2.6.1 Harmful interference

The protection requirements of the DTT service from harmful interference are well understood and have been studied comprehensively. Relevant recommendations are provided in ITU-R BT.1368 [9]. The digital service protection requirements are typically specified at the point of signal failure. The point of failure is influenced by the receiver Carrier to Noise Ratio (C/N), a level below which the receiver will not be able to demodulate the digital signal.

By contrast, the analogue TV service is more susceptible to interference. The protection requirements of the analogue service have also been studied comprehensively and relevant recommendations are provided in ITU-R BT.417 [8]. Increasing interference will cause gradual reduction in the perceived picture quality of the TV signal received, up to a point where the general public will no longer be interested in watching TV. The C/N ratio for the analogue service is typically specified at a certain perceived level of acceptable picture quality.

2.6.2 FCC methodology

Conceptually, the FCC methodology can be explained by means of figure 2.2. Let the two circles represent two PU TV transmitters, transmitting on the same channel. The noise-limited protected contour radius of a PU, i.e. before the introduction of SUs to the same spectrum, is denoted by r_{nl}. This radius is a function of the PU protection requirements. Note that, depending on the definition of harmful interference, r_{nl} does not necessarily define the coverage region of the PU in question.

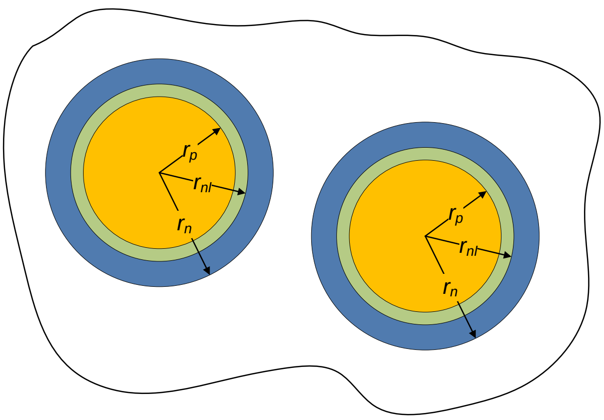


Figure 2.2: FCC definition of SO [1]

It is argued in [1] and [10] that all locations where TV reception was possible prior to the appearance of SUs cannot be declared protected. To account for this, [1] introduces the concept of an erosion margin. The protected contour of the PU, taking the erosion margin into account, is denoted by r_p.

The erosion margin is necessary, as it is not possible to afford the incumbents the same level of protection as prior to the introduction of SOs in the same spatio-temporal frequency domain. Even the most remote secondary transmitter with very little transmit power will cause the noise floor to increase at the noise-limited protected contour (r_{nl}), hence causing interference to the PU. Therefore, the introduction of an erosion margin is necessary to account for these cases. It is up to the administrations in question to decide on a value for the erosion margin, as this will have an influence on the SOs available and ``interference˝ caused to the PU.

The radius r_n includes an additional keep-out region (depicted in blue), which is a function of the SU transmitter power, and SU antenna height Above Ground Level (AGL). The additional keep-out region provides an additional buffer zone in which PU transmitters and receivers may not seek protection, but SUs may also not transmit. The keep-out region accounts for a worst case placement of SU relative to PU receivers at the edge of the protected contour (r_p), to ensure that the PU protection requirements are not violated. Any location outside r_n can then be regarded as an SO, which can be exploited by SUs.

Note that the aforementioned example is for the case where only the effect of PUs in the co-channel is considered. Depending on the regulatory constraints on the SU, the adjacent channel conditions may also have to be considered. Generally, the adjacent channel radii, r_n and r_p are smaller than for the co-channel. Once again, it is up to the administration in question to decide the thresholds of the adjacent-channels' protected contour. For a mathematical treatment of the FCC methodology, refer to [1].

The latest parameters derived from the FCC methodology and as used in the USA is available in the Code of Federal Regulations [36]. The regulations provide the field strength thresholds required at the protected contour. The distance of the additional keep-out region is specified in terms of the antenna height above average terrain, as well as device type. The device types can be fixed or personal/portable. Maximum permissible transmission power is limited according to device type [36]. The geolocation database providers are required to correctly implement the requirements of the regulations, from where it is provided to querying SU devices.

The approach followed by the FCC is a fixed power allocation method. As described above, there are predefined SU device types. Key technical parameters for these devices are defined according to the device type. The FCC methodology allocates fixed maximum power limits according to the height of the SU device above the average terrain and the location of the SU device. The maximum power is fixed, however, so all SU devices with the same height above average terrain will be assigned the same fixed maximum power limit. The fixed power limit is enforced by means of the additional keep-out region.

2.6.3 SE43 methodology

Section 2.2.2 pointed out that the methodology followed to calculate SOs in Europe is different from the method used in the USA. The European framework is based on the methodology developed by Ofcom [42]. The methodology that will be used for the larger European framework is being developed in the European Communications Committee (ECC) SE43 project team [43].

The SE43 methodology specifies the protection of the PU in terms of degradation in location probability. By specifying the maximum permitted degradation in location probability to the PU, location-specific maximum Effective Isotropic Radiated Power (EIRP) emission levels can be specified. The SE43 methodology provides a flexible framework in which each of the European administrations can implement their respective planning values to determine PU coverage and SU technical parameters.

The SE43 methodology follows an approach where the output power assigned to an

SU is location-specific, and not only tied to the device type and height above average terrain as with the FCC methodology. Each SU device is required to submit its key technical parameters and location to the geolocation database. A maximum power limit specific to the device and location is returned. The concept of a static keep-out region is not enforced; instead the maximum SU transmit power is re-evaluated for each location.

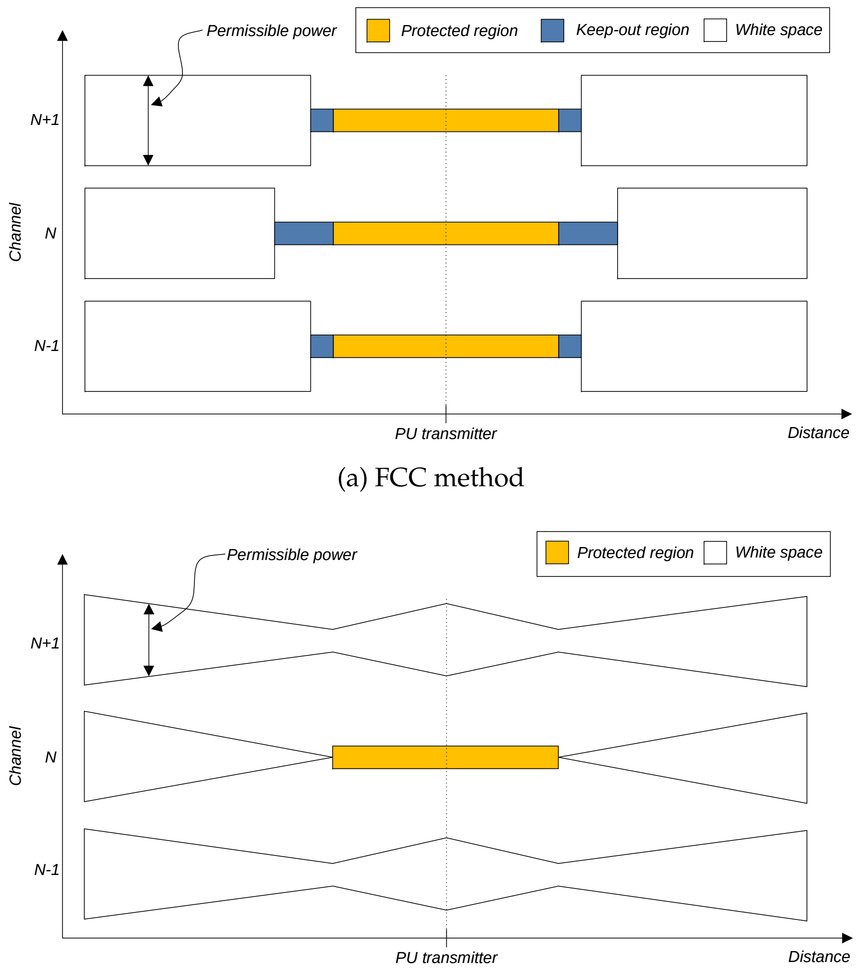
Furthermore, the SE43 methodology can be used to take the protection requirements of adjacent channels $n \pm 1, n \pm 2, n \pm 3, ..$ into account. For a mathematical treatment of the SE43 methodology, refer to [43] and [42].

2.6.4 Comparison of FCC and SE43 methodologies

The power allocation methods of the FCC methodology and SE43 methodology are respectively shown in figures 2.3a and 2.3b. The figures depict the permissible maximum SU transmit power as a function of the height of the bars as indicated. The figures depict the frequency-spatial relationship for the PU transmitter located as indicated. The x-axis represents the increase or decrease in longitude from the PU transmitter location. Figures for the frequency-spatial relationship versus latitude can also be drawn. For explanatory purposes, the longitudinal distance is depicted on the x-axis.

The colours used in figure 2.3a correspond to the same coloured regions in figure 2.2. For the FCC method, secondary transmissions are prohibited in the protected region of the transmitter. An additional keep-out region is required, depending on the SU device type and height above average terrain. The adjacent channel restrictions are also shown. Generally the protected and keep-out regions required on the adjacent channels are smaller than for the co-channel. The uniform height of the white space bars indicates the fixed way in which the maximum permissible transmit power is enforced on the SU device [2].

In figure 2.3b, the conceptual merits of the location-specific power allocation method are shown. For the SE43 method, secondary transmissions are prohibited in the protected region of the transmitter in the co-channel. The maximum permissible transmit power gradually increases as the SU device is located farther from the edge of the protected region.



(a) FCC method

(b) SE43 method

Figure 2.3: Comparison of power allocation for FCC and SE43 methodologies [2]

In the adjacent channel, secondary transmissions are allowed at the PU transmitter location and in the protected region. The maximum permissible transmit power gradually reduces as the SU is moved closer to the edge of the protected region and then increases as the SU moves away from the protected region. The permissible transmit power at the edge of the protected region is lower than within the protected region. This is to honour the interference constraints of TV receivers located at the edge of the adjacent channel's protected region. In a similar fashion the same rule applies for adjacent channels $n \pm 2, n \pm 3, ..$; however, the power constraint will be relaxed as the channel offset increases [43], [2].

2.7 SO modelling

In section 1.1.6, SO modelling was proposed as an alternative approach to quantify the amount of spectrum available for secondary reuse. In this section the core related work in this research field is presented. It is important to note that SO modelling is closely related to the geolocation database approach. For all practical purposes the geolocation database models the propagation of radio waves, and performs computations from which SOs are returned, i.e. the geolocation database performs SO modelling.

A key differentiation is made between the process of modelling SOs and the practical implementation of such functionality in a geolocation database. Additional complexities relating to computation time, storage cost and dissemination of information are imposed as design requirements on the geolocation database. These issues are important and not trivial to address [70].

In order to gain a better understanding of the nature and properties of the SO available in the region under study, the database functions, overheads and implementation issues are typically ignored in an attempt to simplify the problem. SO modelling therefore focuses on the computations and calculations that need to be performed to quantify SOs in the region under study, without emphasising the practical implementation aspects of such functionality within a fully-fledged geolocation database.

2.7.1 Related international work

The work of Mishra et al. [1] is considered by many researchers in this field as the pioneering work in the quantification of white space or SO [71], [10]. Mishra et al. quantified the white space available in the USA, illustrating with their analysis how the definition of the erosion margin and harmful interference influence the SO available

[1]. The ITU-R P.1546 version 3 model was used to obtain propagation predictions and all transmitters in the DTT database and master low power database of the FCC were considered. SO is quantified in terms of the number of channels available, weighted by area and population.

Mishra et al. report that there has been previous work on estimating the white space available in the USA, prior to the FCC ruling on November 14, 2008 [11]. It is argued in [1] that the results from these studies are not comparable to the current work, as the availability criteria used are not consistent with the current FCC methodology.

In [72], the aforementioned work of Mishra et al. is extended for the USA to determine the amount of white space capacity available using Shannon's capacity theorem. The capacities for various SU network scenarios are described by unit area and unit population. A study illustrating the economic viability of deploying a secondary network in the available white space is also presented.

In [73], Nekovee et al. present the first work on quantification of SO outside the USA. The white space available in the UK is quantified at 18 different locations. The contiguousness of the available channels are also investigated. The authors derive a methodology to predict the white space from DTT coverage maps, provided by the Ofcom. Conceptually, the methodology followed is similar to the FCC method. It is however not clear from the study what the protection requirements of the PUs are, as the coverage maps used are pre-computed. Furthermore, the scale of this study is not comparable to the work of Mishra et al.

The work of Van de Beek et al. [74] quantified the white space availability in 11 European countries for channels 21-60, in terms of the number of available channels weighted by area and population. The ITU-R P.1546 version 4 model is used to obtain propagation predictions. The SO available to a hypothetical zero-watt secondary transmitter is considered.

Additional results focusing in more detail on Germany are also presented. The effect of using a different propagation model is investigated by comparing the SO results of the ITU-R P.1546 model with the SO results obtained using the Longley-Rice Irregular Terrain Model (ITM). This work is extended by also studying the effects of considering the adjacent channel protection requirements in [10].

In [75], the SO in channel 21-69 is studied for a region encompassing the Peloponnese and a part of southern continental Greece using an in-house developed Longley-Rice ITM. The secondary network considered is an 100 node WRAN transmitting at 4 W EIRP. Instead of using the actual locations of the TV transmitter locations and calculating the protected region, the DTT allotments as set out at RRC-06 are taken as the protected region of the PUs.

It is argued that this provides a better long term view of the SO available, as all the allotments are protected from harmful interference. However, it can also be argued that this contradicts the philosophy of DSA, as not all allotments have been licensed to and are occupied by DTT broadcasters. Notwithstanding this, an average of 125 MHz (15.63 channels) are available as SOs.

In [28], Dudda et al. analyse the TV white space available in channels 21-60 for Germany. The Longey-Rice propagation model is used for propagation prediction of the TV coverage areas. SU transmissions are predicted with the Okumura-Hata propagation model. The SE43 methodology is implemented. The Cumulative Distribution Function (CDF) of the number of available channels available to secondary devices transmitting at a given EIRP is presented to quantify the SO available.

Dudda et al. extend the aforementioned work by analysing the capacity of a LTE cellular network deployed in the TV white space. Of interest is that Single-Frequency Network (SFN) gains and SU interference are also considered in the analysis [71].

In [76], the white space available for channel 21-60 in the province of Bologna, Italy, is analysed using the ITU-R P.526 propagation model and SE43 methodology. The white space available under a geolocation only and hybrid (spectrum sensing and geolocation) approach is investigated by comparing the predicted SO results with the spectrum occupancy measurements performed at six locations in the province.

In [77] the possible utility of TV white space is presented from the perspective of a Telecom operator. The work done is by BT corporation in the UK. The authors discuss the database structure, white space availability and white space capacity according to their proprietary SO model. Lastly, a few use cases are investigated, namely: in home wireless multimedia streaming, high speed wireless broadband and rural broadband.

In [78], the aggregate interference caused by SU networks in TV white space is investigated for Finland. The aggregate interferences experienced under the FCC and SE43 methodologies are compared. The ITU-R P.1546 version 4 propagation model is used.

In [79], the Parabolic Equation Method is used to predict white space in the South-West UK. The focus of this work is geared more towards the accuracy of the propagation model than quantification of white space, hence the SOs available are only qualitatively assessed. A spectrum sensing threshold approach is followed to determine white space. The grid spacing of the predictions is 10 km. The model results are validated by correlating the model results with a measurements taken at one location.

Abovementioned work is extended in [80], considering a smaller area within the UK, increasing the grid spacing to 1 km and performing validation measurements in more locations. The model is found to correlate well in open and flat areas, but not well in built-up areas due to path obstructions. The grid resolution is further reduced in [81] to 100 m. The improved model is shown to be within 10 dB of the measured power at the measurement sites. This grid spacing is in line with what Ofcom is suggesting for the implementation of their geolocation database [42].

In [82], the authors analyse TV white space availability in Japan, using the ITU-R P.1546 version 3 model, accounting for land and sea paths. The FCC methodology is applied with the parameters as specified in the Code of Federal Regulations [36]. The SO available is expressed in terms of area and population.

2.7.2 Related local work

The utility of DSA in the terrestrial TV frequency bands is gaining increased attention and awareness in South Africa. In section 2.2.3, the early interest of ICASA and the field trial network under development were discussed. In section 2.4.2, the spectrum occupancy measurement campaigns that have already been conducted in South Africa were discussed. In the measurement sphere, the academic work of Lysko et al. [64] and Masonta et al. [63] is the pioneering work.

In [64], Lysko et al. predict the TV white space available at a measurement location in Bergvliet, Cape Town, South Africa. The propagation model used to predict the white space available is the free space loss propagation model. Furthermore, the prediction is provided only for a point location in South Africa. This is because the main aim of the work was to compare the predicted results with the measured results. A threshold-based approach as defined in section 2.5.2 was used as the availability criterion to determine SO.

To the best of our knowledge, no work on the quantification of the SO in the terrestrial TV frequency bands of South Africa on provincial or national level has been conducted.

2.8 Research trends

From the literature surveyed, a few trends in the field can be observed. Firstly, core to DSA is the definition of an SO, and its corresponding availability criterion. This availability criterion is chosen precisely to protect the PUs against harmful interference. There are the proponents of a spectrum sensing only approach to DSA. Others favour a hybrid approach, featuring spectrum sensing in combination with a geolocation database. A geolocation only approach is seen currently to be the favoured option, at least for DSA to the terrestrial TV frequency bands, as it presents a workable solution that can fit into the existing regulatory frameworks of administrations. The geolocation database approach has been adopted by the USA (refer to section 2.2.1) and is under consideration by Ofcom and the Eurpean administrations (refer to section 2.2.2).

Due to geolocation currently being the preferred regulatory option to enable secondary access, SO modelling is seen to receive a lot of attention in the research community. With regard to SO modelling, issues such as which propagation model and what model parameters to use become relevant. Very relevant is the choice of either the FCC or SE43 methodology to determine an SO. The literature studied also highlights that there will not be a single methodology that will suit all administrations.

2.9 Towards a contribution

From the related work presented it is clear that the topic of SO modelling as a means to obtain quantitative estimates of SO availability is relevant and timeous. Analysis of the SO available in a geographic region is the first step towards the development of a secondary use case. Furthermore, the literature studied suggests that a quantitative estimate of the SO available in the terrestrial TV frequency bands of South Africa has not been presented before. This is identified as a new research problem, warranting investigation, the result of which is a unique and new contribution to the domain of knowledge. The grounds for the unique contribution were stated in section 1.3.

2.10 Conclusion

In this chapter the literature applicable to the domain of knowledge was presented. The digital dividend and TV white space were discussed. An overview of how the regulators of other administrations are exploiting the digital dividend was provided. Factors pertaining to SO in South Africa were discussed.

Relevant spectrum occupancy measurement campaigns in the international and local spheres were highlighted. The main approaches to exploiting SO were discussed. Finally, related work in the field of SO modelling was discussed and the case for a unique contribution, as evident from the literature, was made. The next chapter proceeds to describe the conceptual design and implementation details of the system model.

Chapter 3

System model

The focus of this chapter is to develop and describe the system model. Motivations are given for model features implemented. The system model is described conceptually by means of flow diagrams depicting the logical flow of operations. Finally, the necessary formulae and design choices for the implementation of the system model are also presented.

3.1 Overview

The conceptual layout of the system is now presented. First, the motivation for incorporating the ITU-R P.1546 propagation model in the system model is discussed in section 3.2. Section 3.3 gives a high-level overview of the ITU-R P.1546 propagation model. Section 3.4 discusses the model features that were not implemented. Then, in section 3.5, flow diagrams are used to describe the logical flow of the system. The system implementation is discussed in section 3.6.

Conceptually the system can be divided into two distinct phases:

- Prediction phase.
- Analysis phase.

In the prediction phase, all the necessary operations are completed to obtain a field strength estimate for a designated number of receiver locations. The field strength estimates are saved to disk in a data structure. The analysis phase operates on the field strength data structure to calculate the SO map, the required metrics for SO analysis and visualisation of results.

The prediction phase is the focus of the discussion in this chapter. The analysis phase is a post-processing operation, and it is duly discussed in chapter 5.

3.2 Motivation for choice of propagation model

The selection of the ITU model is motivated by the widespread acceptance and use of ITU-R P.1546 for the planning of terrestrial broadcast networks. It should be re-emphasised that, as stated in section 1.2, the research goal is to obtain a quantitative estimate of the SO available in the terrestrial TV frequency bands of South Africa. With this in mind, it is important to consider that the choice of the underlying propagation model is not only based on technical, but also on political merit.

Technically there are models that are more accurate and path specific than the ITU-R P.1546 model. However, the ICASA has used the ITU-R P.1546 before for spectrum management and frequency coordination purposes. For instance, revision 3 of the ITU-R P.1546 model was used as the basis of the regional co-ordination and planning for the digital terrestrial broadcasting service in bands III, IV and V for ITU regions 1 and 3. This coordination process was formalised at the ITU RRC-06, and is known as the GE-06 agreement [4].

The ITU-R P.1546 model parameters as used for the GE-06 agreement are documented in the proceedings of RRC-06 [4]. The digital channel entries in the Final Terrestrial Broadcasting Plan of 2008 and the ICASA TV transmitter database came about as a result of South Africa's GE-06 planning efforts.

The ITU-R P.1546 model is therefore a verified and validated model. The predictions obtained with the model are trusted by regulatory bodies and are in many instances used as the basis from which spectrum policy decisions are made. This does not imply that the ITU-R P.1546 is the most accurate propagation model in existence. However, a considerable amount of trust is placed in the prediction accuracy of the model by administrations and regulatory bodies.

For these reasons, the design decision to incorporate the ITU-R P.1546 propagation model into the system model was taken. The rationale is that should the model be correctly implemented and used, the results obtained with the model can be regarded as valid and of practical relevance, especially by regulators.

3.3 Propagation model overview

The ITU-R P.1546 model is a point to area prediction method that is valid for frequencies of 30 MHz to 3 GHz. The model is a statistical prediction model that is derived from empirical data. The model produces valid predictions for distances between transmitter and receiver of 1 km to 1000 km [30].

The ITU-R P.1546 model predicts the median electrical field strength exceeded for a specified percentage of time, at a specified distance and frequency, for the propagation path under analysis. The model predicts field strength based on the interpolation or extrapolation of the empirically derived field strength curves. The value predicted is typically for an area of 500 m x 500 m or larger. The field strength predictions are normalised to an ERP of 1 kW [30].

The model requires the following parameters to provide an electrical field strength prediction value: transmission frequency, effective antenna height of the transmitter, antenna height of the receiver, distance between transmitter and receiver, type of propagation path and percentage time probability. The propagation path can be land-based, sea-based or a mixed path. The predicted electrical field strength value returned represents the electrical field strength that is exceeded for the specified percentage of time.

Furthermore, the model includes prediction adjustments that can be used to improve the predicted field strength values by accounting for various effects:

- Receiving or mobile antenna heights other than 10 m.
- Short urban or suburban paths.
- Small area prediction improvement based on terrain clearance angle (TCA).
- Location variability other than 50%.
- Correction for tropospheric scatter.
- Adjustment for different climatic zones.

Figure 3.1 provides a prediction curve that is obtained through implementation of the propagation model. The curve shows the predicted field strength for a radiator emitting 1 kW ERP at various effective antenna heights versus distance. The prediction curve is for a land path, frequency of 600 MHz, location probability of 50%, time probability of 50%, receiver antenna height of 10 m. No additional corrections are considered. The predicted electrical field strength returned for a given frequency, height, and distance represents the electrical field strength that is exceeded 50% of the time and at 50% of the locations within the prediction area.

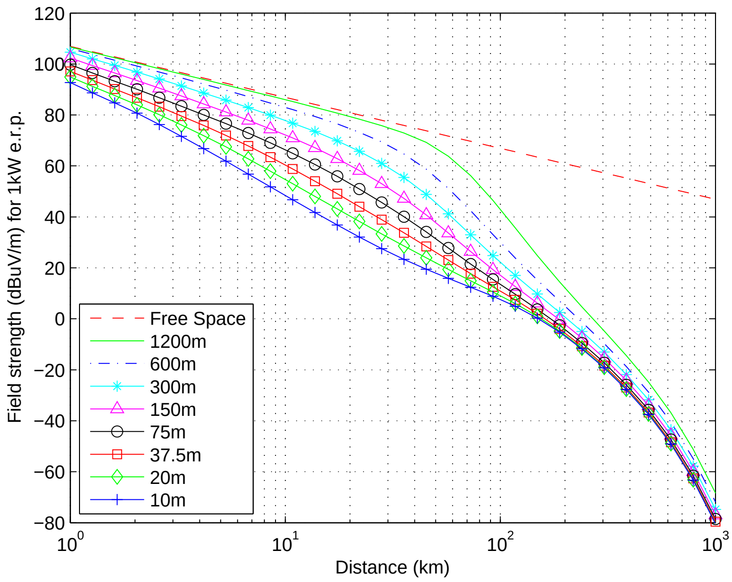


Figure 3.1: ITU-R P.1546 prediction curve: 600 MHz, 50% time, 50% locations

3.4 Model features not implemented

The model implementation presented in this chapter complies with revision 4 of the P.1546 recommendation [30]. However, some of the features of the model are not implemented, as these features, it can be argued, are not essential to the requirements of the system model. The propagation model features omitted from implementation are briefly discussed below.

3.4.1 Propagation path

The system model implements only land propagation paths. Sea paths and mixed propagation paths are not implemented, as these path modes are not required for the analysis region. There are areas next to the coast where the propagation path will encounter land to sea and sea to land transitions. Field strength predictions over propagation paths which cross these transitions will in general not be as accurately predicted.

However, the effect of these transitions is very localised in nature, as South Africa does not have land areas with large seas in between. The complexity and extra processing time required to implement the additional path modes do not justify the possible increase in localised prediction accuracy.

3.4.2 Time probability

The system model does not implement interpolation as a function of percentage time. The field strength prediction curves are provided for nominal time probabilities of 1% 10% and 50%. The interpolation method allows for the choice of any time probability between 1% and 50%. The analyses done in this thesis are all for a time probability of 50%, hence implementation of time probability interpolation is not required.

The 50% time probability curves are used for coverage prediction, expressing the percentage of time the predicted field strength is exceeded. A time probability of between 1% and 10% is used for interference-based studies [9], [83], [4].

3.4.3 Adjustment for short urban or suburban paths

This adjustment is valid for path lengths that are shorter than 15 km and that experience attenuation caused by building clutter of uniform height over flat terrain. This adjustment is not implemented as it is only applicable to areas where the uniform clutter height assumption holds. Knowledge of the clutter height is required for the correction to be effective.

In practice, a spatial dataset for designating urban/suburban areas and a spatial dataset denoting representative clutter height would be required for South Africa to implement this correction effectively. The former spatial data is available through the national land cover spatial dataset [84] or land use classification spatial data of Census 2011 [85]. To the best of the author's knowledge the latter spatial data is not available.

Furthermore, the effect of this adjustment will always result in attenuation of the field strength. Therefore, by not implementing the adjustment, the coverage area of the PU transmitter will be possibly be overpredicted in areas where the clutter height is above the receiver.

3.4.4 Climatic zone adjustment

The field strength prediction curves of the ITU-R P.1546 propagation model are based on measurements in temperate climates. The vertical refractivity gradient in the lowest 65 m of the earth's atmosphere is used to determine the dominant climatic region.

According to the geographical division of RRC-06, South Africa has a predominantly temperate climate characterised by a vertical refractivity gradient of $dN_0 = -43,3$ N-units/km. The upper northern half of the Northern Cape province is seen to have a mean refractivity, $dN = -30$ N-units/km. These refractivity gradients are for a 50% time probability [4]. The geographical division maps are made available as part of the ITU Digitized World Map (IDWM), at a cost.

Field strength predictions in areas where the refractivity gradient differs greatly from the reference refractivity gradient (as per temperate climate) will not be so accurately predicted.

The abovementioned RRC-06 geographical division is based on the ITU-R P.453 recommendation [86], which provides formulas for the calculation of the refractivity gradient and contoured maps of the mean refractivity gradients for the world. Vertical refractivity gradient data of the entire world is available with a grid cell size of 1.5° and is obtainable from the ITU-R radio communication bureau in electronic form [87].

Determination of the median vertical refractivity gradient

The variation of the vertical refractivity gradient in the lowest 65 m of the atmosphere is now evaluated to determine whether the field strength prediction curves can be used without adjustment, and what the effect of not adjusting the curves is on prediction accuracy. The vertical refractivity gradient for South Africa is evaluated over a uniform grid, spaced at five arc-minutes. Values for sample points that do not coincide with the grid points of the vertical refractivity gradient are obtained by bi-linear interpolation, as per recommendation P.1144 [88].

The statistical parameters for the vertical refractivity gradient are provided in table 3.1. Figure 3.2 provides the empirical CDF of the refractivity gradient as calculated from the sampled grid locations. The mean and median refractivity is seen to be close to the reference refractivity gradient of $-43,3$ N-units/km, confirming that South Africa has a predominantly temperate climate.

Table 3.1: Statistical parameters: vertical refractivity gradient (dN) for South Africa, lowest 65 m, 50% time

Parameter	Value
Minimum	-106.7384
Maximum	-23.5461
Mean	-42.2476
Median	-42.5514
Standard deviation	7.9042

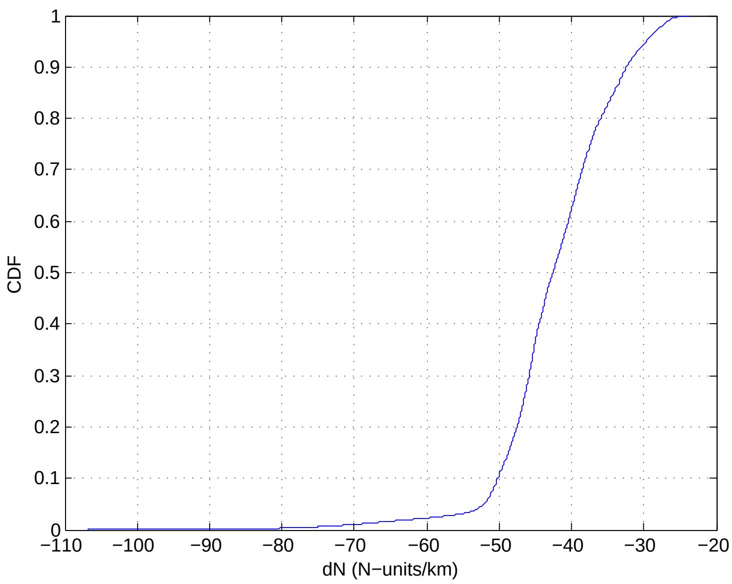


Figure 3.2: Empirical CDF: vertical refractivity gradient for South Africa, lowest 65 m, 50% time

Effect on propagation prediction

The standard deviation in table 3.1 suggests that there is some variation in the refractivity gradient. The adjustment that the mean and standard deviation in refractivity gradient for South Africa has on the radio climatic adjustment parameter is illustrated in figure 3.3 as a function of distance. It can be seen that should no climatic zone adjustment be made, the propagation model will, on average, underpredict field strength by up to 0.1 dB. The vertical refractivity gradient taken at the standard deviations around the mean shows that the propagation model will in some instances overpredict field strength by up to 0.7 dB and underpredict field strength by up to 0.15 dB.

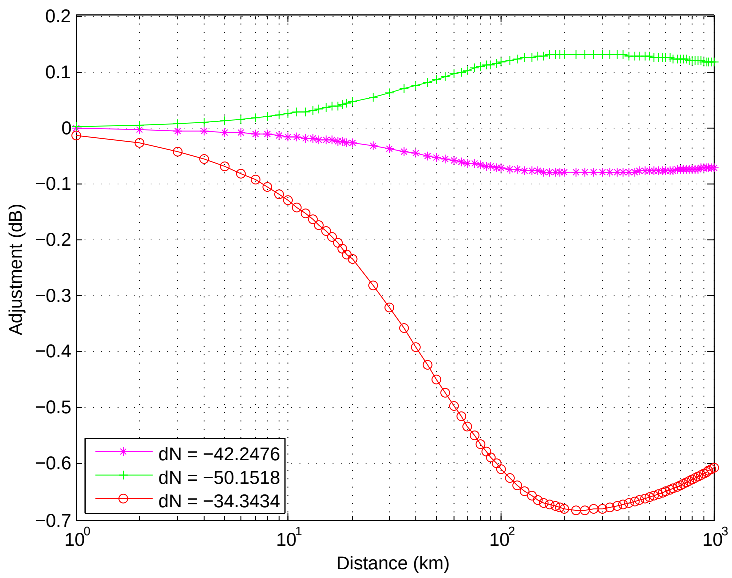


Figure 3.3: ITU-R P.1546 climatic zone adjustment

The procedure and formulas for the climatic zone adjustment of the field strength curves can be found in annex 7 of recommendation P.1546 [30]. The decision is taken not to implement the climatic zone adjustment parameter, as the reference curves are representative of the mean refractivity gradient value found in South Africa. Furthermore, the processing overhead involved in improving the field strength prediction outweighs the benefit of improving the prediction accuracy.

3.5 Logical flow breakdown

The interaction between the various system elements can be better described with the aid of flow diagrams. The flow diagrams describe the logical course or flow of actions that have to be completed to accomplish propagation prediction and SO analysis. The flow diagrams develop the logic in increasing levels of detail as required.

3.5.1 Flow diagram syntax

Each block in the flow diagram is assigned a unique number, visible above the upper left corner of each block. The numbering system is assigned in a hierarchy of levels, level 1 being denoted by {x.0}. Expanding levels are sub-numbered accordingly.

For example, level 2 is numbered {x.x}, level 3 is {x.x.x}, level 4 is {x.x.x.x} and so forth. Numbering does not necessarily indicate the flow of logic and is assigned merely for easier referencing in the text. All references to function blocks in the text will be enclosed in {curly} braces.

The flow diagram blocks are expanded to show additional detail as required. Flow diagram expansion entry and exit points are indicated by the tan coloured blocks with a dotted outline. Triangles indicate decision points in the logic.

3.5.2 Prediction phase

The logic for the prediction phase is shown in figure 3.4. The prediction phase is responsible for implementing all the logic required to obtain field strength estimates for the designated receiver locations. The prediction phase starts with the initialisation of all parameters, constants and data structures {1.0}.

The analysis region is broken down into a mosaic of $1^\circ \times 1^\circ$ tiles. The memory footprint of data structures loaded to RAM is smaller when the tiled approach is employed. The tiles that store the field strength values are loaded one by one to the RAM as required {2.0}. Each tile is identified by a reference vector, which references each cell in the tile to a geographic location on earth. The geo-referencing of tiles is discussed in detail in section 3.6.1.

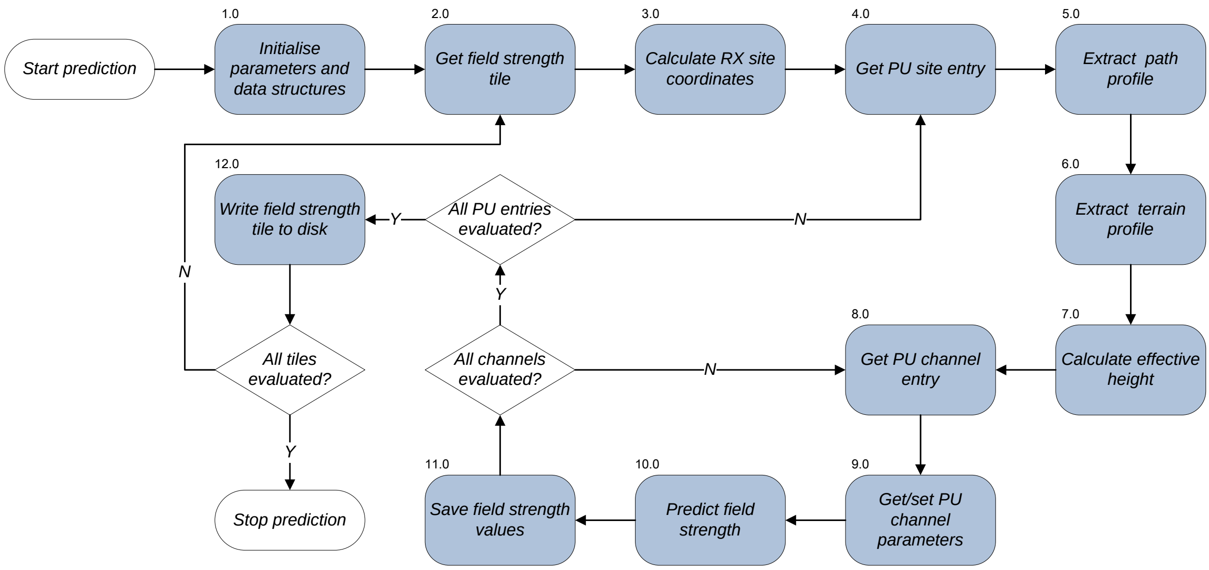


Figure 3.4: Logical flow: Prediction phase

The geographical coordinate of each cell in the field strength tile is determined {3.0}. These coordinates represent the receiver locations that will be evaluated. Subsequently the first transmitter site entry in the PU data structure is loaded {4.0}. The PU entry contains information on the site name, geographic coordinates and the list of channels broadcast from the transmitter site.

With the transmitter and receiver coordinates known, the distance and azimuth between transmitter and receiver can be determined {5.0} and the terrain profile for the propagation path can be extracted from the Digital Elevation Model (DEM) {6.0}. The mean effective height parameter can be calculated {7.0} from the outputs of {5.0} and {6.0}.

Next, the technical parameters of the first channel entry at the PU transmitter site are loaded {8.0}. The technical parameters include channel number, channel frequency, ERP, polarisation, antenna height AGL and channel type (digital or analogue). The channel technical parameters are used to set the input parameters specific to each channel {9.0}.

With the required parameters calculated in the preceding blocks, the field strength can now be predicted {10.0}. The predicted field strength values are saved to the field strength tile in question {11.0}. Block {8.0} - {11.0} is repeated until all channel entries for the given PU transmitter site have been predicted. Block {4.0} - {11.0} is repeated for all transmitter site entries in the PU data structure. The prediction of field strength values for the tile is now complete and the field strength tile is written to disk for further analysis later {12.0}. This process is repeated until predictions for all field strength tiles in the analysis region have been completed.

Logical flow expansion: Block 1.0, Initialise parameters and data structures

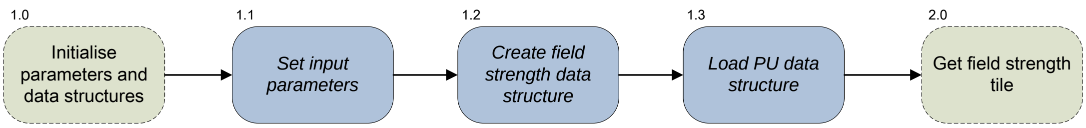


Figure 3.5: Logical flow expansion: Prediction phase, Block 1.0

The logical flow expansion for block {1.0} is shown in figure 3.5. The input parameters for the prediction phase include system constants and input parameters required throughout the prediction phase {1.1}. Block {1.1} maintains the list of system-wide input parameters, to ensure that all elements use the same initialisation values, constants, units of measurement and geographic datum.

The region that is to be analysed is defined and the field strength tile data structure is created accordingly. The data structure is returned as a mosaic of $1^\circ \times 1^\circ$ tiles which is written to disk {1.2}.

Finally, the PU data structure is loaded into RAM {1.3}. The PU data structure contains the TV transmitter technical parameters relating to transmitter coordinates and technical channel parameters.

Logical flow expansion: Block 6.0, Extract terrain profile

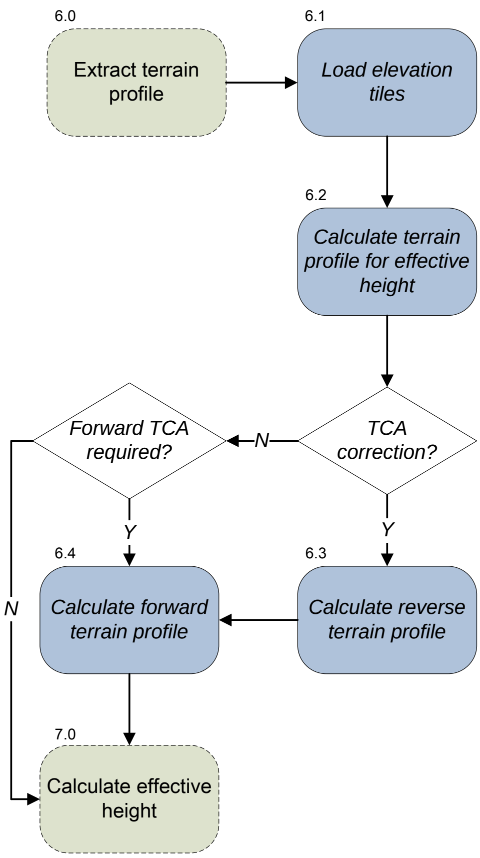


Figure 3.6: Logical flow expansion: Prediction phase, Block 6.0

The logical flow expansion for block {6.0} is shown in figure 3.6. The purpose of block {6.0} is to determine the terrain profile for the path traversed between transmitter and receiver. The tiles that need to be loaded from the DEM first need to be determined and loaded to RAM {6.1}. Then the terrain profile is extracted for the effective height parameter {6.2}. Should the forward and/or reverse TCA be required, the forward {6.4} and reverse {6.3} terrain profiles are also extracted from the relevant elevation tiles.

The extracted terrain profile is utilised for the calculation of the effective antenna height parameter {7.0}, calculation of reverse {9.2} and forward {9.3} TCA and correction of negative effective antenna heights {10.5}.

Logical flow expansion: Block 9.0, Get/set PU channel parameters

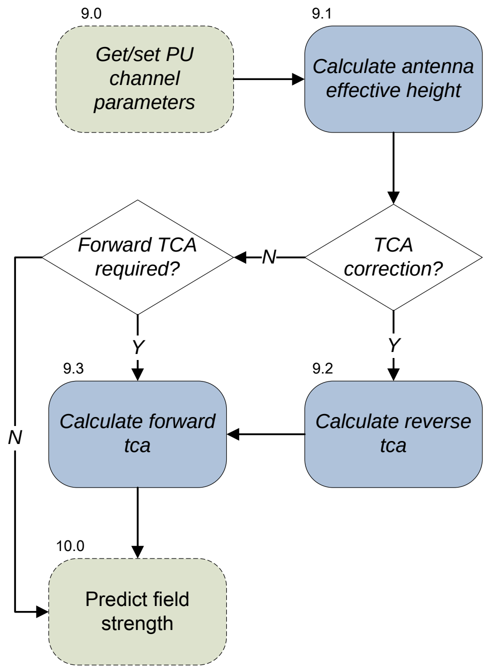


Figure 3.7: Logical flow expansion: Prediction phase, Block 9.0

The logical flow expansion for block {9.0} is shown in figure 3.7. The antenna effective height is calculated for the current channel entry by adding the antenna height of the channel entry to the effective height parameter that was calculated in {7.0}. The antenna height for each channel entry is treated separately, as antennas may be mounted at different heights on the same mast. This also means that the effective antenna height parameter and parameters that depend on the antenna height need to be calculated separately for each channel entry at a given transmitter site {9.1}.

The forward {9.3} and/or reverse {9.2} TCA parameters are calculated should these parameters be required. The forward and reverse TCA is used for prediction adjustment based on TCA (see {10.6.4}). The forward TCA parameter is also required for block {10.5}, which corrects for negative effective antenna heights.

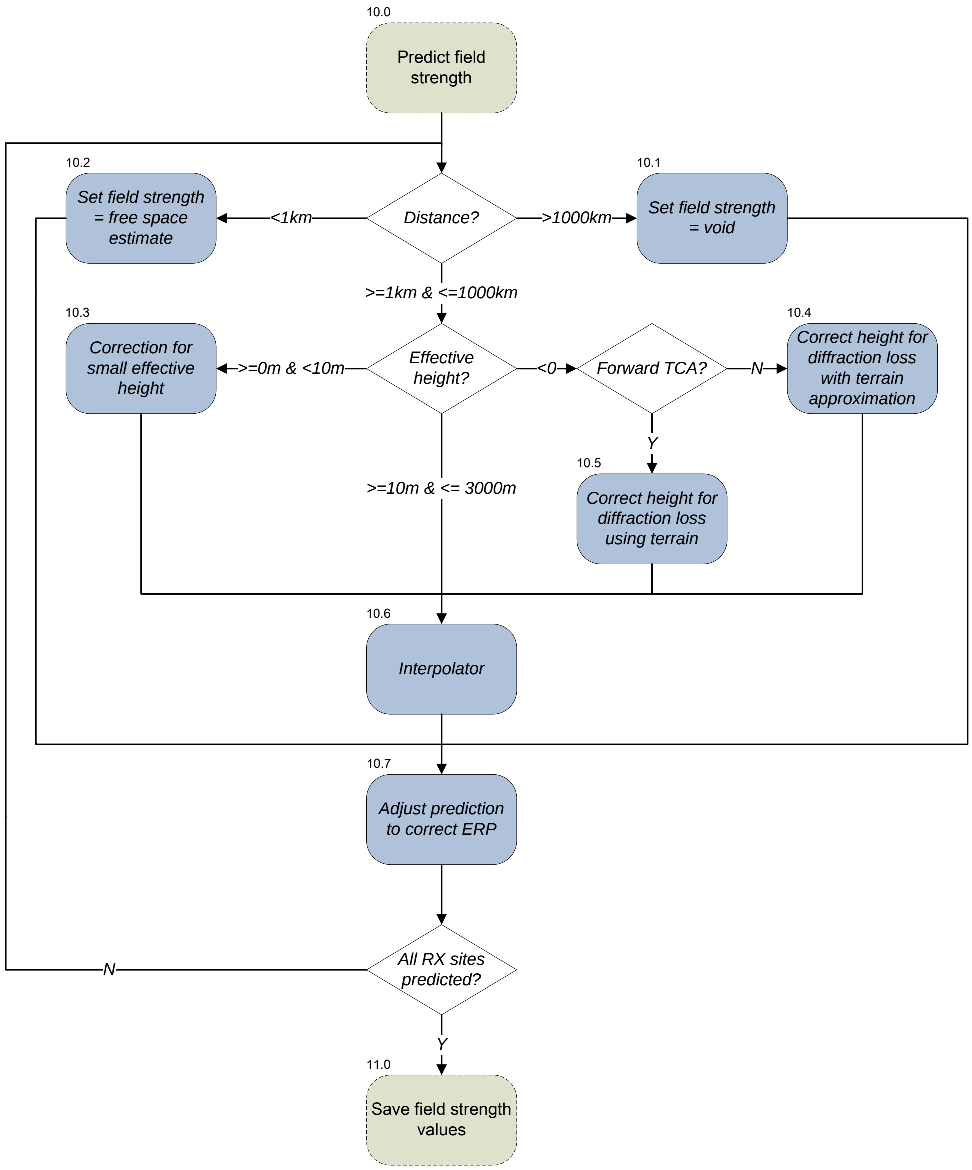


Figure 3.8: Logical flow expansion: Prediction phase, Block 10.0

Logical flow expansion: Block 10.0, Predict field strength

The logical flow expansion for block {10.0} is shown in figure 3.8. Block {10.0} contains the core logic of the ITU-R P.1546 propagation model. The preceding blocks calculated the input parameters that will now be evaluated to produce a field strength estimate. The interpolator logic {10.6} is further expanded below for clarity.

As discussed in section 3.3, the ITU-R P.1546 propagation model is valid for distances between 1 km and 1000 km. Field strength values at distances below 1 km are estimated by the standard free space loss equation {10.2}. Distances beyond 1000 km are not predicted and only assigned a void value {10.1}.

The effective height parameter is also checked for valid input ranges of between 10 m and 3000 m. The location of a transmitter site in a valley, surrounded by mountains, can result in negative values of effective antenna height. These values need to be adjusted for, either explicitly by using the forward TCA {10.5} or by terrain approximation {10.4}. Very short transmitter antenna heights, relative to the surrounding terrain, can result in effective antenna heights below 10 m, which also need to be accounted for {10.3}.

A field strength value can now be predicted from the relevant field strength curves using the interpolator {10.6}. The predicted field strength value returned by the interpolator is relative to 1 kW ERP. The predicted value needs to be adjusted to the actual transmitter ERP to yield the correct field strength prediction {10.7}. Block {10.1} to {10.7} is repeated until a field strength prediction for every receiver location is obtained.

Logical flow expansion: Block 10.6, Interpolator

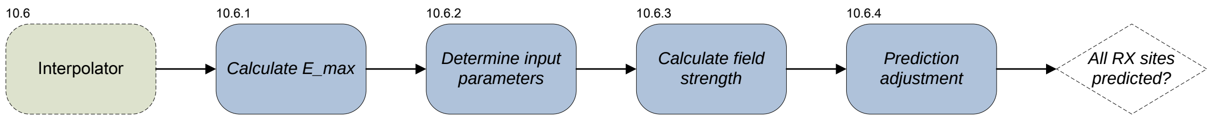


Figure 3.9: Logical flow expansion: Prediction phase, Block 10.6

The logical flow expansion for block {10.6} is shown in figure 3.9. With valid input values of distance, effective antenna height, frequency and percentage time, the interpolator can produce a field strength estimate. Key to the interpolator functioning is the calculation of the E_max parameter {10.6.1}. E_max represents the free space field strength obtained at a certain distance and frequency. No field strength prediction interpolated from the curves may ever exceed E_max. E_max is used in {10.6.3.9} and {10.6.4.5} to limit the predicted field strength.

The next step is to determine the input parameters for the interpolator {10.6.2}. The field strength is then calculated via interpolation {10.6.3} and the field strength prediction is improved with optional adjustments if so required {10.6.4}.

The logical flow expansion for {10.6.2}, {10.6.3} and {10.6.4} will now be further discussed in the sections that follow. To aid in the understanding of the flow diagrams, the variable names need to defined as shown in table 3.2. f, h and d denote the input frequency, height and distance respectively. f_inf, h_inf and d_inf denote the corresponding nominal value on the field strength curve just below or equal to the input f, h and d. Similarly, f_sup, h_sup and d_sup denote the corresponding nominal value on the field strength curve that is just greater than the input f, h and d.

Table 3.2: Variable names and description used in block {10.6}

Variable name	Meaning
E	Field strength
E_max	Free space field strength for 1 kW ERP
f	Input frequency
h	Input effective antenna height
d	Input distance
$perc$	Percentage time
f_inf, h_inf, d_inf	Nominal value $\leq$ input value
f_sup, h_sup, d_sup	Nominal value $\geq$ input value
$f\_interp, h\_interp, d\_interp$	Interpolation of f,h and d
Ef_inf, Eh_inf, Ed_inf	Field strength for f_inf, h_inf and d_inf
Ef_sup, Eh_sup, Ed_sup	Field strength for f_sup, h_sup and d_sup

Variables f_interp, h_interp and d_interp are boolean, and denote whether f, h or d will need to be interpolated or just read directly from the field strength curve. Variables Ef_inf, Eh_inf and Ed_inf denote the field strength for f_inf, h_inf and d_inf. Variables Ef_sup, Eh_sup and Ed_sup denote the field strength for f_sup, h_sup and d_sup.

For the land-based propagation paths, there are a total of nine ITU-R P.1546 field strength curves. There is a separate field strength curve for each combination of the three time probabilities (1%, 10%, 50%) and three frequencies (100 MHz, 600MHz, 2GHz). The nominal values in the ITU-R P.1546 field strength curves for height are 10 m, 20 m, 37.5 m, 75 m, 150 m, 300 m, 600 m and 1200 m. The nominal values for distance are shown in table 3.3 for reference.

Table 3.3: Nominal values for distance in ITU-R P.1546 field strength curves

Distance (km)												
1	2	3	4	5	6	7	8	9	10	11	12	13
14	15	16	17	18	19	20	25	30	35	40	45	50
55	60	65	70	75	80	85	90	95	100	110	120	130
140	150	160	170	180	190	200	225	250	275	300	325	350
375	400	425	450	475	500	525	550	575	600	625	650	675
700	725	750	775	800	825	850	875	900	925	950	975	1000

Logical flow expansion: Block 10.6.2, Determine input parameters

The logical flow expansion for block {10.6.2} is shown in figure 3.10. For each of the input values (f, h, d) it is determined whether the input value is a nominal value, i.e. can be looked up directly from the relevant field strength curve. For frequency (f), should the input value coincide with a nominal value, interpolation of frequency is not necessary, and $f\_interp = 0$ {10.6.2.1}. Similarly, the same logic follows for height {10.6.2.4} and distance {10.6.2.7}.

Should the input frequency (f) not coincide with a nominal value, interpolation is required and $f\_interp = 1$, with f_inf set at the nearest nominal frequency below f and f_sup set at the nearest nominal frequency above f {10.6.2.2}, {10.6.2.3}. The same logic follows for height {10.6.2.5}, {10.6.2.6} and for distance {10.6.2.8}.

Logical flow expansion: Block 10.6.3, Calculate field strength

The logical flow expansion for block {10.6.3} is shown in figure 3.11. Two function prototypes are introduced in the flow diagram to aid in explaining the logic and making the diagram self-explanatory:

- Function $Lookup(f, d, h, perc)$
- Function $CalcFS(Ex\_inf, Ex\_sup, x\_inf, x\_sup, x)$

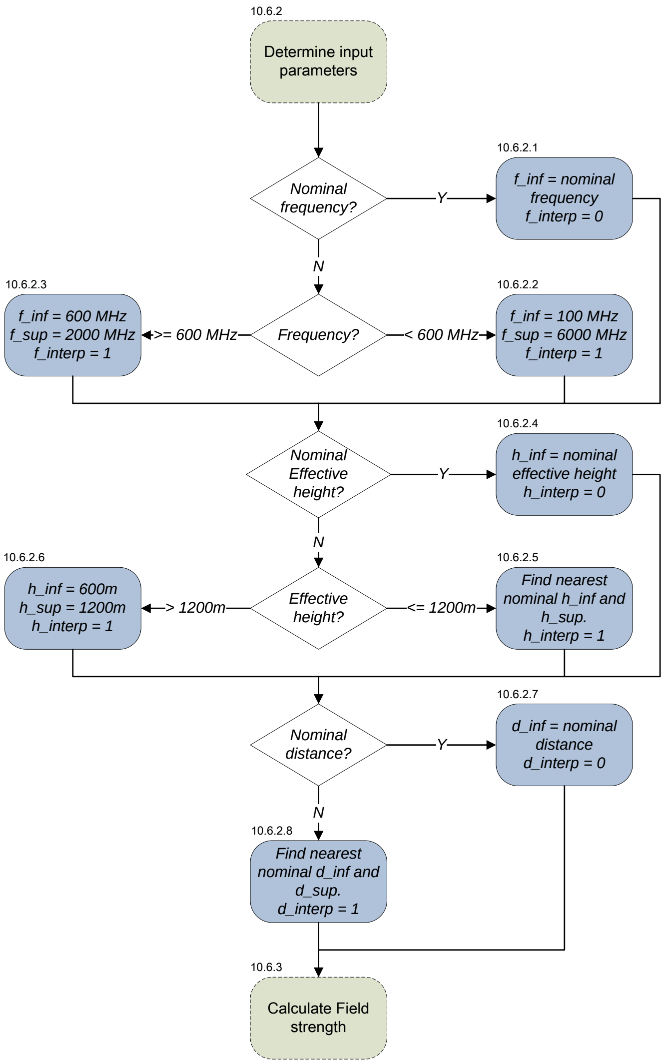


Figure 3.10: Logical flow expansion: Prediction phase, Block 10.6.2

Function $Lookup(f, d, h, perc)$ accepts four input parameters, namely frequency, distance, height, and percentage time. This function performs a lookup of the field strength value from the the relevant ITU-R P.1546 field strength curve. The input parameters therefore all need to be nominal values as discussed above for frequency and height, and shown in table 3.3 for distance.

Function $CalcFS(Ex\_inf, Ex\_sup, x\_inf, x\_sup, x)$ accepts five input parameters, determined by the value of x. The syntax is consistent with the convention given in table 3.2. This function performs linear interpolation for the logarithm of the input value x as given by equation 3.1 [30]:

$$E = Ex\_inf + \frac{(Ex\_sup - Ex\_inf)log_{10}(x/x\_inf)}{log_{10}(x\_sup/x\_inf)} \tag{3.1}$$

where $x = f, h$, or d.

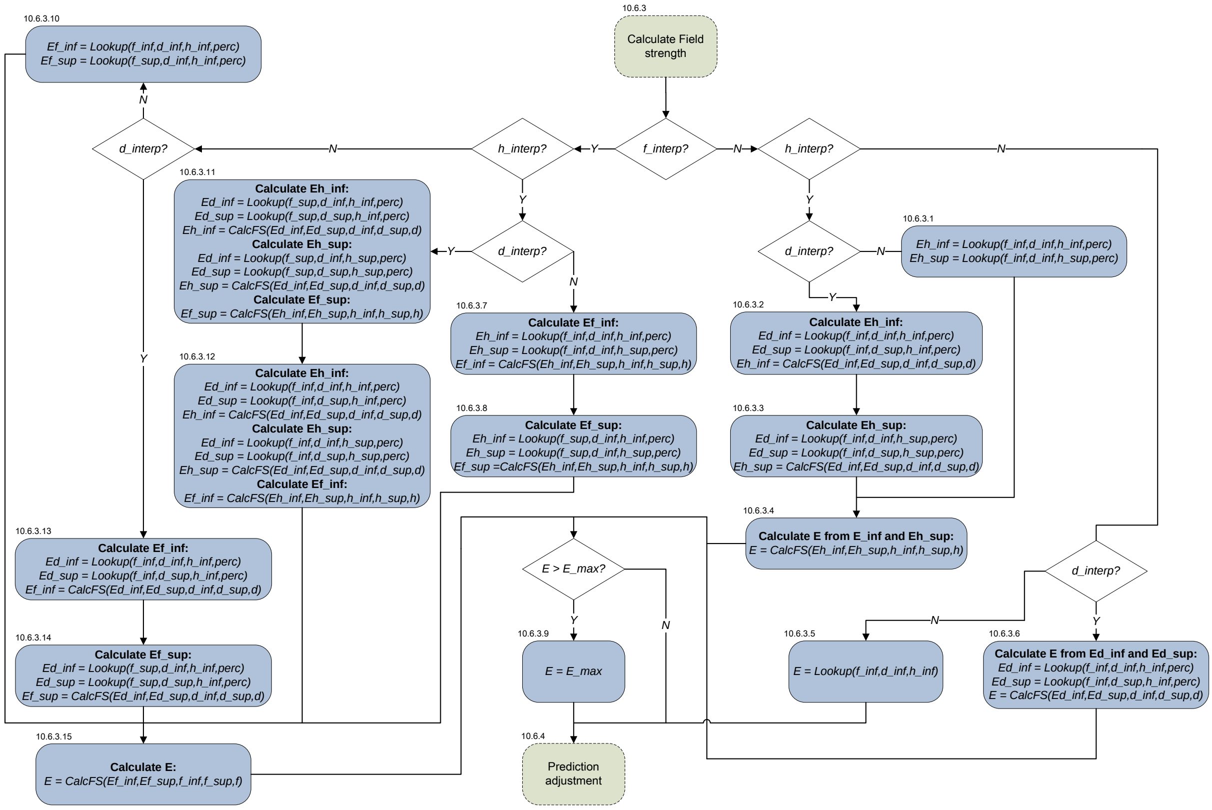


Figure 3.11: Logical flow expansion: Prediction phase, Block 10.6.3

Logical flow expansion: Block 10.6.4, Prediction adjustment

The logical flow expansion for block {10.6.4} is shown in figure 3.12. This block details the adjustments or corrections that can be added to the predicted field strength to improve the accuracy of the prediction. The TCA correction {10.6.4.1} uses the reverse TCA that was calculated in {9.2}.

The Tropospheric scatter correction {10.6.4.2} provides a field strength estimate due to the tropospheric scatter propagation mode. This field strength is denoted E_{ts}. The P.1546 recommendation calls for E_{ts} to be compared with the field strength (E) predicted by the model. For certain paths, the P.1546 could possibly underpredict the field strength, E. If $E_{ts} > E$, the recommendation states that E_{ts} should rather be used as the predicted field strength. This correction also requires the forward and reverse TCA as input parameters {9.2}, {9.3}.

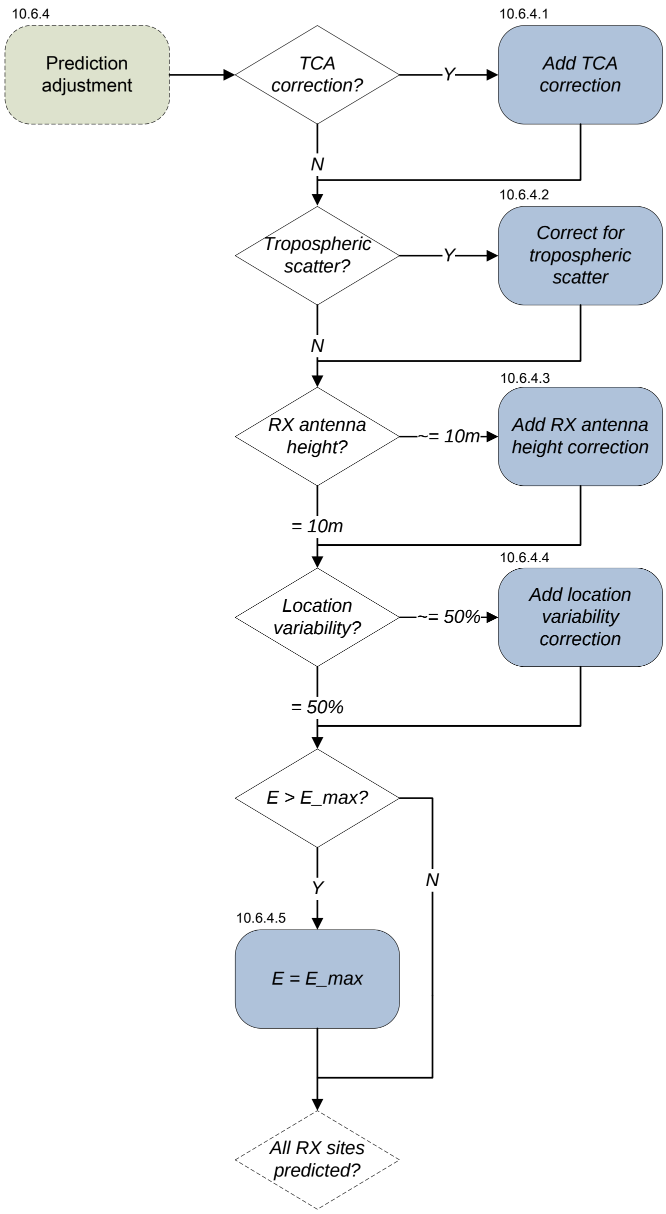


Figure 3.12: Logical flow expansion: Prediction phase, Block 10.6.4

The receiver antenna height correction accounts for receiver antenna heights other than 10 m {10.6.4.3}. The default receiver height is intentionally set at the representative clutter height of 10 m, as numerous other ITU recommendations assume the receiver antenna is at the representative clutter height for planning purposes.

By default the ITU-R P.1546 field strength curves predict a field strength for 50% of locations within the area of analysis. The location variability correction {10.6.4.4} allows other location probabilities to be used.

After the corrections have been applied, the field strength E is compared to E_max to ensure that the predicted field strength does not exceed free space loss {10.6.4.5}.

3.6 System implementation

The system model is implemented in the Matlab® software package. The discussion for the system implementation will be presented in the form of mathematical equations and algorithms where required. The function blocks that are self-explanatory or only deal with logical decisions will not be revisited again, as the logical flow presented in section 3.5 covered these issues in detail. It should be noted that equations in this section which are not specifically referenced, refer to equations from the ITU-R P.1546 recommendation [30].

3.6.1 Grid system

The grid system defines the geographical extent over which the field strength values will be predicted. Typically, the geographical extent in this work is the surface area of South Africa. The grid spacing or grid cell size is also an important parameter, as it influences data resolution and computation time required.

The coordinate system used in the grid is also of importance, as the ground distance of a grid system defined in a geographic coordinate system is not constant. Ground distance for grid systems in a geographical coordinate system remains relatively constant in the east/west or longitudinal direction, whilst changing more in the north/south or latitudinal direction. The horizontal grid spacing of a metric coordinate system, i.e. the ground distance, can be roughly estimated by equation 3.2 [89]:

$$\Delta x_{metric} = F \cdot cos(\varphi) \cdot \Delta x_{degree} \tag{3.2}$$

where Δx_{metric} is the east/west grid cell size in metres, estimated for a given latitude (φ) in degrees, Δx_{degree} is the grid cell size in degrees at the equator, and $F = 111,319$ km is the empirical constant to convert from degrees to kilometres.

Table 3.4 shows how the horizontal grid cell size or ground distance varies in kilometres for a geographical grid spacing of 1° at different latitudes.

Table 3.4: Variation in ground distance with latitude, grid cell size is 1°

Latitude	Ground distance (km)
0°	111,319
−22°	103,213
−24°	101,694
−32°	94,404
−35°	91,187

The grid geometry for a single cell in a square grid system defined within a geographical coordinate system is shown in figure 3.13. The cell size or grid spacing in the case of a square grid system is denoted by $\Delta x_{degree} = d$.

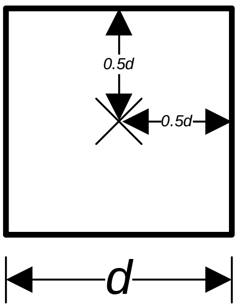


Figure 3.13: Grid cell geometry

The shape of a square grid system simplifies the geo-referencing of cells in the grid. Consider the 1° × 1° quadrangle which spans from 16°E - 17°E and 23°S - 22°S. Let the cell size $\Delta x_{degree} = 0,2°$, hence 5 cells per degree.

The grid geo-reference system used in the data structures is shown in figure 3.14. The left and bottom axes depict the latitude and longitude respectively, while the right and top axes depict the corresponding row and column numbers of the grid. A regular grid is geo-referenced by the north-western corner coordinate of the data grid in conjunction with the number of cells per degree.

The grid system in figure 3.14 is referenced and described in full by the following vector: $[5\ \ -22\ \ 16]$, where parameter 1 is the number of cells per degree, parameter 2 is the northern latitudinal extent of the grid and parameter 3 is the eastern longitudinal extent of the grid. The data grid row $(R1, R2, .., R5)$ and column $(C1, C2, .., C5)$ ordering are also indicated in the figure. Note that row 1 (R1) of the data grid is located at the southern extent of the geo-referenced grid.

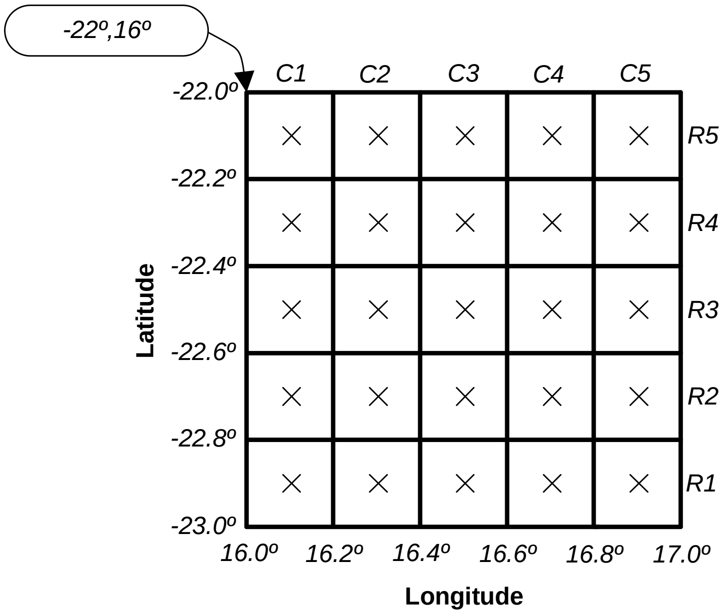
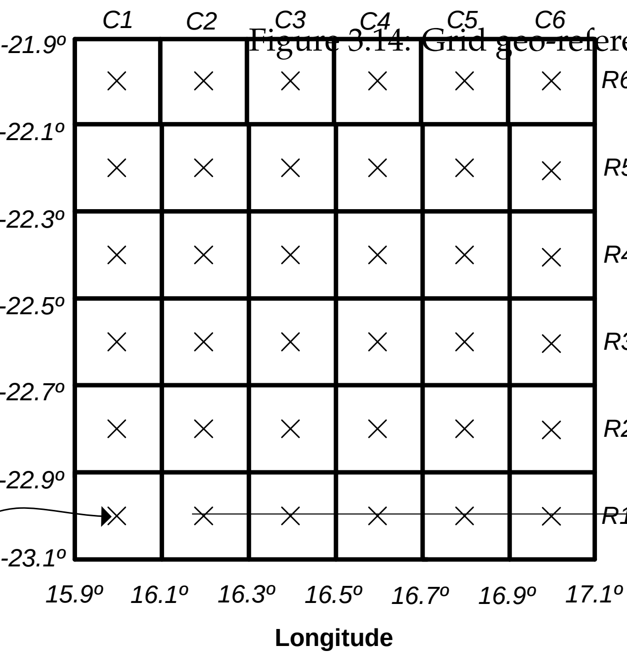


Figure 3.14: Grid geo-reference system: regular data grid structure in Matlab®



3.6.2 Calculation of the geodesic

In the study field of geodesy, the geodesic on the reference ellipsoid is the shortest distance between two points on the ellipsoid along the surface of the ellipsoid. The geodesic is therefore an approximation of the shortest surface distance between two points on earth. In general, the problem of calculating geodesic distance can be formulated as the the direct and inverse problem [90]:

Direct problem: Given the latitude and longitude of a point on the surface of the ellipsoid, along with the geodesic distance and forward azimuth. Find the latitude, longitude and reverse azimuth at the finishing point.

Inverse problem: Given the latitude and longitude of the starting- and finishing-point on the surface of the ellipsoid, find the geodesic distance between the points, the forward azimuth and reverse azimuth.

The Matlab® `Distance` and `Reckon` functions are used for solving the inverse and direct geodesic distance problems respectively. These functions implement the Vincenty method [91] for solving the geodesic. This method has been shown to provide accurate results in the sub-millimetre range, which is more than sufficient for the purposes of calculating path length distance in the order of metres. This method provides accurate results for solving the geodesic as long as the starting- and finishing-points are not situated at nearly opposite or exactly opposite sides of the earth. This is referred to as antipodal behaviour. Due to the geographical location of South Africa, antipodal behaviour for the geodesics calculated will not be a problem.

3.6.3 Elevation database

The elevation database is a integral part of the system model because of the following reasons:

- The effective height parameter is not provided by the information obtained from

ICASA. Elevation data is therefore required to calculate the effective height parameter.

- Many of the prediction adjustment models require elevation information, for instance TCA adjustment, tropospheric scatter adjustment, and correction of negative effective heights.

Motivation for DEM choice

For the purposes of this thesis, a DEM is required for the extraction of the terrain profiles between transmitter and receiver. Accordingly, the DEMs considered are now briefly discussed.

The Shuttle Radar Topography Mission (SRTM) DEM is derived from an 11-day mission that recorded elevation values for the the entire land mass of the earth between 60° north latitude and 56° south latitude at a grid cell size of 1 x 1 arc-second latitude/longitude using a single-pass radar interferometer. Elevation data for a grid cell size of 1 arc-second is available for the USA. For the rest of the world, these 1 arc-second quadrangles are re-sampled to either 3 arc-second or 30 arc-second quadrangles by averaging. A 30 arc-second and 3 arc-second cell size represent an approximate ground distance of 1 km and 90 m respectively [92].

The, ASTER global DEM provides elevation values for the entire land mass of the earth between 83° north latitude and 83° south latitude at a grid cell size of 1 x 1 arc-second latitude/longitude. The ASTER measurement device is still in orbit and returns new data to earth on a continual basis. The data returned from the instrument is used to periodically update the DEM. [93]

The dataset is accompanied by a quality assessment file that gives the number of observations that have been made for a particular grid cell on earth. The observation count can be used as a indicator of trust for the reported elevation value. The DEM has void pixels for which no ASTER measurements are available. These voids are patched from other lower resolution DEM datasets. Currently the ASTER DEM is not favoured for use in South Africa due to the low observation count values over South Africa [94].

The Chief Directorate: National Geospatial Information (CD:NGI) of South Africa provides the following data:

- Contour lines with an interval of 20 m and spot heights as found on the 1:50 000 topographical map series.
- Contour lines with an interval of 5 m to 20 m and spot heights as derived from the 1:10 000 orthophoto map series.
- 25 m and 50 m DEM.

Only the 20 m contour interval data is available for the entire country. The other two datasets provide only partial coverage of South Africa. Furthermore, the contour lines alone cannot be used to accurately derive a DEM for the entire country.

Recently, work has been done for the purpose of hydrological modelling in South Africa. The SRTM 3 arc-second dataset is improved by generating a new DEM from the SRTM data and the CD:NGI 20 m contour lines [94]. There is also work in progress to derive a DEM using a fusion approach based on 1:10 000 partial coverage orthophoto contour lines, the 1:50 000 topographic map contour lines, and the SRTM 3 arc-second dataset [95].

These approaches improve the absolute vertical error of the SRTM dataset through interpolation. The findings of [94] and [95] confirm that the SRTM 3 arc-second DEM currently provides the best full coverage elevation dataset of South Africa. International SRTM validation tests report an absolute height error of 6 m at a 90% confidence interval for Africa [96]. Voids are also of concern in the SRTM 3 version 2.1 dataset, and are discussed in the section that follows.

Evaluation of voids in the elevation dataset

The SRTM 3 version 2.1 dataset contains "no-data" holes or voids where reflections or shadowing prevented the measurement instrument from determining the elevation. These values are denoted by the value of -32768 in the data. The occurrence of voids in the dataset renders the data less useful. An terrain profile line running through one of these areas with voids is problematic, as no value can be returned for these areas.

The number of voids present in the SRTM DEM is evaluated for South Africa. This is done by determining which SRTM tiles are required to cover the entire landmass of South Africa. The voids in each $1^\circ \times 1^\circ$ SRTM tile is evaluated. In total 156 1° tiles are required to cover South Africa. 22 of the tiles had no voids present. The results for the other tiles that have voids are displayed in table 3.5.

Table 3.5: Statistical parameters: number of voids per 1° SRTM v2.1 tile

Parameter	Value
Minimum	1
Maximum	26739
Mean	575,14
Median	70,5
Standard deviation	2404,4

In total, the region analysed contained 77068 grid cells with voids, out of a total of 225014556 cells, which means that 0.0343 % of the grid cells are voids. This number may be small, but due to the way in which the SRTM measurement instrument functions, voids tend to group in areas of excessive reflectivity (water bodies, deserts) and shadowing (mountains).

Consider the $1^\circ \times 1^\circ$ quadrangle, which spans from 19°E - 20°E and 33°S - 34°S (shown in figure 3.15). The SRTM elevation data is shown, together with the voids, denoted by black areas in the figure. In total 26739 voids are present in this SRTM tile.

In [97] the void-filling methods most suitable for the SRTM dataset are investigated. The authors classify the voids found in the dataset according to void size and terrain relief class. The voids are classified into 8 classes based on size, and 6 classes based on terrain relief. The terrain relief classification methodology is derived from the 15 terrain relief classes as pioneered by [98]. The most appropriate void-filling method (interpolation method and/or use of auxiliary DEM data) is identified for each void class. A decision table is the output of the research, in each case stating the best void-filling method to use based on terrain relief type and void size.

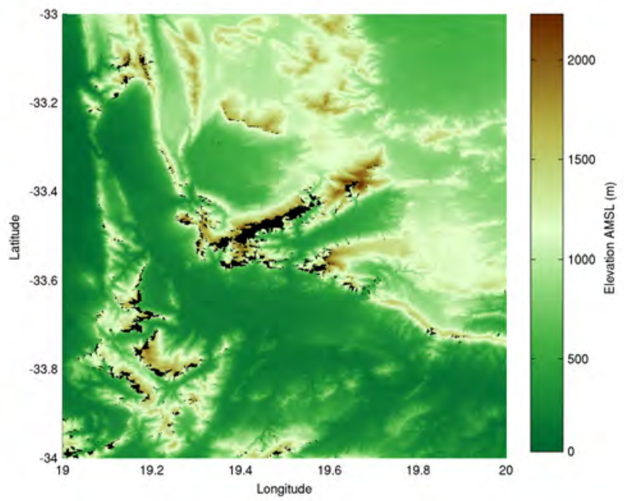


Figure 3.15: SRTM v2.1 elevation tile, voids in black

This methodology has also been applied to SRTM 3 v2.1 dataset, and the void-filled DEM tiles are available from [99]. The void-filled dataset is also known as SRTM v4 dataset. It is identical to the SRTM v2.1, except for the voids which have been filled with the appropriately interpolated values.

From the discussion above it follows that for the purposes of the system model it will therefore be better to use a DEM that does not have any voids. The improved DEMs using the contour lines from CD:NGI feature improved absolute height accuracy [95], [94]. However, the treatment of voids is not as extensive as in [97]. The decision was therefore taken to use the SRTM v4 dataset [99] as the DEM in the system model.

SRTM grid system

By means of a similar example as in section 3.6.1, consider the 1.2° × 1.2° quadrangle which spans from 15.9°E - 17.1°E and 23.1°S - 21.9°S. Let the cell size be $\Delta x_{degree} = 0,2°$, hence 5 cells per degree. An explanation of the SRTM DEM grid reference system is shown in figure 3.16. The SRTM DEM grid is geo-referenced by the centre coordinate of the south-western corner's cell in conjunction with the number of cells per degree. The data grid rows start at the southern extent of the geo-referenced grid. Also of importance is the offset in longitude and latitude of the grid cell boundaries as illustrated in the figure.

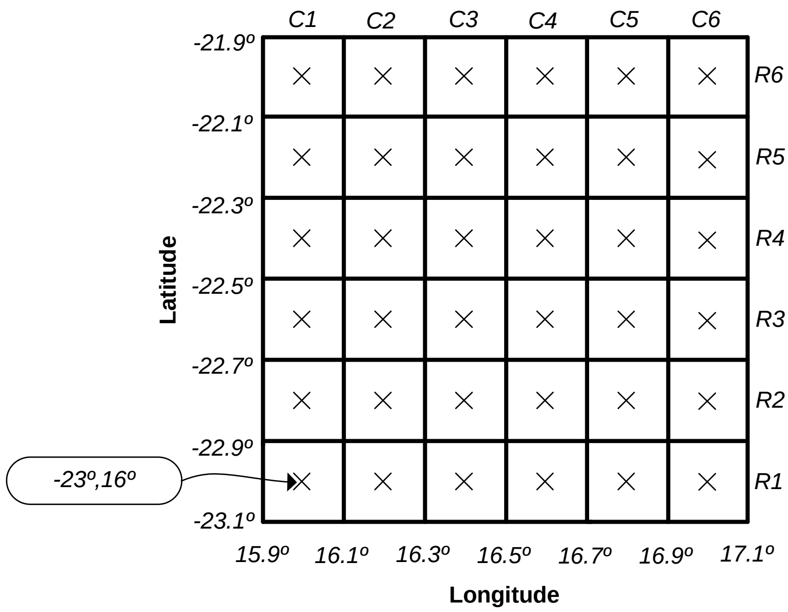


Figure 3.16: Grid geo-reference system: SRTM DEM

Note that figure 3.16 is merely an illustrative example to explain the grid system used by the SRTM DEM. The grid spacing is in reality 3 arc-seconds ($\Delta x_{degree} = 0,0008\dot{3}°$) or 1200 cells per degree. The SRTM dataset is provided as a mosaic of 1° × 1° tiles with abovementioned grid system and grid spacing. Each tile can be uniquely identified according to the reference vector. Tiles are loaded as required, and the necessary elevation values are constructed.

3.6.4 Prediction phase implementation

Block 1.1: Input parameters and constants

The system-wide input parameters and constants together with default values, where applicable, are shown in table 3.6. South Africa's official geographic datum, the Hartebeesthoek 94 datum (Hart94), uses the WGS84 ellipsoid as the reference surface of the earth [100]. The WGS84 ellipsoid is therefore taken as the reference surface of the earth [101]. The LatLon (Latitude/Longitude) geographical coordinate system is used throughout the prediction phase to minimise unnecessary distortion due to coordinate transformations or projections.

Table 3.6: System constants and default input parameters

Parameter	Description
$c = 300 \times 10^6$ m/s	Velocity of an electromagnetic wave in a vacuum
$k = 1.38 \times 10^{-23}$ J/K	Boltzmann's constant
$T_0 = 290$ K	Absolute temperature
$h_{rx} = 10$ m	Receiver antenna height
$d_{step} = 100$ m	Step size between samples for terrain profile extraction {6.0}
Δx_{degree}	Grid cell size in degrees
WGS84	Reference ellipsoid
LatLon	Geographical coordinate system

Block 1.2: Field strength data structure

The analysis region needs to be defined before the field strength data structure can be created. The analysis region is defined by loading the relevant shapefile, containing, for instance, provincial or national borders, into the model. The ESRI shapefile format stores the geometry of spatial features as a shape, which is described by a set of vector coordinates. The Matlab® `Shaperead` function reads the shapefile into a vector structure from where it can be manipulated in the model. The minimum number of $1^\circ \times 1^\circ$ tiles required to cover the geometry defined by the vector coordinates is determined. Each tile is uniquely defined by its reference vector as explained in section 3.6.1.

A data structure is created for each grid cell present in the grid structure of the each tile, with the following fields:

- Channel number
- Service type: analogue or digital
- PU site responsible for prediction
- Field strength prediction

The mosaic of tiles is written to disk. The relevant tiles will be loaded as and when required by block {2.0}, thereby facilitating the efficient use of RAM.

Block 1.3: PU data structure

The PU data structure aggregates all the technical information available on the PUs of interest into a database. The database maintains a data structure for the following fields:

- Transmitter site geographical coordinates
- Transmitter station name
- Structure of channel entries in use at the transmitter site

The structure of channel entries contains the following fields:

- Channel number
- ERP
- Antenna height AGL
- Service type: analogue or digital

- Service status: Operational, Licensed or Spare
- Antenna polarisation
- Channel frequency

The PU data structure is populated with entries from the terrestrial TV transmitter database and Final Terrestrial Broadcasting Plan, as obtained from ICASA. Full details of the transmitter database is provided in section 5.1.

Block 3.0: Calculation of receiver site coordinates

The receiver site coordinates are calculated by using the Matlab® `Setltln` function. The function accepts a regular grid, its reference vector, and row and column numbers of the coordinates that is to be found. The coordinates at the centre point of each cell are returned.

Block 5.0: Path profile extraction

Block {5.0} is responsible for determining the path length and azimuth of each transmitter-receiver pair. The distance from the transmitter to each of the receiver locations needs to be calculated. The forward azimuth is also required. The distance parameter is required by block {10.0} and the forward azimuth parameter is required by block {6.0}. The parameters are calculated by using the Matlab® `Distance` function. The use of the internal Matlab® function is motivated in section 3.6.2.

Block 6.1: Load elevation tiles

The SRTM $1^\circ \times 1^\circ$ tiles that contain the elevation data are loaded into RAM. Elevation tiles are loaded in and out of memory as required, in order to prevent the possibility of a memory overflow occurring. The details of the SRTM DEM are provided in section 3.6.3.

Block 6.2: Calculate terrain profile for effective height

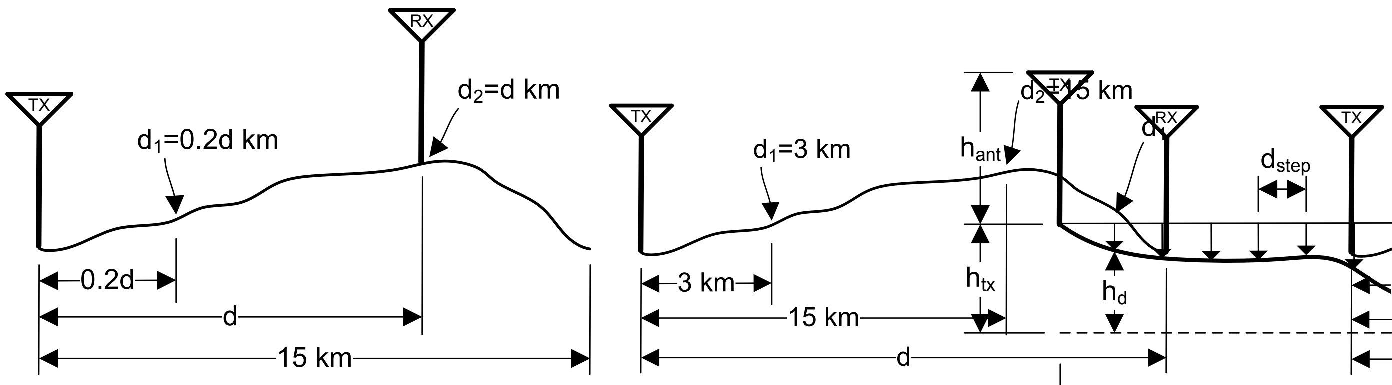
The terrain profile that is required to calculate the effective antenna height parameter in {7.0} is given by equation 3.3:

$$d_1 = 0.2d\,\text{km};\ d_2 = d\,\text{km}, \qquad \text{for } d < 15\text{km} \qquad (3.3a)$$

$$d_1 = 3\,\text{km};\ d_2 = 15\,\text{km}, \qquad \text{for } d \geq 15\text{km} \qquad (3.3b)$$

where d is the path length between transmitter and receiver in kilometres. d_1 and d_2 is the distance along the path in kilometres, as measured from the transmitter in the direction of the receiver.

Figures 3.17a and 3.17b illustrate the terrain profile implied by equations 3.3a and 3.3b, respectively. The transmitting antenna is denoted with TX whilst the receiving antenna is denoted with RX in the figures.



(a) $d < 15$ km (b) $d \geq 15$ km

Figure 3.17: Terrain profile required to calculate the effective height

Block 6.3: Calculate reverse TCA

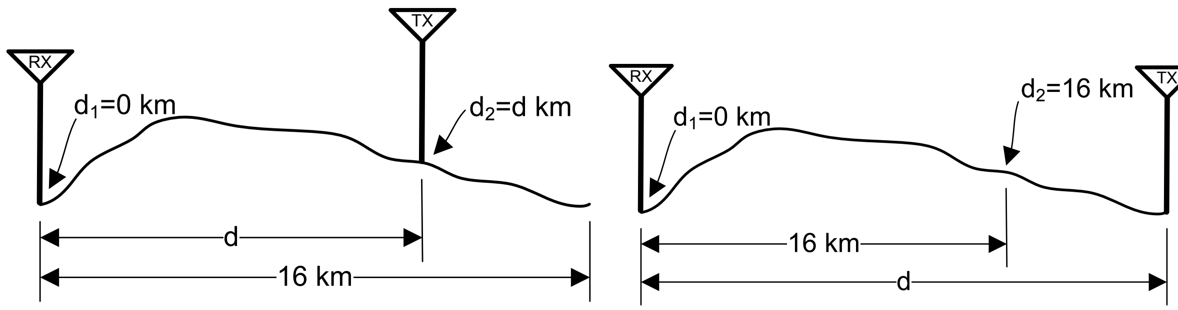
The terrain profile that is required to calculate the reverse TCA is given by equation 3.4:

$$d_1 = 0\,\text{km};\ d_2 = d\,\text{km}, \qquad \text{for } d < 16\text{km} \tag{3.4a}$$

$$d_1 = 0\,\text{km};\ d_2 = 16\,\text{km}, \qquad \text{for } d \geq 16\text{km} \tag{3.4b}$$

where d is the path length between transmitter and receiver in kilometres, and d_1 and d_2 is the distance along the path in kilometres, as measured from the receiver in the direction of the transmitter.

Figures 3.18a and 3.18b illustrate the terrain profile implied by equations 3.4a and 3.4b, respectively. The transmitting antenna is denoted with TX whilst the receiving antenna is denoted with RX in the figures.



(a) $d < 16$ km (b) $d \geq 16$ km

Figure 3.18: Terrain profile required to calculate the reverse TCA

Block 6.4: Calculate forward TCA

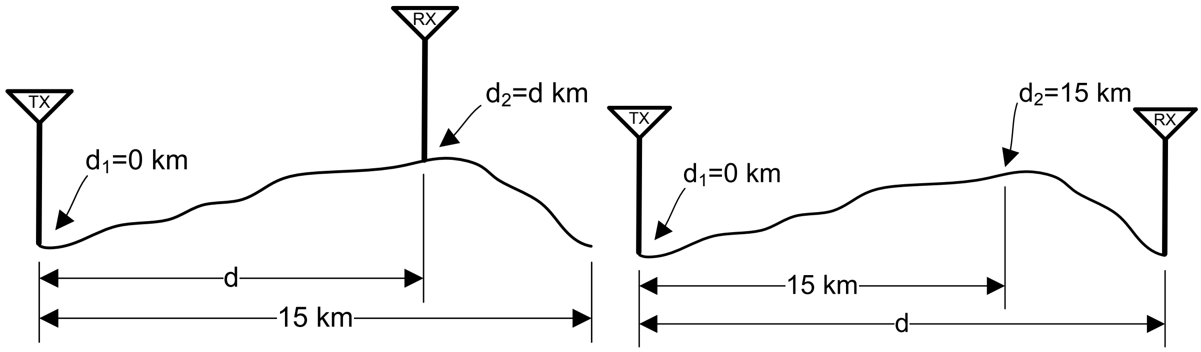
The terrain profile that is required to calculate the forward TCA is given by equation 3.5:

$$d_1 = 0\,\text{km};\ d_2 = d\,\text{km}, \qquad \text{for } d < 15\text{km} \tag{3.5a}$$

$$d_1 = 0\,\text{km};\ d_2 = 15\,\text{km}, \qquad \text{for } d \geq 15\text{km} \tag{3.5b}$$

where d is the path length between transmitter and receiver in kilometres, and d_1 and d_2 is the distance along the path in kilometres, as measured from the transmitter in the direction of the receiver.

Figures 3.19a and 3.19b illustrate the terrain profile implied by equations 3.5a and 3.5b, respectively. The transmitting antenna is denoted with TX whilst the receiving antenna is denoted with RX in the figures.



(a) $d < 15$ km (b) $d \geq 15$ km

Figure 3.19: Terrain profile required to calculate the forward TCA

Block 7.0: Calculation of effective height

The effective antenna height is defined as the average height (elevation) of the transmitting antenna above the terrain, averaged between distance d_1 and d_2 in the direction of the receiving antenna [30].

First, the mean effective height of the terrain between d_1 and d_2 is calculated. The parameters d_1 and d_2 are defined in equation 3.3. The average height of the terrain between d_1 and d_2, in the direction of the receiving antenna, can be determined as shown in equation 3.6:

$$\bar{h} = \frac{1}{n}\sum_{i=1}^{n} h_{d_i}, \quad d_i = d_1 + \frac{i(d_2 - d_1)}{n} \tag{3.6}$$

where $\bar{h}$ is the mean effective height of the terrain in metres, n is the number of points sampled on the path length between d_1 and d_2, and h_{d_i} is the height of the terrain Above Mean Sea Level (AMSL) at distance d_i from the transmitter in metres.

The number of points, n, is determined by the distance interval of stepping between d_1 and d_2. The distance interval is determined by the step size parameter, d_{step}, as defined in table 3.6.

Block 9.1: Calculation of effective antenna height

The effective antenna height is calculated by adding the height of the antenna AGL to the mean effective height of the transmitter site above terrain. Antennas may be mounted at different heights on the same mast; hence channel entries at the same transmitter site will not have the same mean effective height relative to the surrounding terrain.

To calculate the effective antenna height in the direction of the receiving antenna, equation 3.6 is substituted into equation 3.7:

$$h_{eff} = h_{ant} + h_{tx} - \overline{h} \tag{3.7}$$

where h_{eff} is the effective antenna height in the direction of the receiving antenna in metres, h_{ant} is the height of the transmitter antenna AGL in metres, h_{tx} is the height of the transmitter site AMSL in metres, and $\overline{h}$ is the averaged height of the terrain between d_1 and d_2, also in metres.

The parameters that are required to calculate the effective antenna height are shown in figure 3.20. The downward pointing arrows illustrate the points (d_i in equation 3.6) at which the height of the terrain AMSL (h_{d_i} in equation 3.6) are sampled with step size d_{step}. The antenna height AGL (h_{ant}) and transmitter site AMSL (h_{tx}) are also shown to illustrate how these parameters relate to each other. Parameters d_1 and d_2 are the distances as defined in equation 3.3.

Refer back to the logical flow of figure 3.4. By calculating the mean effective height ($\overline{h}$) of the terrain once for every path length from each transmitter site {7.0}, and simply adding the correct antenna height and transmitter site height for the relevant channel entry on each repetition {9.1}, the computation time of the prediction process is reduced.

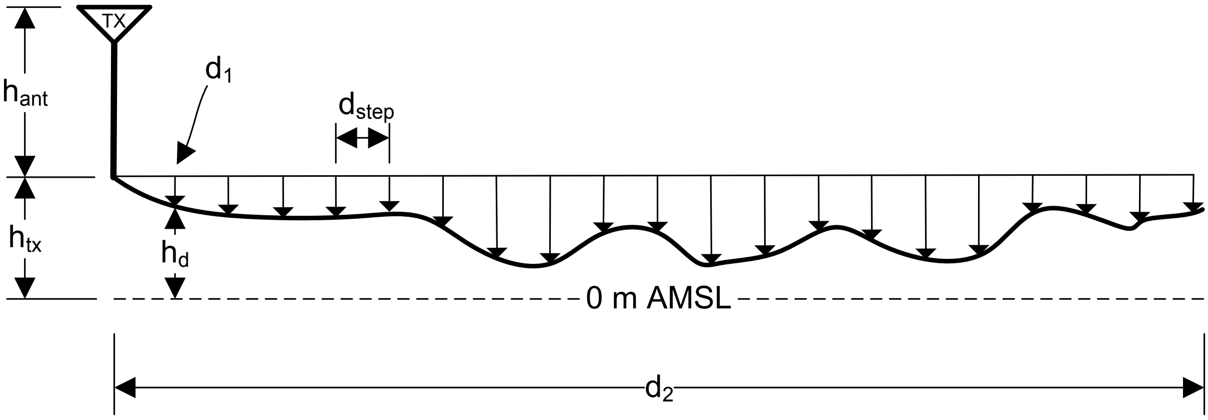


Figure 3.20: Parameters required for the calculation of effective height

Block 9.2 & 9.3: TCA calculation

The forward TCA is the elevation angle of the line from the transmitting antenna which clears all terrain obstructions in the direction, but not extending beyond, the receiving antenna over a distance.

Similarly, the reverse TCA is the elevation angle of the line from the receiving antenna which clears all terrain obstructions in the direction, but not extending beyond, the transmitting antenna.

For the calculation of the TCA, the curvature of the earth should not be compensated for in the extracted terrain profile. The values of the forward and reverse TCA are defined and limited as follows:

$$\theta_{tca} = \theta \tag{3.8a}$$

$$\theta_{tca} \leq 40^\circ \tag{3.8b}$$

$$\theta_{tca} \geq 0.55^\circ \tag{3.8c}$$

where θ_{tca} is the TCA (reverse or forward) in degrees. θ_{tca} is limited to the range of permissible values as shown in equation 3.8b and equation 3.8c. θ is the elevation angle in degrees.

The elevation angle, θ is calculated for the forward TCA and the reverse TCA respectively. Figure 3.21 illustrates how θ is calculated. Parameters d_1 and d_2 are also depicted. The values for d_1 and d_2 are calculated using equation 3.4 and 3.5 for the reverse and forward TCA respectively.

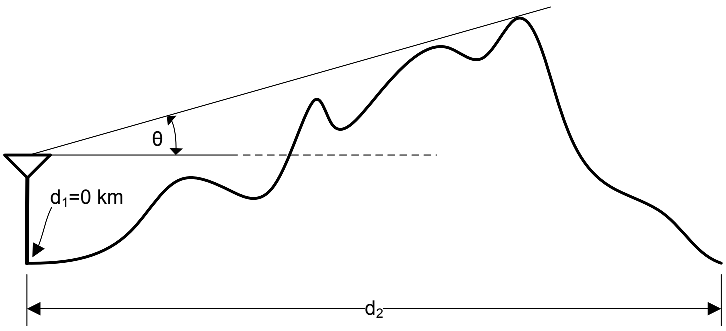


Figure 3.21: Determining the TCA

Block 10.2: Free space estimate of field strength

When a field strength prediction is required for a distance of less than 1 km between transmitter and receiver, the field strength is estimated by the free space loss equations [30]. The free space field strength for 1 kW ERP is given by equation 3.9:

$$E_{fs}(d) = 106.9 - 20log_{10}(d) \tag{3.9}$$

where E_{fs} is the free space field strength in dBμV/m and d is the distance in kilometres. Approximating the near field distance of the transmitting antenna , $d_{nf} = 0.01$km. The field strength, E, is then estimated at $d < 1$ km by:

$$E = E_{fs}(0.01) \qquad \text{for } d \leq d_{nf} \tag{3.10a}$$

$$E = E_{fs}(d) \qquad \text{for } d_{nf} < d \leq 0.1 \text{ km} \tag{3.10b}$$

$$E = E_{fs}(0.1) + (E_{fs}(1) - E_{fs}(0.1))log_{10}(d/0.1) \qquad \text{for } 0.1 \text{ km} < d \leq 1 \text{ km} \tag{3.10c}$$

where E is the estimated field strength in dBμV/m.

Block 10.3: Correction for small effective height

If the effective height is below 10 m but not negative, the following correction needs to be applied:

$$
\begin{aligned}
E &= E_{zero} + 0.1h(E_{10} - E_{zero}) \\
E_{zero} &= E_{10} + 0.5(E_{10} - E_{20} + C_{hneg10})
\end{aligned}
\tag{3.11}
$$

where E is the field strength in dBμV/m, E_{10} and E_{20} are the field strengths from the P.1546 curves for $h = 10$ m and $h = 20$ m respectively. C_{hneg10} is the correction obtained from equation 3.12, but setting $h = -10$ m.

Block 10.4: Correction for diffraction loss with terrain approximation

If the effective height input parameter is negative, account can be taken of diffraction loss due to nearby obstacles. The correction C_h is calculated using equation 3.12. Correction C_h is added to the field strength that is calculated using equation 3.11, setting $h = 0$.

$$C_h = 6.03 - J(v) \tag{3.12a}$$

$$J(v) = \left[6.9 + 20log_{10}(\sqrt{(v-0.1)^2+1} + v - 0.1)\right] \tag{3.12b}$$

$$v = K_v \theta_{eff} \tag{3.12c}$$

$$\theta_{eff} = tan^{-1}(-h/9000) \tag{3.12d}$$

$$K_v = 1.35 \text{ for } 100 \text{ MHz}$$

$$K_v = 3.31 \text{ for } 600 \text{ MHz}$$

$$K_v = 6 \text{ for } 2 \text{ GHz}$$

where C_h is the adjustment value in dB and θ_{eff} is the TCA in degrees.

The TCA is approximated by calculating the clearance angle for an obstruction of height h at a distance of 9 km from the transmitter. The distance of 9 km is chosen halfway between the path lengths of 3 km and 15 km, which are normally used to calculate the effective height parameter for receivers further than 15 km from the transmitter. These path length values were defined in equation 3.3. K_v is linearly interpolated for non-nominal values of frequency.

Block 10.5: Correction for diffraction loss using terrain database

An alternative method can also be used to account for diffraction loss if the effective height input parameter is negative. Block {10.5} functions similarly to {10.4}. However, the correction C_h is now calculated by taking the actual terrain profile between the transmitter and receiver into account. This is done by calculating the forward TCA {9.3} using equation 3.8, and substituting the result into equation 3.12c. C_h, as determined with equation 3.12a, is added to the field strength that is calculated using equation 3.11, setting $h = 0$.

Block 10.6.1: Calculating E_max

The *E_max* parameter is calculated using the free space field strength equation for 1 kW ERP:

$$E\_max = E_{fs}(d) \tag{3.13}$$

where E_{fs} is the free space field strength in dBμV/m, given by equation 3.9 and d is the distance in kilometres.

Calculating the field strength

Block {10.6.2} does not contain any mathematical formulae, as only variable assignment and logical decisions are made. This block has been sufficiently discussed in section 3.5.2 and figure 3.10.

In block {10.6.3}, two functions were introduced to aid in explaining the logical flow.

The formula for function $CalcFS$ is given by equation 3.1. The purpose and function of $Lookup$ was described in section 3.5.2. The logic that determines when and how these functions are called is accurately described by the flow diagram in figure 3.11.

Block 10.6.4.1: TCA correction

The TCA correction improves the prediction accuracy by taking the terrain obstacles at the receiver into account. This correction is applicable to a small area around the receiver site, typically 500 m x 500 m or less. The correction C_{tca}, in dB, is added to the predicted field strength and is given by:

$$C_{tca} = J(v') - J(v) \tag{3.14a}$$

$$v' = 0,036\sqrt{f} \tag{3.14b}$$

$$v = 0,065\,\theta_{tca}\sqrt{f} \tag{3.14c}$$

where $J(v')$ and $J(v)$ are given by respectively substituting equation 3.14b and 3.14c into equation 3.12b, f is the frequency in MHz and θ_{tca} is the reverse terrain clearance angle in degrees, as calculated with equation 3.8.

Block 10.6.4.2: Tropospheric scatter propagation mode

The field strength estimate for the tropospheric scatter propagation mode is calculated by firstly determining the path scatter angle, θ_s, in degrees:

$$\theta_s = \frac{180d}{\pi ka} + \theta_{tca_f} + \theta_{tca_r}\,,\ \theta_s \geq 0 \tag{3.15}$$

where d is the path length in kilometres, k is the effective earth radius factor, a is the radius of the earth in *kilometres*, θ_{tca_f} is the forward TCA and θ_{tca_r} is the reverse TCA, both in degrees.

The path scatter angle is calculated using a spherical approximation of the earth, hence $a = 6370$ km. The effective earth radius factor is taken as $a = 4/3$. The forward and reverse TCA are calculated in each instance with equation 3.8.

The field strength for tropospheric scatter can now be calculated as follows:

$$\begin{aligned} E_{ts} &= 24.4 - 20log_{10}(d) - 10\,\theta_s - L_f + 0.15\,N_0 + G_t \\ L_f &= 5log(f) - 2.5\,((f) - 3.3)^2 \\ G_t &= 10.1(-log_{10}(0.02t))^{0.7} \end{aligned} \tag{3.16}$$

where E_{ts} is the field strength due to troposcatter in dBμV/m, d is the distance in kilometres, θ_s is the path scatter angle in degrees, L_f is the frequency dependent loss with f in MHz, N_0 is the median surface refractivity in N-units and G_t is the time dependant enhancement with percentage time t.

Determination of the median surface refractivity

The median surface refractivity in equation 3.16 is typically set at $N_0 = 325$ N-units, which is the median value for temperate climate conditions. South Africa's climate is predominantly temperate, as was shown in section 3.4.4. However, this parameter is recalculated for South Africa to determine the empirical median surface refractivity.

Recommendation P.453 [86] provides contoured maps of the median surface refractivity for the world with a grid cell size of 1.5° and is obtainable from the ITU-R radio communication bureau in electronic form [102]. The surface refractivity for South Africa is evaluated over a uniform grid, spaced at 5 arc-minutes. Values for sample points that do not coincide with the grid points of the surface refractivity are obtained by bi-linear interpolation, as per recommendation P.1144 [88].

The statistical parameters for the vertical refractivity gradient is provided in table 3.7. Figure 3.22 provides the empirical CDF of the refractivity gradient as calculated from the sampled grid locations. From the analysis, the median surface refractivity parameter is set at $N_0 = 332.9943$ N-units in equation 3.16.

Table 3.7: Statistical parameters: median surface refractivity (N_0) for South Africa, extrapolated to sea level

Parameter	Value
Minimum	315.4416
Maximum	349.7077
Mean	333.1502
Median	332.9943
Standard deviation	8.9665

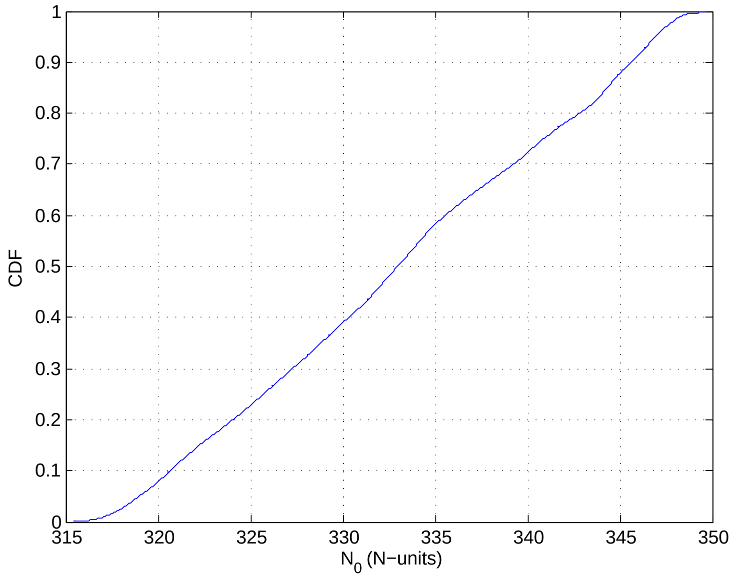


Figure 3.22: Empirical CDF: median surface refractivity extrapolated to sea level

Block 10.6.4.3: Receiver height correction

The correction for receiver height has different correction procedures for urban and non-urban paths, and whether the receiver is above or below the clutter height. These procedures are described in detail in annex 5, section 9 of the P.1546 recommendation. For the purposes of the work presented in the thesis the correction $C_{clutter}$ in dB is implemented only for receiver heights above the representative clutter height of 10 m:

$$\begin{aligned} C_{clutter} &= K\,log_{10}(h_{rx}/R), \quad R = 10 \text{ m}, \, h_{rx} \geq R \\ K &= 3.2 + 6.2 log_{10}(f) \end{aligned} \tag{3.17}$$

where h_{rx} is the receiver antenna height AGL in metres, R is the representative clutter height in metres and f is the frequency in MHz. $C_{clutter}$ is added to the predicted field strength E.

Block 10.6.4.4: Location variability

For location probabilities other than 50%, the field strength $E(q)$, which will be exceeded for q% of locations, is given in dBμV/m by:

$$E(q) = E_{q=50\%} + Q_i(q/100)\sigma_L, \quad 1\% \leq q \leq 99\% \tag{3.18a}$$

$$\sigma_L = K + 1.3log_{10}(f) \tag{3.18b}$$

where $E_{q=50\%}$ is the field strength for 50% location probability in dBμV/m, Q_i is the inverse Gaussian Complementary Cumulative Distribution Function (CCDF) as a function of probability q, and σ_L is the standard deviation of the Gaussian distribution that is either derived from the local mean values in the study area or approximated using equation 3.18b with frequency f in MHz.

The procedure for approximating the inverse Gaussian CCDF is provided in annex 5, section 15 of the P.1546 recommendation [30]. Preferably σ_L must be derived for the local area of interest or a representative value must be used. If this information is not available, the approximation in equation 3.18b can be used with $K = 1.2$ for receivers below the representative clutter height, $K = 1$ for reception at the clutter height and $K = 0.5$ for rural areas.

Block 10.7: Adjust prediction to correct ERP

The magnitude of the power density, P_D, in W/m^2 can be expressed as follows [103]:

$$P_D = EH \tag{3.19}$$

where E is the electrical field strength magnitude in V/m and H is the magnetic field strength in A/m. In free space, the ratio of the electrical field and the magnetic field in an electromagnetic wave is constant and can be expressed in terms of the intrinsic impedance of free space:

$$\frac{E}{H} = 120\pi \tag{3.20}$$

Substituting equation 3.20 into equation 3.19 gives:

$$P_D = \frac{E^2}{120\pi} \tag{3.21}$$

Rewriting for E:

$$E = \sqrt{P_D 120\pi} \tag{3.22}$$

The power density, P_D, in W/m^2 on a unit sphere due to an isotropic radiator producing power P_T at its centre, can be expressed as follows [103]:

$$P_D = \frac{P_T}{4\pi r^2} \tag{3.23}$$

where power P_T is in watts and radius r is in metres.

Considering the power density in the principal direction of the transmitting antenna with gain G_T:

$$P_D = \frac{P_T G_T}{4\pi r^2} \tag{3.24}$$

Substituting equation 3.24 into equation 3.22 yields:

$$E = \frac{\sqrt{30 P_T G_T}}{r} \tag{3.25}$$

where E is the electrical field strength in V/m and r is the distance from the transmitter in metres.

Rewriting equation 3.25 in terms of μV/m:

$$E = 1 \times 10^6 \frac{\sqrt{30 P_T G_T}}{r} \tag{3.26}$$

Rewriting equation 3.26 in terms of dBμV/m gives:

$$E = 20log_{10}(1 \times 10^6) + 10log_{10}(30) + 10log_{10}(P_T G_T) - 20log_{10}(r) \tag{3.27}$$

Refer to equation 3.27. For a fixed distance r, the relative field strength due to an increase in power P_T and/or gain G_T can be expressed as a ratio, as all other terms evaluate to constants:

$$E = 10log_{10}\left(\frac{P_{T_{new}} G_{T_{new}}}{P_{T_{ref}} G_{T_{ref}}}\right) \tag{3.28}$$

where $P_{T_{new}}$ and $P_{T_{ref}}$ are respectively the new and reference transmitter powers in watts, and $G_{T_{new}}$ and $G_{T_{ref}}$ are respective new and reference antenna gains in the linear domain.

The ITU-R P.1546 field strength prediction curves are for an ERP of 1 kW, hence by setting $P_{T_{ref}} G_{T_{ref}} = 1$ kW and substituting into equation 3.28:

$$E = 10log_{10}(P_{T_{new}} G_{T_{new}}) - 30 \tag{3.29}$$

where E is the field strength in dBμV/m, adjusted for $P_{T_{new}} G_{T_{new}}$. This equation holds only if the distance d remains unaltered.

3.7 Conclusion

In this chapter the system model was developed and described. The incorporation of the ITU-R P.1546 propagation model into the system model was motivated. Model features implemented were investigated and motivated. The flow of logic in the system was described through the use of flow diagrams. The selection of a DEM and other geographic assumptions were motivated. The system implementation details were also thoroughly discussed.

The deliverable from this chapter is a system model with an integrated standards compliant propagation model that is able to produce the geo-referenced field strength coverage maps required for the analysis of SO. It is not only of value for the work conducted in this thesis, but is also of practical relevance to any activity involving network planning or propagation prediction. The next chapter proceeds with the verification and validation of the system model.

Chapter 4

Verification and Validation

The focus of this chapter is on the verification and validation of the system model. The methodology followed to verify the constituent elements of the system model is described and developed. The operational validation of the system model is also discussed.

4.1 Verification methodology

The procedure followed to verify the system model is adopted from [104] and briefly described below. The goal of the verification process is to ensure that the system model as described in chapter 3 is correctly implemented. In [104], a methodology and techniques for the verification and validation of simulation models are developed. The general methodology discussed for verification is as follows:

1. Following good general programming practice and modularity as dictated by software engineering practice.

2. Verifying intermediate simulation model outputs, through tracing and/or statistical testing.

3. Comparing final simulation outputs with analytical results, using statistical tests.

The above model verification methodology is also advocated by [105], and is termed bottom-up dynamic testing. The sub-components of the system model are tested first, and thereafter the full system model is tested as a whole.

The use of statistical tests for verification is advocated in [104]. However, it is also argued that statistical testing is not required to verify the correctness of the system model, should the model have only deterministic inputs. For models adhering to this criterion the system model response or output must be identical to the theoretically determined response, with the exception of the numerical inaccuracies caused through computation.

4.2 System model verification

The process that is followed for formal verification of the system model is now described. The system model can be regarded as a deterministic model, and therefore statistical testing is not necessary for verification. The general procedure followed for verification of the system model is described in 4.2.1. The verification procedure for blocks {6.0}, {7.0} and {9.1} is described in more detail in section 4.2.2.

4.2.1 General verification methodology

Throughout the implementation of the system model the general guidelines of good programming practice and modularity have been observed. This is in line with step 1 of the verification methodology discussed above.

Chapter 3 described the flow of logical and mathematical formulae in detail for each modular functional block. The functional blocks and system model as a whole have deterministic inputs. The functional blocks are verified on a per block basis. Each functional block is fed a series of known input parameters. These input parameters are chosen so as to verify each possible path of logical flow through the functional block. The outputs of the functional blocks were respectively compared with the theoretically determined analytical results. This procedure corresponds with step 2 of the verification methodology: the verification of intermediate simulation model outputs.

After verifying that all the constituent functional blocks are implemented correctly, the final output of the system model is verified. The input parameters are once again chosen to verify each possible path of logical flow that can be taken through the system model. The system model outputs are compared with the theoretically determined analytical results to verify their correctness. This procedure corresponds with step 3 of the verification methodology.

Abovementioned verification steps 1 to 3 were performed for each of the functional blocks of the system model.

4.2.2 Verification of blocks 6.0, 7.0 and 9.1

The verification for blocks {6.0}, {7.0} and {9.1} is now described in more detail, as a slightly different approach compared to the abovementioned general system verification methodology, was followed. Furthermore, these functional blocks are required to furnish the ITU-R P.1546 propagation model (block {10.0}) with the correct effective antenna height. The TV transmitters entries for South Africa, which is found in the PU data structure, contain only the actual antenna heights in meter. The TV transmitter databases of other administrations in many instances already contain the effective antenna height parameter. For the purposes of this thesis it is therefore of interest to ensure that effective antenna heights are computed correctly.

The purpose of this verification procedure is three-fold:

- Verify that the implementation loads the correct elevation tile from the elevation database.

- Verify that the correct elevation value is extracted from the relevant SRTM tile.
- Verify the implementation of the mathematical formulae for blocks {7.0} and {9.1}.

Methodology

The implementation of blocks {6.0}, {7.0} and {9.1} is verified by comparing the outputs of the functional blocks with the outputs of an independent implementation that performs the same functionality. This procedure corresponds to step 2 of the verification methodology discussed above. The independent implementation referred to is a web-based application on the ITU website that calculates the effective height parameter using the SRTM v2.1, 3 arc-second DEM [106].

The web implementation differs in some respects from the system model implementation. These differences will have an impact on the analysis metrics. Inspection of the web-based implementation's source code reveals a few differences. Our system model assumes an ellipsoidal earth model, whilst the web implementation assumes a spherical earth model. Furthermore, the SRTM v 2.1 dataset, which is void-filled with DTED-0 data, is used by the web implementation [106]. The system model uses the SRTM v4 DEM [99]. Finally, the step size, d_{step}, is 100 m for the system model. The step size for the web implementation is not known.

For the verification analysis, the output values of the independent implementation will be regarded as the reference values, whilst the output of the functional blocks will be regarded as the predicted values. The input parameters are the geographical coordinates of the transmitter sites in the PU data structure. At the time of analysis, there were 716 unique transmitter sites in the data structure, which are regarded as the input samples. The geographical coordinates of these transmitter sites are shown in figure 4.1 as point markers.

The output parameter that is compared is a parameter called the maximum effective height, h_{max} [4]. This parameter is calculated as follows:

$$h_{max} = max\{h_{eff}^{x^\circ}\}, \quad x^\circ = 0, 10, 20, ..., 350 \tag{4.1}$$

where $h_{eff}^{x^\circ}$ is the antenna effective height in metres, for forward azimuth, x°. The forward azimuth, x°, is measured clockwise from north in degrees. $h_{eff}^{x^\circ}$ is calculated using equation 3.7, and setting $d_1 = 3$ km and $d_2 = 15$ km.

For the verification analysis, the antenna height AGL, $h_{ant} = 0$ m. h_{ant} is set as shown as the h_{ant} parameter has a linear effect on the end result, as was shown in equation 3.7.

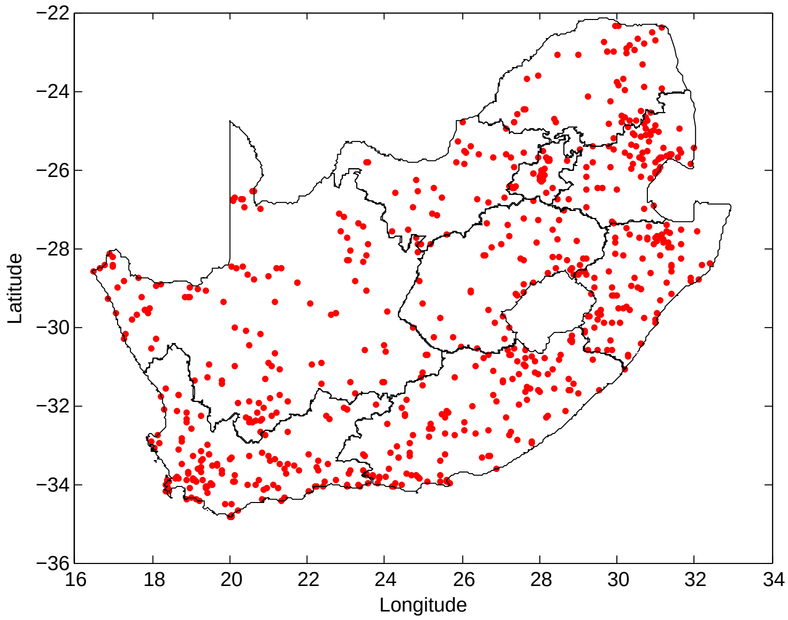


Figure 4.1: Input coordinates used for verification analysis

Analysis metrics

First order statistics are used to evaluate the verification results. The metrics considered are absolute error, maximum error, mean absolute error and Pearson's correlation coefficient [107]. The absolute error is expressed as shown in equation 4.2

$$\epsilon_i = |x_i - x_j|, \quad i = 1, ..., n \tag{4.2}$$

where x_i is the predicted value, x_j is the corresponding reference value and n is the number of samples. The corresponding maximum error is calculated as follows:

$$\epsilon_{max} = max\{\epsilon_i\}, \;\; i = 1, ..., n \tag{4.3}$$

The mean absolute error, ϵ_{mae}, is defined as follows:

$$\epsilon_{mae} = \frac{1}{n} \sum_{i=1}^{n} |x_i - x_j| \tag{4.4}$$

where x_i is the predicted value, x_j is the corresponding reference value and n is the number of samples.

Finally, Pearson's correlation coefficient, r_ϵ is determined as follows [107]:

$$r_\epsilon = \frac{\sum_{i=1}^{n} (x_i - \overline{x_i})(x_j - \overline{x_j})}{\sqrt{\sum_{i=1}^{n} (x_i - \overline{x_i})^2} \sqrt{\sum_{i=1}^{n} (x_j - \overline{x_j})^2}} \tag{4.5}$$

where x_i is the predicted values, x_j is the corresponding reference value, $\overline{x_i}$ is the predicted values mean, $\overline{x_j}$ is the reference value mean and n is the number of samples.

Verification results

The results of the metrics considered are summarised in 4.1. The empirical CDF of the absolute error is shown in figure 4.2. The mean absolute error and median absolute error suggest that the predicted and reference values are very similar. The standard deviation can be attributed to the differences in implementation as discussed above.

The maximum error, ϵ_{max} is however noteworthy. Further investigation into the cause of this large error can be attributed to a data point for a transmitter site which is located on a peninsula, close to the ocean. The retrieved elevation tile for the independent implementation retrieved a transmitter site height of 0 m, whilst the system model returned a transmitter site height of 113.19 m. This discrepancy can be attributed to the fact that the two implementations assume different earth models.

Pearson's correlation coefficient, r, indicates a strong positive linear relationship that is statistically significant ($p < 0,05$). The coefficient of determination, r^2, indicates a good linear fit between the reference and predicted output values. It can therefore be concluded that the functional blocks {6.0}, {7.0} and {9.1} are verified as having been implemented correctly.

Table 4.1: Statistical parameters: Absolute error

Parameter	Value
ϵ_{max}	113,19
ϵ_{mae}	1,817
Standard deviation	5,338
Median ϵ	0,678
r	0,9997
p-value	$< 0,05$
r^2	0,9994

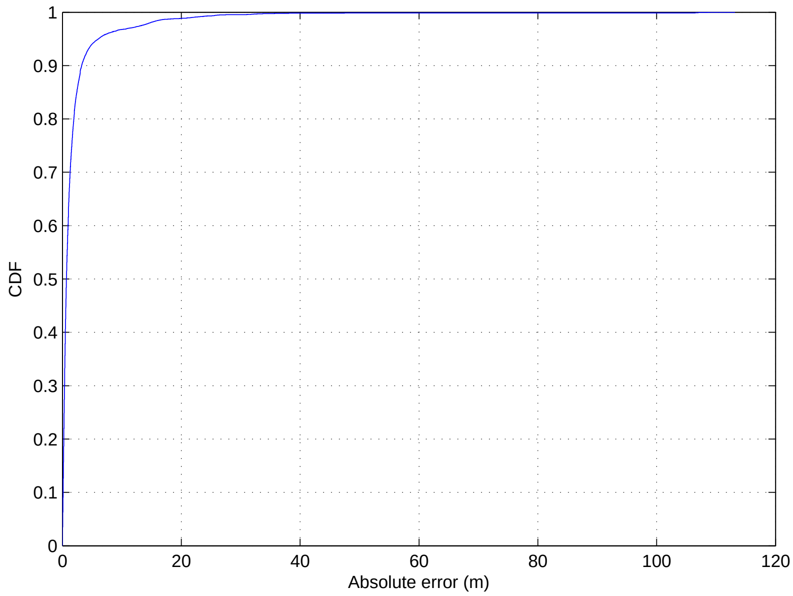


Figure 4.2: CDF: Absolute error for maximum effective height (h_{max})

4.3 System model operational validation

Operational validation is the process of determining whether the model's output has the accuracy required for the model's intended purpose over the model's application domain. Thus, the operational validation of a model is confirmed if it can be determined that the model is fit for the intended purpose [105].

In section 3.2 the motivation for incorporating the ITU-R P.1546 propagation model into the system model was given. It was argued that the propagation model is a valid model since a considerable amount of trust is placed in the model by administrations and regulatory bodies. The predictions obtained with the model are trusted by regulatory bodies and are in many instances used as the basis from which spectrum policy decisions are made. It was also noted that revision 3 of the model was used as the basis of the regional co-ordination an planning effort for the GE-06 agreement [4].

Section 3.4 noted that revision 4 of the propagation model was incorporated into the system model. A motivation was also given for the model features that were not implemented.

In section 4.2 the constituent elements of the system model was verified. The system model as a whole was also shown to be verified by comparing the final system outputs with the theoretically determined analytical results.

From the above it follows that the system model implements a valid propagation model. The implementation of the system model was verified to produce the correct output. The operational validation of the system model as a whole is now performed by comparing the outputs of a published prediction study to the results obtained by means of using the system model developed in chapter 3. The ability to determine SO from the system model predictions are also validated.

Methodology

Recall from section 2.7, that the work of Van de Beek et al. [74] quantified the white space availability in 11 European countries for channels 21-60 (470 MHz - 790 MHz), in terms of the number of available channels weighted by area and population. The ITU-R P.1546 version 4 model is used to obtain propagation predictions. The SO available to a hypothetical zero-watt secondary transmitter is considered. Abovementioned work is extended by also studying the effects of considering the adjacent channel protection requirements in [10].

The work in [10] is appropriate to validate system model developed in chapter 3, as the same propagation model type and version is used as the basis for these studies. The origin of the ITU-R P.1546 model used in [10], is unknown. However, for the purposes of validation, the propagation model used in [10] is regarded as an independent implementation. Furthermore, the ability to determine SO from the propagation predictions can also be validated by post-processing the results with the parameters as specified in [10].

To validate the developed system model, the SO weighted by area for the co-channel and adjacent channel availability criteria is recalculated for one of the countries in the study, i.e. the Netherlands. The resulting SO metrics are then compared to the published result in [10].

4.3.1 Analysis parameters

The system model input parameters and constants are used as was defined in table 3.6 of chapter 3. In addition to these parameters, the system model parameters used in the validation study are detailed in table 4.2. Deviations from the parameters used in [10] will be discussed accordingly. It must be noted that some of the metrics and concepts used in this validation study are introduced in chapter 5.

The grid spacing of 60 arc-seconds corresponds to a quadrangle of approximately 1.85 km $\times$ 1.85 km at the equator. Recall that the developed system model computes all calculations directly in geographical coordinates. The study in [10] was performed on a Lambert Azimuthal Equal-Area projected analysis surface with a square grid spacing of 2 km. However, results from the study and system model can be directly compared due to similar spatial resolutions being used for performing the propagation predictions and analysis.

Table 4.2: System model parameters for validation study

Parameter	Value
Δx_{degree}	60 arc-seconds
Transmitter antenna pattern	Omnidirectional
Propagation path	Land only
Location probability	50%
Time probability	50%
Diffraction loss correction	Terrain approximation method
Tropospheric scatter correction	No
TCA correction	No
Effective antenna height	Maximum effective height, h_{max}

The transmitter antenna patterns are all assumed omnidirectional. The propagation path considered is land only. The time and location probability was set at 50%, consistent with the general analysis parameters. The diffraction loss correction is applied through the terrain approximation method. This correction was discussed in section 3.6.4, block {10.4}. The tropospheric scatter correction is not considered, nor is the correction based on TCA, as these parameters require terrain data of the path traversed. It must be noted that the abovementioned propagation model parameters are not explicitly defined in [10].

The TV transmitter database for the Netherlands, publicly available from [108], was used as input data for the PU database. At the time of analysis, there were 71 unique transmitter sites in the data structure, with a total of 287 entries. At the time the study in [10] was performed, the database contained 281 entries. The maximum effective height parameter, h_{max} is already computed and available in the TV transmitter database for the Netherlands, and does not need to be computed. Figure 4.3 provides a visualisation of the transmitter sites present in the PU data structure for the Netherlands. The shapefile used in the validation study was obtained from [109].

The parameters used for the calculation of the validation metrics are detailed in table 4.3. The Netherlands has already completed analogue switch-off and therefore only the protection requirements for the DTT service are relevant. The protection requirements for the DTT service are calculated using the input parameters as defined for E_{min_f} in section 5.2.2. The modulation type used by all the digital transmitters are assumed to be 64-QAM as was done in [74] and [10], which implies a C/N of 18.7 dB. The protected contour in equation 5.5 is determined by setting the erosion margin, $\psi = 1$ dB as was done in [10]. From using these parameters the co-channel and adjacent channel availability decisions in equation 5.6 and 5.7 can be applied and the necessary validation metrics can be determined.

Table 4.3: Parameters for calculation of validation metrics

Parameter	Value
DTT protection	E_{min_f}
Modulation	64-QAM
Erosion margin	$\psi = 1$ dB

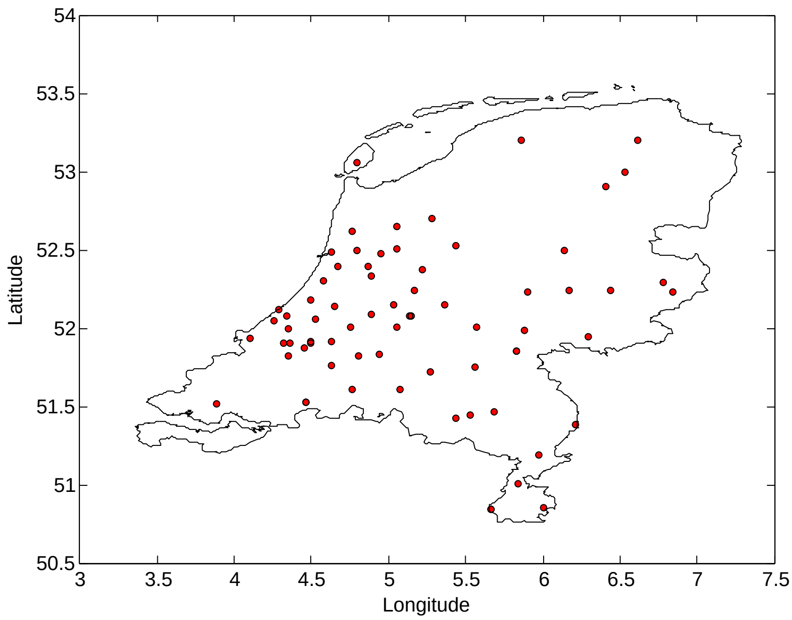


Figure 4.3: PU data structure visualisation for the Netherlands

Operational validation results

The mean values for the SO weighted by area ($\bar{s}_a$, $\bar{s}_a^{'}$) are reported for the co-channel and adjacent channel availability criteria respectively, in table 4.4. The validation metrics are shown for the results obtained via the developed system model, as well as the published results, as taken from table 2 in [10]. The mean values are also expressed as a fraction of the total number of UHF TV channels in the band. This fraction is expressed as a percentage and reported in brackets next to the actual mean values in table 4.4. The weighted mean values are rounded to the first decimal place, whilst the fractions are rounded to the nearest integer.

Table 4.4: Comparison of weighted mean values for UHF SO in the Netherlands

	$\bar{s}_a$	$\bar{s}_a'$
System model	25.8 (64%)	11.2 (28%)
Published result	23.7 (59%)	9.7 (24%)

The system model results are seen to be in good agreement with the published results for both the co-channel and adjacent channel availability criteria. The differences in the results can be attributed to a number of factors that are sources of uncertainty in the published result implementation. For instance, the exact ITU-R P.1546 propagation model parameters are not known for the published result. Furthermore, some of the parameters in the TV transmitter database may have changed over time. Calculations were performed on a projected map in the published result, whilst all calculations are performed in geographic coordinates in the system model. However, all these uncertainties taken into account, the developed system model is shown to provide output which is comparable and within acceptable range of the published result in [10]. It can thus be concluded that the system model is indeed fit for the intended purpose; hence operational validation is attained.

4.4 Conclusion

In this chapter the verification and validation process and methodology followed were discussed. The system model is verified to have been implemented correctly. Operational validation confirmed that the system model produces output that is acceptable for the intended purpose of the model. The next chapter describes the analysis methodology and metrics considered for evaluation.

Chapter 5

Analysis methodology

In this chapter the methodology followed to analyse SO is described in detail. First, the choice of input data used is discussed and motivated. Thereafter the protection requirements of the incumbent service are described and the definition adopted for harmful interference is stated. From the protection requirements, the availability criterion for the determination of SOs is formulated. Finally, the metrics evaluated in the analysis are defined.

5.1 PU data structure

The PU data structure is populated with information obtained from the Final Terrestrial Broadcasting Plan of 2008 [5] and the ICASA TV transmitter database. The Final Terrestrial Broadcast Plan is publicly available in the government gazettes, whilst the TV transmitter database was made available for research purposes by ICASA.

It is important to note that the TV transmitter database is regarded as a living document [110]. New entries are added continually and technical parameters of the present channel entries may change. Section 2.2.3 pointed out that the performance period is yet to commence. Sentech is still in the process of the DTT broadcast network roll-out. Technical parameters of analogue and digital entries may change as new DTT sites are deployed. Furthermore, analogue switch-off still needs to take place.

The landscape has changed since the RRC-06 band plans as detailed in the Final Terrestrial Broadcasting Plan of 2008 [5] were made. Digital migration is now directly to the DVB-T2 standard, instead of DVB-T, for which the RRC-06 channel assignment plans were originally made.

The SKA bid has been jointly awarded to South Africa and Australia. This impacts the DTT frequency plans that are made for the Northern Cape. The latest information at the time of writing suggests that communities in RFI-critical areas of the Northern Cape will now be receive digital TV via the satellite platform [45].

These imminent changes will affect the temporal and geographical relevance of predictions made, using the given input data. The results obtained with the system model should therefore always be viewed with due consideration of the input data used. For this reason the channel entries considered are provided in the appendices.

5.1.1 Input data for PU data structure

The PU data structure as discussed here will be used as the input dataset for all the results that follow in the rest of the thesis. The PU data structure includes the following entries as obtained from the ICASA TV transmitter database and Final Terrestrial Broadcasting Plan of 2008:

- All analogue channel entries with service status operational (OPE / OP) or licensed (LIC / LI), as found in the ICASA TV transmitter database.
- All digital channel entries as found in the Final Terrestrial Broadcasting Plan of 2008.

The entries currently not considered in the analysis, and hence not added to the PU data structure, can be summarised as follows:

- Analogue channel entries with service status spare (SPA / SP). These entries are per definition spare frequencies in the band plan for the analogue service [5].
- Analogue channel entries with other service statuses; typically these entries are from previous band planning exercises.
- Digital channel entries other than the entries given in the Final Terrestrial Broadcasting Plan of 2008.

The rationale for structuring the database will be discussed and motivated accordingly in sections 5.1.2 and 5.1.3 below.

5.1.2 Motivation for analogue entries considered

Comparison of the analogue entries in the ICASA TV transmitter database with the Final Terrestrial Broadcasting Plan of 2008 yields a few noteworthy observations. The Final Terrestrial Broadcasting Plan of 2008 contains the analogue and analogue self-help channel entries in annexure D and annexure E respectively [5].

The information in the TV transmitter database for entries with operational or licensed status is consistent with the information in annexure D and E, with the exception of a few extra channel entries present in the TV transmitter database. The extra entries represent additions of new self-help stations since the Final Terrestrial Broadcasting Plan had been published in the government gazette. In total 1743 unique analogue entries are present in the Final Terrestrial Broadcasting Plan, whilst the ICASA TV transmitter database contains 1800 unique analogue entries.

Both sources of information provide the transmitter site names, geographic coordinates, channel number, vision carrier frequency, ERP, polarisation, frequency offset, channel status and programme assigned for each channel entry. The TV transmitter database provides information on the antenna height AGL and site height AMSL in addition to aforementioned information. This is the one of the reasons for preferring the TV transmitter database as source for the analogue data. Without knowledge of the antenna heights of the transmitter sites, the prediction accuracy of the system model is compromised.

Following from the above, the decision was taken to use the 1800 unique analogue entries from the ICASA transmitter database as input data for the analogue service. The ICASA TV transmitter database contains the latest channel entry information and also provides the much-needed antenna height parameter.

5.1.3 Motivation for digital entries considered

As discussed in section 2.2.3, the RRC-06 band plans as detailed in the Final Terrestrial Broadcasting plan of 2008 were made to enable digital migration through a process of dual illumination [5]. The digital entries required to enable dual illumination, without interfering with the existing analogue service, are detailed in annexure F and annexure G for the DTT and mobile DTT services respectively. Two erratums to the digital entries of the Final Terrestrial Broadcasting Plan have been published since the introduction of the plan in 2009 [111], [112].

Comparison of the digital entries in the ICASA TV transmitter database with the Final Terrestrial Broadcasting Plan of 2008 and erratums yields the following observations. Both sources of information provide the transmitter site names, geographical coordinates, channel number, ERP, polarisation and channel status. The TV transmitter database provides information on the antenna height AGL and site height AMSL in addition to the aforementioned information. The Final Terrestrial Broadcasting Plan also indicates to which multiplex each digital entry is assigned.

The digital channel entries are denoted in the TV transmitter database with service status GO6, referring to the Regional Agreement GE06, adopted at RRC-06 and documented in the final acts of RRC-06 [4]. The digital channel entries in the ICASA TV transmitter database are to a certain extent consistent with the information published in the Final Terrestrial Broadcasting plan and published erratums. However, the TV transmitter database has numerous channel entries not present in the Broadcasting plan of 2008. In total 533 digital entries are present in the Final Terrestrial Broadcasting Plan, whilst the ICASA TV transmitter database contains 1577 digital entries.

It must be noted that many digital channel entries in the TV transmitter database are duplicate entries, i.e. having the same coordinates and channel, but with different ERPs and/or antenna heights. The extra digital channel entries in some instances refer to channels that are currently occupied by the analogue service. Furthermore, there is no differentiation made in the TV transmitter database between DTT and mobile DTT channel entries. It is also not possible to deduce which digital entries in the TV transmitter database are active during dual illumination, and which are spare entries for future planning requirements. As mentioned in section 5.1, the ICASA TV transmitter database should be regarded as living document [110]. The digital entries present in the database cannot be used as is, as this would result in interference with the deployed analogue service.

However, the digital entries as set out in the Final Terrestrial Broadcasting Plan and published erratums contain the relevant digital entries for the dual illumination period [5], [111], [112]. Digital migration is being done according to the Final Terrestrial Broadcasting Plan and published erratums [47]. The decision is taken to use the 533 digital entries as found in the Final Terrestrial Broadcasting Plan and erratums, as input data for the digital service. Taking these entries into account, a freeze date is set, after which no additional entries are added to the PU data structure. This freeze date will allow the results to reflect the SO statistics for full dual illumination, until analogue switch-off. The motivation for setting a freeze date is three-fold:

- It enables analysis to be based on active digital and analogue transmissions, at a predefined cut-off date. This allows for more realistic reporting of the SOs available, given said digital coverage and said freeze date.

- It would be impossible to know which of the digital channel entries are operational and which are spare were a freeze date not set. This information is not provided in any publicly accessible documents, and to the best of the author's knowledge, not divulged elsewhere.

- Assuming that all the digital entries in the TV transmitter database are active is also not correct. This has the effect that many of the digital entries will in totality overlap and interfere with the analogue broadcasting service. These band plan arrangements are not practical until analogue switch-off has occurred.

The antenna height parameter is not provided by the Final Terrestrial Broadcasting Plan, however. This information is retrieved for each digital entry in the plan from the matching transmission site in the ICASA TV transmitter database. The methodology followed to do this is discussed in section 5.1.5 below.

5.1.4 Possible temporal SO analysis scenarios

Given the input data considered for the analogue and digital service, the SO can be analysed for three discrete points in time.

- The SO before the start of the dual illumination period, i.e. the analogue service only, denoted by t_A.

- The SO right after analogue switch-off, i.e. the digital service only, denoted by t_D.

- The SO at a predefined point in time in-between, i.e full dual illumination right before analogue switch-off, denoted by t_{DU}.

These three temporal points in time can be defined by the set $\mathcal{T} = \{t_A, t_{DU}, t_D\}$. The analysis will be performed for these discrete points in time in order to compare the change in SOs with time.

5.1.5 Methodology for adding entries to the PU data structure

The methodology followed when adding entries to the PU data structure is now briefly discussed. The unique identifier for each entry is the combination of the latitude and longitude coordinates of each entry. Therefore, entries with the same latitudes and longitude coordinates are pooled under the same transmitter site in the PU data structure. Data is used as is, except where invalid, out-of bound data values or duplicate entries occur.

When the PU data structure was populated with data from the TV transmitter database and Final Terrestrial Broadcasting Plan, several duplicate entries were found. These duplicates are denoted by entries having the same geographic coordinates and channel number. In the case of duplicates, the entry with the highest ERP and/or antenna height is regarded in each instance. This ensures that the coverage area of the primary service is overpredicted rather than underpredicted. The other entry is omitted from inclusion in the PU data structure.

DTT and mobile DTT entries

The motivation for using the Final Terrestrial Broadcasting Plan and erratums as input data for the digital entries was discussed in section 5.1.3. The DTT and mobile DTT entries added to the PU data structure are detailed in appendix A and B respectively. The duplicate entries omitted are provided in table A.1 for the DTT entries. Of the total 533 digital entries, 525 are added to the PU data structure.

The antenna height parameters for the digital entries were obtained by matching each entry with its corresponding transmission site in the ICASA TV transmitter database. In each instance the maximum antenna height assigned at each site was taken as the representative height for the digital entries at that site. It should be noted that some digital sites are theoretical sites, and still need to be built, hence the antenna heights obtained for these sites are set at the representative planning value.

As stated previously, the input data is taken as the ground truth; hence the analysis is done with the technical parameters as provided, even though it might be that the input data deviates from the current or the future reality.

Analogue entries

The motivation for using the ICASA TV transmitter database as input data was discussed in section 5.1.2. The analogue entries added to the PU data structure are detailed in table C.3 - C.23 of appendix C. Note that the total number of entries in these tables amount to 1866 entries. The entries that were modified or omitted are detailed with their respective reasons in table C.1 of appendix C. Furthermore, entries were omitted due to the occurrence of duplicates. The list of entries omitted due to duplication is provided in table C.2 of appendix C. The total number of entries considered after the modifications and omissions are 1800 analogue entries.

Antenna radiation pattern

The antenna radiation pattern of all entries in the PU data structure is taken as omnidirectional, as per the recommendation of ICASA [110]. Due to the omnidirectional assumption, it is not possible to have more than one entry for frequency and channel at a transmitter site. This may explain some of the duplicate entries in the input data. It is feasible that directional antennas may be mounted on the same transmitter site and transmit on the same frequency without interference.

However, the approach of always using the highest ERP and/or antenna height combination for duplicate entries ensures that coverage is always overpredicted for the instances where sites make use of directional antennas.

5.1.6 Visualisation of the PU data structure

Figure 5.1 provides a visualisation of the transmitter sites present in the PU data structure. The visualisation contains three colour markers, used to denote the different types of transmitter stations:

- Red - Stations with analogue, DTT and Mobile DTT frequency assignments.
- Blue - Stations with only analogue frequency assignments.
- Green - Stations with only DTT and mobile DTT frequency assignments.

For each of the markers visualised, information pertaining to the technical parameters of the channels assigned at each transmitter station is kept in the PU data structure, as discussed in section 3.6.4.

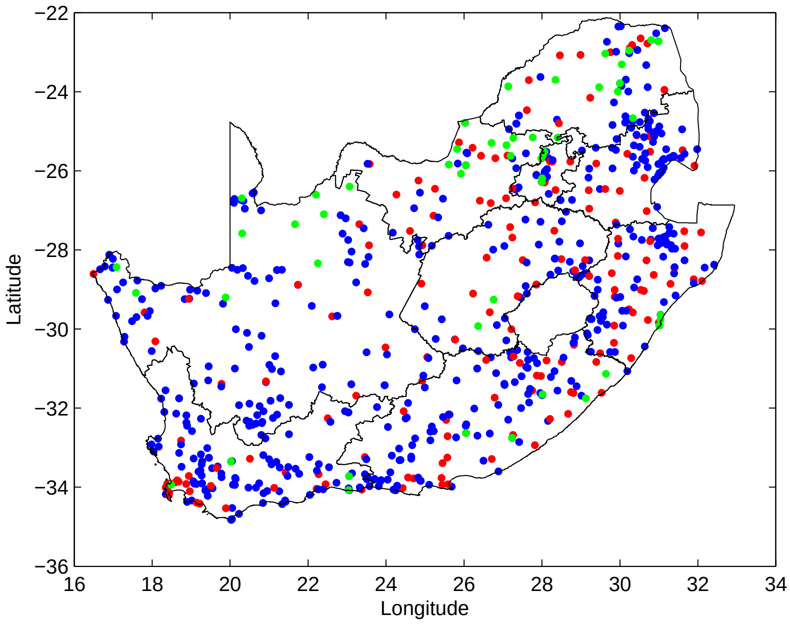


Figure 5.1: PU data structure visualisation

5.2 Protection requirements

In this section the protection requirements of the terrestrial TV spectrum incumbent are discussed. The transmitter stations and receivers of the terrestrial TV network must be protected from harmful interference caused by the secondary reuse of the spectrum. Two parameters that are of importance in the calculation of the protection requirements of the transmitter are the minimum field strength E_{min}, and the usable field strength E_{med}. The minimum field strength, E_{min}, is the minimum field strength value for which acceptable picture quality at the reception site will be ensured, in the presence of natural noise, but in the absence of external interference and man-made noise. In practice, however, terrestrial transmissions in the same and adjacent channels will cause additional interference. The usable field strength, E_{med}, is the value for which acceptable picture quality in the presence of natural and man-made noise and external interference will be possible. The usable field strength is also termed the minimum median field strength in some ITU recommendations [4]. The usable field strength parameter will therefore always be higher than the minimum field strength parameter, as account is taken of man-made noise and external interference.

5.2.1 Analogue

The PAL-I standard is used for analogue transmission, except for channel 13, which utilises the sharper PAL B/G roll-off filter. The channel bandwidth is 8 MHz, with the vision carrier located 1,25 MHz above the lower side band [113], [5]. There is a carrier offset, specified as a fraction of the line frequency for some of the channel entries. For the analysis the nominal vision carrier frequency (Channel lower side band plus 1,25 MHz) is taken as the input frequency for all analogue channels.

ITU-R BT.417 provides guidelines on the minimum and usable electrical field strength values for the analogue TV service for which protection may be sought [8]. Table 5.1 provides the minimum and usable electrical field strength values for the analogue service. The minimum (E_{min}) and usable (E_{med}) field strength values will ensure acceptable picture quality at the receiver, assuming a receiver antenna height of 10 m and typical reception equipment parameters. In rural areas, for planning purposes, it is assumed that the typical reception equipment is of a higher quality. The minimum and usable field strength values specified as $E_{min_{a(rural)}}$ and $E_{med_{a(rural)}}$ respectively, may then be used. However, in practice this may not be the case. The analogue field strength protection values as used in the development of the Final Terrestrial Broadcast plan of 2008 correspond with the values of E_{med_a} as detailed in table 5.1. Recall that the TV channel numbers and corresponding frequency ranges for band III, IV and V were detailed in section 2.2.3 and table 2.3 for South Africa.

Table 5.1: Analogue minimum and usable electrical field strength [5,8]

	Band		
Parameter (dBμV/m)	III	IV	V
E_{med_a}	55	65	70
E_{min_a}	53	62 - 63,7	63.8 - 67,1
$E_{med_{a(rural)}}$	49	58	64
$E_{min_{a(rural)}}$	43	52	58

For the analysis, the values for the minimum electrical field strength, E_{min_a}, will be used. The value of E_{min_a} is calculated in band IV and band V as follows [8]:

$$E_{min_a} = 62 + 20log_{10}(f_c/474) \tag{5.1}$$

where E_{min_a} is the minimum electrical field strength for the analogue service in $dB\mu V/m$ and f_c is the centre frequency in MHz of the channel in question.

5.2.2 Digital

The minimum and usable electrical field strengths for the digital service is specified at the threshold of signal failure. ITU-R BT.1368 provides guidelines for the calculation of E_{min} and E_{med} for the DTT and mobile DTT service [9].

The protection requirements for the DTT and mobile DTT service are determined by the system operational parameters. Most notably the number of sub-carriers, sub-carrier modulation technique, code rate and guard interval can be adjusted according to the needs of the network. These system parameters influence the minimum C/N. The C/N, in conjunction with assumptions about the receiver antenna height and the specification of typical receiver equipment, is required to calculate E_{min} and E_{med}.

The minimum C/N is the C/N required to ensure Quasi Error Free (QEF) reception at the receiver. For QEF reception, the target Bit Error Rate (BER) is $BER < 1 \times 10^{-11}$ at the MPEG-2 demultiplexer input for the DVB-T standard. For the DVB-T2 standard the target BER for QEF reception is $BER < 1 \times 10^{-7}$ after the LDPC decoder, which corresponds to an approximate of $BER < 1 \times 10^{-11}$ at the demultiplexer input.

The DTT entries in the TV transmitter database and the Final Terrestrial Broadcast Plan of 2008 were originally planned for the DVB-T standard [5]. In the time that has passed since RRC-06, ICASA has decided to migrate directly to the DVB-T2 standard. The planning procedure for DVB-T2 remains the same as for DVB-T, with the exception of the C/N parameter.

Furthermore, the authors do not have information regarding the system parameter choices for the DVB-T2 or the DVB-H network. Should the system parameters be known, the C/N can be determined from the procedure given in section 14.2 of [114].

The C/N is therefore taken at a representative value for typical fixed mode deployments. The reference planning configuration (RPC1) for fixed mode DTT, taken from RRC-06, is used to assign an indicative value of C/N = 21 dB. Similarly, the RPC2 for mobile DTT, as taken from RRC-06, is used to assign an indicative value of C/N = 19 dB for the mobile DTT service [4].

Typical receiver equipment parameters are shown in table 5.2 for fixed mode DTT reception. The values shown are all taken as representative values from [9].

Similarly, the typical receiver parameters for the mobile DTT service are shown in table

5.3. The receiver parameters for the mobile DTT service are heavily influenced by the type of receiving device; hence the receiver parameters for the portable outdoor, portable indoor, hand-held and mobile reception modes are detailed.

Table 5.2: Typical receiver parameters for fixed mode DTT reception [9]

	Band		
Parameter	III	IV	V
Antenna gain (dBd)	5	10	12
Noise figure (dB)	5	7	7
Feeder loss (dB)	3	3	5

Table 5.3: Typical receiver parameters for the mobile DTT reception modes [9]

	Portable			Hand-held			Mobile		
Parameter	III	IV	V	III	IV	V	III	IV	V
Antenna gain (dBd)	-2	0	0	-	-9	-7	-5	-2	-1
Noise figure (dB)	6	6	6	-	6	6	5	5	5
Feeder loss (dB)	0	0	0	0	0	0	0	0	0

All the digital entries assigned to multiplex 1 and multiplex 2 in the PU data structure are for the fixed reception mode. Multiplex 3 and 4 are intended for the mobile DTT service. The mobile DTT reception mode considered will be portable outdoor, as the portable indoor, hand-held or mobile reception modes require higher protection requirements. The aforementioned use of the multiplexes is consistent with the Digital Migration Regulations of 2012 [47], and the Mobile Television Regulations of 2010 [48].

The procedure for calculating the minimum and usable field strength parameters from the C/N and reception parameters in tables 5.2 and 5.3 are detailed in equations 5.2 and 5.3 below.

The usable field strength, E_{med_f} in $dB\mu V/m$, for fixed mode reception can be calculated as follows [9]:

$$E_{med_f} = E_{min_f} + P_{mmn} + C_l \tag{5.2}$$

where E_{min_f} is the minimum field strength for fixed mode reception in $dB\mu V/m$, P_{mmn} is budget for man-made noise in dB and C_l is the location correction factor in dB.

RRC-06 derived planning values are: $P_{mmn} = 1$ dB for band III, $P_{mmn} = 0$ dB for band IV and V, and $C_l = 9$ dB for 95% of locations [4].

The usable field strength, E_{med_p} in $dB\mu V/m$, for the mobile DTT reception modes can be calculated as follows [9]:

$$E_{med_p} = E_{min_p} + P_{mmn} + C_l + L_h + L_b \tag{5.3}$$

where E_{min_p} is the minimum field strength for mobile DTT reception in $dB\mu V/m$, P_{mmn} is budget for man-made noise in dB, C_l is the location correction factor in dB, L_h is the height loss in dB and L_b is the building entry loss in dB.

RRC-06 derived planning values are: $P_{mmn} = 1$ dB for band III, $P_{mmn} = 0$ dB for band IV and V, and $C_l = 9$ dB for 95% of locations [4]. L_h is determined for a receiver height of 1,5 m, i.e. below the representative clutter height of 10 m. Building entry loss is added if the reception mode is portable indoor or hand-held [9].

The minimum field strength, E_{min} in $dB\mu V/m$, required at the receiving location is given by [9]:

$$\begin{aligned} E_{min} &= \phi_{min} + 120 + 10log_{10}(120\pi) \\ \phi_{min} &= L_f - A_a + P_{smin} \\ A_a &= G + 10log_{10}(1.64\lambda^2/4\pi) \\ P_{smin} &= C/N + P_n \\ P_n &= NF + 10log_{10}(kT_oB) \end{aligned} \tag{5.4}$$

where ϕ_{min} is the minimum power flux density (dbW/m^2), L_f is the feeder loss (dB), A_a is the effective antenna aperture (dBm^2), P_{smin} is the minimum required receiver input power (dBW), G is the receiver antenna gain (dBd), λ is the signal wavelength (m), C/N is the required receiver carrier to noise ratio (dB), P_n is the receiver noise input power (dBW), NF is the receiver noise figure (dB), k is Boltzmann's constant (J/K), T_o is the absolute temperature (K) and B is the receiver noise bandwidth (MHz).

To calculate E_{min_f}, the receiver parameters substituted into equation 5.4 are taken from table 5.2, the constant values are taken from table 3.6 and $B = 7.61$ MHz. Note that the channel bandwidth is 8 MHz, but the actual DVB-T signal bandwidth is 7.61 MHz [9]. Similarly, E_{min_p} is calculated by substituting the receiver parameters from table 5.3 into equation 5.4.

Table 5.4 provides the minimum and usable electrical field strength values for the fixed mode and portable outdoor DTT service, as calculated using the aforementioned procedure and parameters. From the table it can be seen that the minimum usable field strength is in each instance significantly higher than the minimum field strength requirements. Typically, E_{med} is used as the planning value for the digital service. The centre frequency of the channel is taken as the input frequency for all digital channels.

Table 5.4: Digital service: minimum and usable electrical field strength [4, 9]

	Band		
Parameter (dBμV/m)	III	IV	V
E_{med_f}	47,9 - 50,9	53,4 - 55,1	55,3 - 58,5
E_{min_f}	38,9 - 41,9	44,4 - 46,1	46,3 - 49,5
E_{med_p}	62,6 - 66,5	73,1 - 75,7	75,9 - 80,8
E_{min_p}	41,9 - 44,9	48,4 - 50,1	50,3 - 53,5

5.3 Formulation of the availability criterion

Section 1.1.4 pointed out that an SO is the existence of a frequency band segment, satisfying an availability criterion, that DSA or OSA devices can utilise for their communications purposes [20]. The PUs must be protected from harmful interference caused by the secondary reuse of the spectrum. This requires a definition of what constitutes harmful interference. The availability criterion should then be chosen in such a manner so as to prevent SUs from causing harmful interference to the incumbent or PU transmissions.

Section 2.6 discussed the issues of harmful interference. The fundamental differences between the FCC and ECC methodologies for formulating the availability criterion for the determination of SOs were also discussed in section 2.6. The benefits and trade-offs of the respective methodologies were also elaborated upon.

It was noted that although the protection requirements of the PU are generally well understood, the issue of how much harmful interference the PU should tolerate is debatable. Each of the administrations in question will need to formulate a definition of harmful interference. To the best of the author's knowledge, these issues has not been debated or addressed by ICASA. Therefore the definition adopted by other administrations, will be used as a guideline in developing an appropriate definition of harmful interference for the purposes of this work.

Recall that the goal of the analysis presented is to obtain a quantitative estimate on the available SOs in the terrestrial TV frequency bands of South Africa. As argued in section 1.3, this has not been done for the South African context. To this end the decision is taken to use the availability criterion as defined by the FCC methodology in this work.

The FCC availability criterion allows an upper bound on SO availability to be determined without the need to consider the technical parameters or the use case of the SU. It is considered an upper bound, because the SO available to an SU transmitting at a hypothetical 0 W is reported. Figure 2.2 shows that this has the same effect as letting $r_n = r_p$, since an SU transmitting at 0 W would not require an additional keep-out region. The use case of the SU is undeniably important. However, in order to obtain a first quantitative estimate of the available SOs in South Africa, the additional keep-out region for the SU will not be considered in the analysis. This formulation of the availability criterion is consistent with the formulation used in related work by [10] and [1].

It can be argued that the FCC methodology is more simplistic to implement than the SE43 methodology. The SE43 methodology increases the complexity of the TV white space system due to the considerable amount of calculations that need to be performed to derive location-specific output power limits [43]. In section 2.6.4 it was noted that the SE43 methodology produces output power emission limits for SUs which are location-specific, whilst the FCC methodology produces fixed output power emission limits based on device type and antenna height above average terrain. However, for the purposes of the analysis performed in this work, adopting the SE43 methodology will not yield additional insight on SOs, as the use case for an SU transmitting at any location with a hypothetical 0 W is considered.

With regards to the FCC methodology, harmful interference is therefore defined as any interference that erodes the noise-limited protection requirements of the incumbent service by more than ψ dB. The concept of an erosion margin is necessary, as was discussed in section 2.6.2. The protected contour (r_p in figure 2.2) is then set as follows:

$$E_{protect} = E_{min_x} + \psi \tag{5.5}$$

where $E_{protect}$ is the field strength at the protected contour, E_{min_x} is the minimum electrical field strength for the relevant service to be protected with $x = a/f/p$ and ψ is the allowable erosion margin in dB.

In the related work, ψ is normally set at 1 dB [10], [1]. The additional keep-out region limits set out in the Code of Federal Regulations of the USA are calculated with ψ set at 1 dB [36]. However, the value of the erosion margin is arbitrary and may differ from administration to administration. A lower value for the erosion margin means that the PU will tolerate less interference from SUs. This unfortunately also means that less SO will be available to the SU because of stricter interference requirements. For the analysis presented $\psi = 0.1$ dB. The erosion margin is therefore set more conservative from the PUs viewpoint, than in the related work.

5.3.1 Co-channel formulation

Recall from section 3.6.1 that the grid system used in the system model is defined in the geographic coordinate system and that the ground distance of such a system varies with latitude. Furthermore, each grid cell in the grid system is geo-referenced to a geographical location on the earth's surface by means of a reference vector.

With this in mind, let the analysis region in question be described in a geographical coordinate system, tied to a square grid system, with grid spacing Δx_{degree}. Let the grid system contain grid cells $i = 1, .., n$.

SO is a function of time, frequency, and space. Let the predicted electrical field strength of the PU transmitter be denoted by $FS_i(c, t)$, where the field strength at the ith grid cell is a function of the time (t) and the channel (c) selected. $FS_i(c, t)$ is determined by considering the effect of all entries in the PU data structure at time t and on channel c for the geographical location of grid cell i.

The maximum of the field strengths predicted for channel c, time t and location i is in each instance considered the wanted field strength and assigned to $FS_i(c, t)$. This has the implication that all transmissions by the incumbent are considered as wanted, eligible of protection against harmful interference from SUs.

The SO of a given grid cell is regarded as a spatio-temporal bin, denoted by $x_i(c, t)$. The availability criterion is then modelled as a binary value, which can be expressed as a unit step function:

$$x_i(c,t) = \begin{cases} 1, & \text{if } FS_i(c,t) < E_{protect} \\ 0, & \text{otherwise} \end{cases}, \quad c \in \mathcal{C}, \quad t \in \mathcal{T} \tag{5.6}$$

where $x_i(c, t)$ is the co-channel availability decision for grid cell i, channel c and time t, evaluated for the co-channel protected region $E_{protect}$ as defined in equation 5.5. The set $\mathcal{T}$ contains the temporal points for which the SO is analysed, as discussed in section 5.1.4. The set $\mathcal{C}$ contains the channel numbers of channels considered in the analysis, so that:

$$\mathcal{C} \subset \{\mathcal{C}_{\text{VHF}}, \mathcal{C}_{\text{UHF}}\}$$

$$\mathcal{C}_{\text{VHF}} = \{4, 5, 6, 7, 8, 9, 10, 11, 13\}$$

$$\mathcal{C}_{\text{UHF}} = \{21, 22, 23, .., 67, 68\}$$

where $\mathcal{C}_{\text{VHF}}$ denotes all the channels in band III and $\mathcal{C}_{\text{UHF}}$ denotes all the channels in band IV and V.

5.3.2 Adjacent channel formulation

It is also of interest to consider the adjacent channel protection requirements, as SU devices can typically cause interference on adjacent channels as well. Equation 5.6 provided the availability decision for the case where only the co-channel protection requirements were considered. In [1], the adjacent channel field strength at the protected contour is set 25 dB lower than for the co-channel case. This value is based on the emission characteristics of the SU devices assumed to be present in the channel. In [10], the adjacent channel field strength at the protected contour is set equal to the protected contour.

The decision is taken to set the protected contour of the adjacent channel at the same field strength as for the co-channel case, as in [10]. This allows for a conservative view of the SOs available, should adjacent channel use also be restricted. The adjacent channel protected contour is chosen to protect incumbents in the adjacent channel from out-of-band interference caused by the operation of SU equipment. This parameter is therefore highly dependent on the characteristics of SU equipment used. The FCC, for instance, sets the adjacent channel protected contour at 25 dB lower than the co-channel protected contour [11].

The adjacent channel formulation for the availability decision can be formulated in a similar fashion as in equation 5.6:

$$x_i^{'}(c,t) = \begin{cases} 1, & \text{if } FS_i(c,t) < E_{protect} \cap FS_i(c \pm 1, t) < E_{protect}^{'} \\ 0, & \text{otherwise} \end{cases}, \quad c \in \mathcal{C}, \quad t \in \mathcal{T} \tag{5.7}$$

where $x_i^{'}(c,t)$ is the adjacent channel availability decision for grid cell i, channel c and time t, evaluated for the co-channel protected region $E_{protect}$, and the adjacent channel protected region $E_{protect}^{'}$ as defined in equation 5.5. The set $\mathcal{T}$ contains the temporal points for which the SO is analysed, as discussed in section 5.1.4. The set $\mathcal{C}$ contains the channel numbers of channels considered in the analysis as discussed in section 5.3.1.

When the channel c is at the lower band edge, $c+1$ is the only adjacent channel. Likewise, $c-1$ is the only adjacent channel if c is at the upper band edge. The adjacent channel availability decision, as formulated in equation 5.7, requires c and $c \pm 1$ to be available. By implication, the upper and lower band channels cannot be considered with the adjacent channel availability criterion.

5.4 Metrics

The metrics that will be evaluated to quantify the SO available in the terrestrial TV frequency bands of South Africa are as follows:

- SO weighted by area
- SO weighted by population

The SO is weighted by area to proportion the relative effect of each grid cell correctly. In section 3.6.1 it was pointed out that all computations are performed directly in the geographical coordinate system. The areas of each of the grid cells therefore vary slightly with latitude. Weighting SO by area ensures that the weight of each observed value is proportioned correctly.

The SO is weighted by population to attribute more weight to grid cells that contain higher population counts. This ensures that this metric represents SO with a bias towards observed values in areas of higher population density.

To quantify the available SOs, the number of available channels available for secondary reuse in a given grid cell, i, can be determined as follows:

$$s_i = \sum_{\substack{c \in \mathcal{C} \\ t \in \mathcal{T}}} x_i(c,t) \tag{5.8}$$

where s_i is the number of available channels in the ith grid cell, $x_i(c,t)$ is the co-channel availability decision for grid cell i, channel c and time t.

Let s_i denote the number of available channels in the ith grid cell for the co-channel availability decision. The number of available channels for the adjacent channel availability decision, $s_i^{'}$ can then be formulated in a similar fashion by substituting the result of equation 5.7 into equation 5.8.

5.4.1 SO weighted by area

The general formulation for the weighted mean of a number of samples is given by [115]:

$$\overline{x}_w = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i} \tag{5.9}$$

where $\overline{x}_w$ is the weighted mean, x_i is the ith sample, w_i is the corresponding weight of the ith sample and n is the number of samples.

To quantify the SOs weighted by area, equation 5.9 can be rewritten as follows:

$$\overline{s}_a = \frac{\sum_{i=1}^{n} a_i s_i}{\sum_{i=1}^{n} a_i} \tag{5.10}$$

where $\overline{s}_a$ is the mean available channels weighted by area, s_i is the number of available channels in the ith grid cell, a_i is the corresponding area of the ith grid cell and n is the number of grid cells in the analysis region.

Let $\overline{s}_a$ denote the areal weighted mean for the co-channel availability decision. The areal weighted mean for the adjacent channel availability decision, $\overline{s}_a^{'}$ can then be formulated in a similar fashion.

Methodology : SO weighted by area

To calculate the SO weighted by area metric, the shapefile of the South African provincial borders as at 10 October 2001 is used as the reference shapefile for defining borderlines. These borders coincide with the provincial borders used for Census 2001 [116]. It is important to note that the borders imposed are virtual boundaries, used to delimit the statistics and the analysis region. The propagation of radio waves is a continuous phenomenon, and will thus in practice extend beyond the region of analysis.

The boundaries in the shapefile are described by closed polygons, which are defined by a set of vector coordinates. To implement equation 5.10, the vector shapefile is converted to a grid raster, with the same grid spacing, Δx_{degree}, as the grid cells in the analysis region. The grid cells representation is however only an approximation on the vector coordinate set.

The area of polygons in the shape file can be estimated by projecting the shape file onto an equal area projection, and then estimating the area on a flat surface by applying Green's theorem [117]. Alternatively, the area can also be computed directly on the ellipsoid. It has been shown in [118], for 1 degree quadrangles, that the difference between the area as estimated on the ellipsoid versus the area as estimated using the Albers Equal Area Projection, using standard parallels 24°S and 32°S, is typically 0.0014% for locations in South Africa.

Table 5.5 shows the provincial surface areas as calculated from the vector coordinates in the shapefile. The areas for the provinces of South Africa are computed as follows, rounded to the nearest kilometre:

1. Directly on the ellipsoid, using Green's theorem.
2. Projection of the vector coordinates to Albers Equal Area Projection and estimating the flat surface's area with Green's theorem.
3. The actual measured land area, as reported by the department of land affairs.

Table 5.5: Area per province, boundaries as at 10 Oct 2001

	Area (km^2)		
Province	Actual	Ellipsoid	Projection
Western Cape	129 370	129 449	129 450
Eastern Cape	169 580	169 954	169 954
Northern Cape	361 830	362 598	362 599
Free State	129 480	129 824	129 824
KwaZulu-Natal	92 100	92 305	92 305
North West	116 320	116 230	116 231
Gauteng	17 010	16 936	16 936
Mpumalanga	79 490	79 487	79 487
Limpopo	123 910	122 821	122 819
All provinces	1 219 090	1 219 606	1 219 605

Table 5.6 compares the percentage difference between the actual measured land area, and the land area as approximated on the ellipsoid or via projection.

Table 5.6: Difference in area per province, boundaries as at 10 Oct 2001

	Difference (%)	
Province	Ellipsoid	Projection
Western Cape	0.062	0.062
Eastern Cape	0.221	0.221
Northern Cape	0.212	0.213
Free State	0.266	0.266
KwaZulu-Natal	0.223	0.223
North West	-0.077	-0.077
Gauteng	-0.435	-0.435
Mpumalanga	-0.004	-0.004
Limpopo	-0.879	-0.881
All provinces	0.042	0.042

Table 5.7 shows the difference in surface area as approximated by grid cells, relative to the actual measured land area. The difference in surface area is shown for different grid spacings (Δx_{degree}) in arc-seconds (“). In each instance the area is computed by estimating the area of each grid cell on the ellipsoid, and summing all the grid cells within a boundary. The difference illustrates the error in surface area made due to rasterising the vector coordinates.

Table 5.7: Difference in area for grid approximation, boundaries as at 10 Oct 2001

	Difference in area (km^2)					
Province	300″	180″	60″	30″	15″	3″
Western Cape	-508	-395	-24	19	4	182
Eastern Cape	-114	57	73	-16	0	229
Northern Cape	202	-99	-43	-10	-18	439
Free State	-451	-18	8	5	-0	152
KwaZulu-Natal	-122	138	-43	-10	8	110
North West	143	191	-7	-11	10	125
Gauteng	148	-8	22	8	-3	18
Mpumalanga	-687	-267	-25	-1	-7	82
Limpopo	121	335	15	2	9	113
South Africa	-1271	-66	-24	-16	3	1449

The percentage difference in area between the actual measured land area and the grid approximation is shown in table 5.8. It is important to note the differences between actual land area and the approximated land area. Clearly, the grid spacing has an influence on the error made when approximating the surface area.

For the analysis, the grid cell approximation for the land area will be used. This is required to furnish a value for a_i, in equation 5.10. Compared to table 5.5 and 5.6, the grid approximation is very close to the projection and ellipsoid approximations, and also the actual measured surface area. It can therefore be concluded that for the purposes of analyses, the grid cell approximation provides a good estimate of surface area.

5.4.2 SO weighted by population

To quantify the SOs weighted by population, equation 5.9 can be rewritten as follows::

$$\bar{s}_p = \frac{\sum_{i=1}^{n} p_i s_i}{\sum_{i=1}^{n} p_i} \tag{5.11}$$

where $\bar{s}_p$ is the mean available channels weighted by population, s_i is the number of available channels in the ith grid cell, p_i is the population count residing in the ith grid cell and n is the number of grid cells in the analysis region.

Let $\bar{s}_p$ denote the population weighted mean for the co-channel availability decision. The population weighted mean for the adjacent channel availability decision, $\bar{s}_p^{'}$ can then be formulated in a similar fashion.

Table 5.8: Percentage difference in area for grid approximation, boundaries as at 10 Oct 2001

	Difference in area (%)					
Province	300″	180″	60″	30″	15″	3″
Western Cape	-0.393	-0.305	-0.018	0.015	0.003	0.141
Eastern Cape	-0.067	0.033	0.043	-0.009	0.000	0.134
Northern Cape	0.056	-0.027	-0.012	-0.003	-0.005	0.121
Free State	-0.348	-0.014	0.006	0.004	-0.000	0.117
KwaZulu-Natal	-0.133	0.150	-0.047	-0.011	0.009	0.119
North West	0.123	0.165	-0.006	-0.010	0.009	0.107
Gauteng	0.872	-0.048	0.133	0.046	-0.018	0.105
Mpumalanga	-0.864	-0.335	-0.032	-0.001	-0.009	0.103
Limpopo	0.098	0.272	0.012	0.001	0.007	0.092
South Africa	-0.104	-0.005	-0.002	-0.001	0.000	0.119

Methodology: SO weighted by population

To calculate the SO weighted by population, the population data as obtained from Census 2001 is used [116]. Figure 5.2 describes the hierarchical fashion in which the census data is organised. Census data is made available at different levels in the data hierarchy. To protect the confidentiality of census respondents, the data is not made available at the Enumeration Area (EA) level. Census data at all levels of the hierarchy is referenced to one another by means of a geo-coding system. Furthermore, for each of the layers in the hierarchy, shapefiles are made available that describe the size and shape of each of the demarcated census areas.

The population data is provided in separate tables. The geo-coding system enables these tables to be merged with the shapefiles. The Censu[illegible]used for obtaining the required data, because the population counts are made available up to the sub-place layer. The Census 2011 data has also been made available recently. At the time of writing, the pop[illegible]s availa[illegible]he mun[illegible]. Statistics South Africa i[illegible] of de[illegible] area l[illegible] 2011, for which the popu[illegible]ta will b[illegible]ble. The [illegible]er will be positioned between the EA and sub-place layers in the hierarchy.

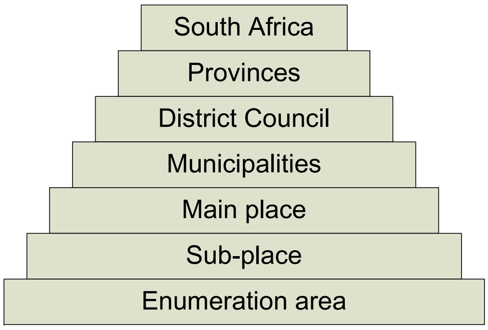


Figure 5.2: Census 2001 data hierarchy

In total, there are 21243 sub-places, each identified by a unique sub-place code. The area for each of the polygons can be estimated with one of the methods discussed in section 5.4.1. However, a few sub-place polygons reported negative area values. These polygons are displayed in table 5.9, together with the corrected area values. These errors occur because of the incorrect ordering of the polygon vertices. External polygon vertices should be ordered clockwise, whilst internal vertices are ordered counter-clockwise. Incorrect vertex ordering causes the wrongful addition or subtraction of area values.

The total area of South-Africa, as estimated by calculating the area of all the sub-place polygons in the corrected shapefile, is 1219580km^2, a difference of 0,040% from the actual land area as reported in table 5.5. The median sub-place area is 1.8 km^2, while the maximum sub-place area is 27000 km^2. Typically, these large sub-places indicate sparsely populated regions.

To compute $\bar{s}_p$, the parameter p_i is required in equation 5.11. The p_i parameter requires the population count for each grid cell. The vector shapefile and population totals for each sub-place needs to be converted to a grid raster, with the same grid spacing, Δx_{degree}, as the grid cells in the analysis region. The irregular shape of the census sub-places complicates this matter, as a plain rasterisation process of the polygon areas will result in an incorrect representation of the population counts.

Table 5.9: Corrected polygons: Census 2001 sub-places

	Area (km^2)	
Sub-place geo-code	Original	Corrected
11614000	-170.2	171.4
17106087	-1.4	1.7
21002010	-1.2	1.8
22219000	-66.7	60.1
23414035	-0.4	2.6
30209000	-4.5	4.5
41604000	-59.4	54.7
50711001	-6.5	30.4
57223015	-33.4	31.2
77304012	-0.3	0.4
80717011	-1.7	2.2
81601003	-0.7	1.6
90813001	-119.1	183.3
91108000	-362.6	317.2

This problem is emphasized in figure 5.3. The grid cell, with a grid spacing of 300 arc-seconds, covering quadrangle 25,08 °S - 25,17 °S and 27,92 °E - 28 °E is overlaid on the sub-place polygons present at the same geographical location. Each closed polygon area represents a sub-place, with a given population count. A conventional rasterisation algorithm will set the grid cell value equal to the population value of the polygon that occupies the largest area within the quadrangle.

This type of grid cell assignment is referred to as majority rule assignment [119]. This approach has the disadvantage that a grid cell which contains multiple sub-places are only mapped to the one sub-place which occupies the majority of area in the grid cell. Furthermore, the effect of sub-places that have smaller areas than the grid cell is neglected. The majority rule assignment causes misrepresentation of the population count, as the sub-place polygons which occupy smaller areas have higher population counts than the polygons that occupy large areas. This is as a result of the way in which

EAs are assigned.

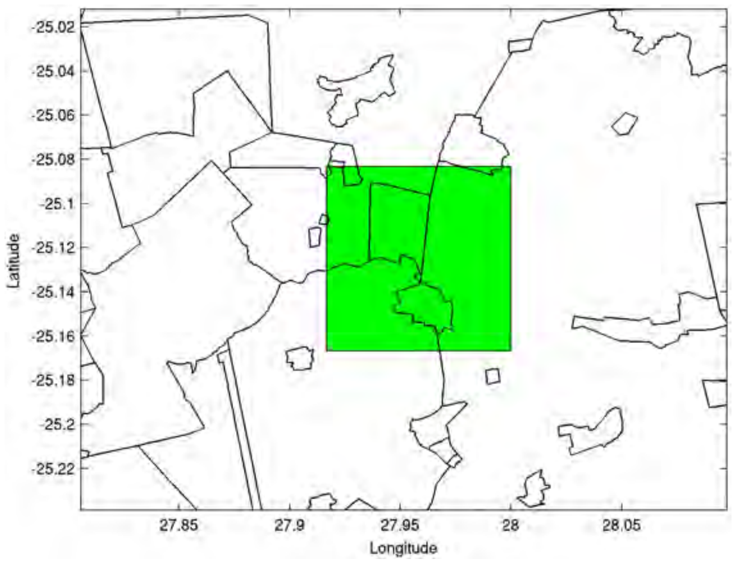


Figure 5.3: Grid cell overlaid on sub-place polygons

Figure 5.2 showed that a sub-place is above the EA in the hierarchy. Typically, each sub-place is constituted of 2 or more EAs. An EA is a small geographical unit of manageable size, assigned to a single person to enumerate during the census. The EA size is influenced by geographical location and population density. Locations with higher population densities would therefore tend to have smaller EAs, and hence smaller sub-place areas [85].

To work around this problem, the areal weighting technique is implemented to provide an approximation of the population count in the area covered by each grid cell [120], [121]. This technique is also referred to as proportional allocation, and has also been used to great effect in the generation of the raster grids for version 3 of the gridded population of the world dataset [119]. It can be argued that this method is very simplistic, as other areal interpolation methods do exist that provide better approximation, by incorporating, for instance, ancillary data.

For the purposes of analysis, the areal weighting method was implemented. The improvement of the population raster grid using ancillary data is left as an area for future work. However, it will be shown in the next section that the areal weighting technique provides a good approximation of the population count.

To use the areal weighting technique, it must be assumed that the density of the population within a sub-place is uniform. The target zone population, V_t, can then be determined as follows [120]:

$$V_t = \sum_s \frac{A_{st}}{A_s} U_s \tag{5.12}$$

where s is the set of source-zones that intersect with target-zone t, A_{st} is the area of overlap between source-zone s and target-zone t, A_s is the total area of source-zone s and U_s is the source zone population count. Equation 5.12 holds, assuming that the source-zone population density, U_s, is uniform over the total source-zone area, A_s.

The population grid rasters are generated from the sub-place shapefile and data tables as is. No additional post-processing has been done to mask out water bodies, lakes and mountains. However, it is thought that the census sub-place shapefile incorporates these features, as 464 sub-places have a density of 0 $people/km^2$.

Grid approximation of the population count

The CCDF of the true population density distribution compared to the population density distributions obtained by approximation with areal weighting is shown in figure 5.4. The population density approximations for a grid raster with grid spacing, Δx_{degree} of 300, 180 and 60 arc-seconds (″) are respectively shown. The true population density is regarded as the population density as computed directly from the polygons in the sub-place shapefile. The density is determined by dividing the population count for each sub-place by the computed area of each sub-place polygon and weighting the results by the area occupied.

From the CCDF it can be seen that the grid raster approximations provides a reasonable approximation of the true population distribution, improving with a decrease in grid spacing. Note that the grid raster approximations are not expected to recreate the true population distribution perfectly. This is due to discretisation error caused by the choice of grid spacing, and the assumption of uniform density across each grid cell.

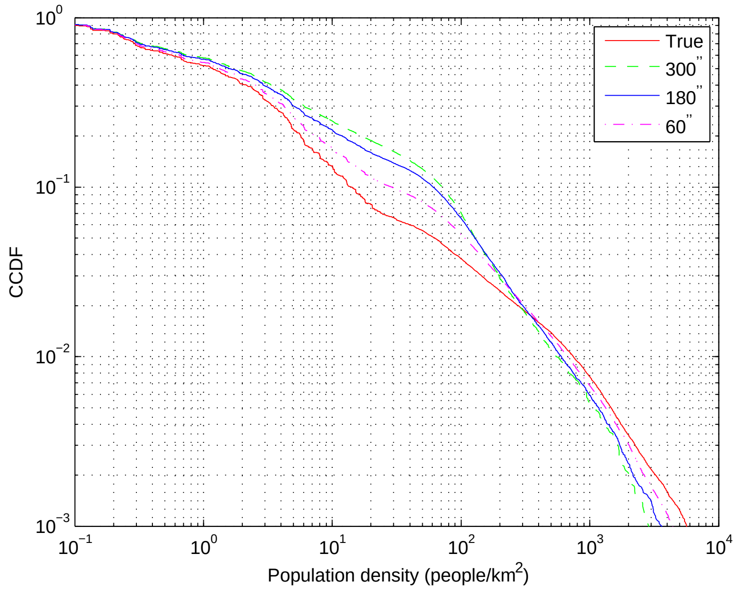


Figure 5.4: CCDF: population density of South Africa

This assumption is required to calculate a population density map from the population count grid raster. Grid spacings larger than the constituting sub-place polygons, cannot be expected to recreate the distribution of the constituting polygon elements, as the grid spacing resolution is too coarse. This is the reason why the areal weighting technique cannot replicate the true population distribution exactly.

The population counts for the grid raster approximations are also investigated to determine if areal weighting technique provides accurate population counts. To this end table 5.10 shows the difference and percentage difference between the true population count for South Africa and the population counts as calculated from the areal weighted grid approximations. The true population count is the population count as calculated from the sub-place shapefiles and data tables. The population counts are shown for 300, 180 and 60 arc-second grid approximations respectively.

Table 5.10: Difference in population counts for areal weighting approximation

	Difference			Difference (%)		
	300″	180″	60″	300″	180″	60″
South Africa	11301	20409	-4067	0.025	0.046	-0.009

From table 5.10, it follows that the population counts are represented very well with the areal weighting method. This is due to the pycnophylactic or volume preservation property of the areal weighting method [122]. The summation of the population count in each grid raster yields the net population count for the region.

The population distribution is not modelled as accurately with the areal weighting method. However, the population counts are the critical parameter required to calculate the weights for the SO weighted by population metric. Hence, for the intended use of the population count data, the method implemented can be deemed fit for purpose.

Figure 5.5 illustrates a map of the population density of South Africa as approximated via areal weighting for a grid spacing of 60 arc-seconds. The map is projected in the Albers Equal Area Projection to minimise areal distortion, using standard parallels 24° S and 32° S and origin 27 ° E, 0 ° S [118]. The density is expressed in people/km^2, and the colour-map is in a logarithmic scale. Note that the densities expressed in the grid raster population density map will deviate from the population densities as calculated directly from the sub-place shapefiles and data tables due to the reasons discussed above.

5.5 Conclusion

The analysis methodology followed to analyse the SOs was described in detail. The choice of input data was motivated in section 5.1. Attention was given to the protection requirements of the incumbent service or PU in section 5.2. The definitions adopted for the protected contour and the determination of SOs available by the co-channel and adjacent channel rules were formulated. Section 5.4 developed the metrics that will be evaluated in the analysis. Finally, a grid raster approximation of the population count and density of South Africa was also derived. The next chapter proceeds to report and elaborate on the results obtained from the analysis.

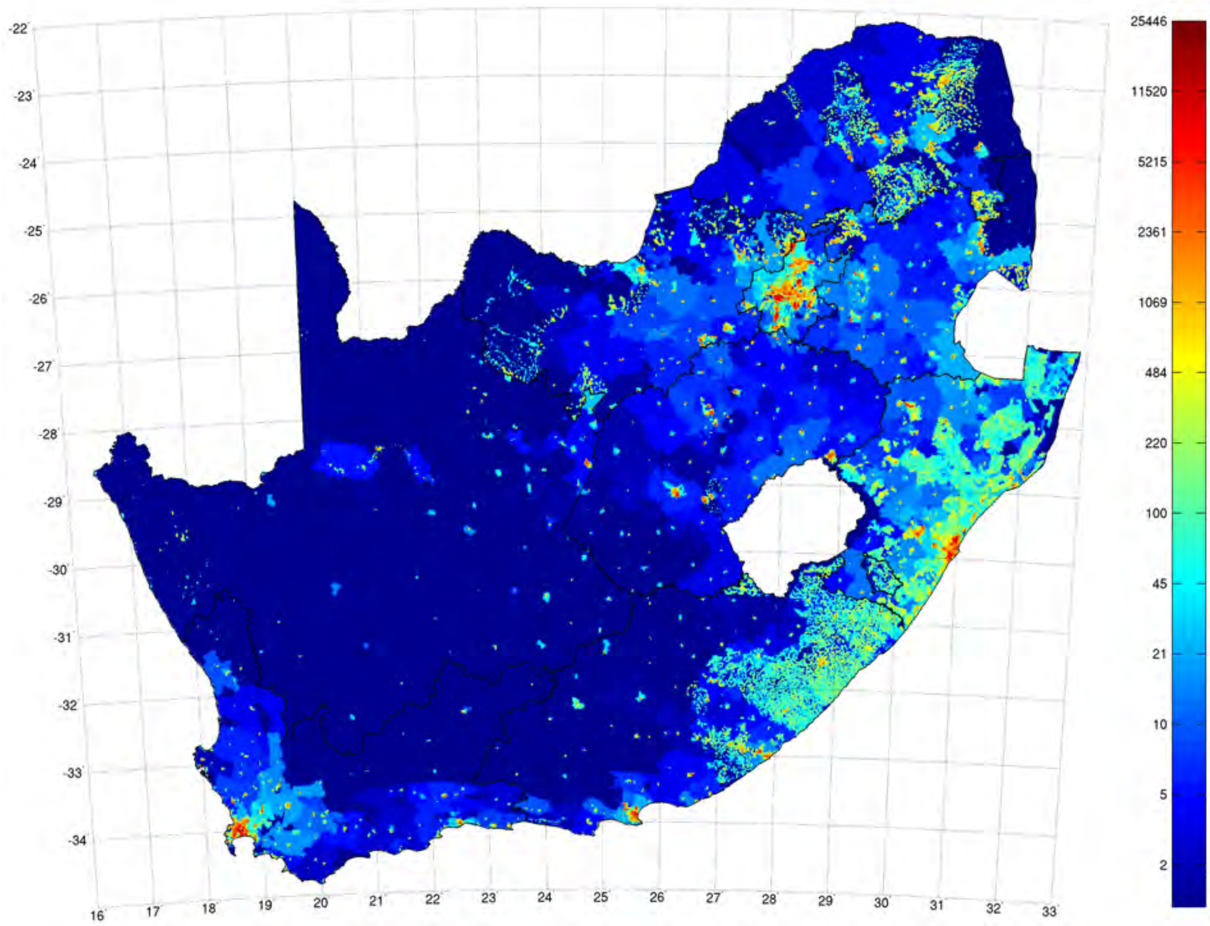


Figure 5.5: Population density of South Africa (people/km^2)

Chapter 6

Analysis of Spectral Opportunity

In this chapter the SO in each of the nine provinces of South Africa is investigated and analysed. First, the SO in the VHF terrestrial TV frequency bands is analysed, then the analysis is performed on the UHF terrestrial TV frequency bands. Thereafter the probability of finding contiguous channels is quantified. The SO available in the UHF band is compared to the SO statistics of the related work in the USA and Europe. Finally, the SO maps for South Africa are presented.

6.1 Overview

The results of analysing the available SOs in South Africa are now presented. The results presented give an upper bound on the available SO in a given frequency band, based on the availability criteria that were developed in chapter 5. In section 5.3 it was pointed out that it is considered an upper bound, because the SO available to an SU transmitting at a hypothetical 0 W is considered.

The analysis results will be presented as follows:

- SO in the VHF terrestrial TV frequency band in section 6.4
- SO in the UHF terrestrial TV frequency band in section 6.5
- Probability of finding contiguous SO in section 6.6
- Comparison of the SO available to related work in section 6.7
- Visualisation of SO maps in section 6.8

For both frequency bands studied, the analysis metrics will be evaluated for the co-channel and adjacent-channel availability decisions. Furthermore, the temporal scenarios considered will be evaluated for the scenarios as discussed in section 5.1.4. The time t for which the analysis metrics will be evaluated will in each instance be denoted as follows:

$$t \in \mathcal{T}$$
$$\mathcal{T} = \{t_A, t_{DU}, t_D\}$$

where t_A is the time before dual illumination, t_{DU} is the time during full dual illumination and t_D is the time after analogue switch-off.

For studying the SO in the VHF terrestrial TV frequency band, the channels c considered are all the channels in band III, defined as follows:

$$c \in \mathcal{C}_{\mathrm{VHF}}$$
$$\mathcal{C}_{\mathrm{VHF}} = \{4, 5, 6, 7, 8, 9, 10, 11, 13\}$$

For studying the SO in the UHF terrestrial TV frequency band, the channels c considered are all the channels in band IV and V, defined as follows:

$$c \in \mathcal{C}_{\mathrm{UHF}}$$
$$\mathcal{C}_{\mathrm{UHF}} = \{21, 22, 23, .., 67, 68\}$$

6.2 Motivation for parameters chosen

The parameters chosen for the system model in this chapter correspond to the parameters used for the regional co-ordination and planning for the digital terrestrial broadcasting service in bands III, IV and V for ITU regions 1 and 3. This coordination process was formalised at the ITU RRC-06, and is known as the GE-06 agreement [4]. Furthermore, the ITU-R P.1546 model parameters as used for the GE-06 agreement are documented in the proceedings of RRC-06.

The rationale for analysing the SO available according to these parameters can be motivated by the fact that the same parameters were used to derive the digital channel entries in the Final Terrestrial Broadcasting Plan of 2008. Using the same parameters allows the analysis results to provide an account of SOs on the same grounds as what the GE-06 plans for South Africa were made.

The RRC-06 methodology does not take any detailed terrain data into account, with the exception of the calculation of the required effective antenna height parameter. The method used is therefore not path-specific. Furthermore, because no terrain data is taken into account, the corrections that improve the propagation prediction are also not considered, as all the corrections require information about the terrain of the path traversed.

The RRC-06 parameters make the system model behave more conservatively, as field strength coverage is possibly overpredicted on some of the outward radials from the PU transmitter in question. This will be shown to be in part due to setting the effective height parameter equal to h_{max}, as detailed in section 6.3 below. Furthermore, all the corrections adjust field the strength predictions downwards. Therefore, the predicted field strength value incorporating the corrections will not be more than the field strength without corrections [4].

Taking the parameters chosen into account, it was also decided that the grid spacing for the analysis would be kept at 60 arc-seconds, in line with the general non-path-specific nature of the RRC-06 parameters. Choosing a finer grid spacing is relevant only if the path and terrain specific corrections are considered in the propagation prediction phase. Thus no detailed terrain influence is considered.

In the next section the input parameters for the system model and calculation of analysis metrics are discussed.

6.3 Analysis parameters

The system model input parameters and constants are used as was defined in table 3.6 of chapter 3. In addition to these parameters, the system model parameters used in this analysis are detailed in table 6.1. Any system model parameter not mentioned in table 6.1 can be assumed to be implemented.

Table 6.1: System model parameters for analysis

Parameter	Value
Δx_{degree}	60 arc-seconds
Transmitter antenna pattern	Omnidirectional
Propagation path	Land only
Location probability	50%
Time probability	50%
Diffraction loss correction	Terrain approximation method
Tropospheric scatter correction	No
TCA correction	No
Effective antenna height	Maximum effective height, h_{max}

The grid spacing of 60 arc-seconds corresponds to a quadrangle of approximately 1.85 km $\times$ 1.85 km at the equator. The transmitter antenna patterns are all assumed omnidirectional as was discussed in section 5.1.5. The propagation path considered is land only. The time and location probability was set at 50%, consistent with the RRC-06 parameters. The diffraction loss correction is applied through the terrain approximation method. This correction was discussed in section 3.6.4, block {10.4}. The tropospheric scatter correction is not considered, nor is the correction based on TCA, as these parameters require terrain data of the path traversed. Finally, the maximum effective height,

h_{max}, is used as the input for the effective antenna height parameter.

To calculate the maximum effective height parameter for a transmitter site, the effective antenna height, h_{eff}, is calculated at 10° intervals for 36 azimuths, starting at 0° north and incrementing up to 350° in a clockwise direction in the horizontal plane. h_{eff} is calculated using equation 3.7 and setting $d_1 = 3$ km and $d_2 = 15$ km. h_{ant} and h_{tx} are set at the relevant antenna height AGL and site height AMSL for the transmitter site in question. The maximum effective height, h_{max}, is then the maximum value of h_{eff} for these 36 computed azimuths. h_{max} was also defined mathematically in equation 4.1.

This method of calculating the effective height results in overprediction of field strength coverage area on the radials for which $h_{eff} < h_{max}$ [4]. This means that the coverage area of PUs will in general be overpredicted on these radials, which in turn favours the PU, but leads to less SOs for SUs. Furthermore, none of the path-specific prediction corrections are considered for this analysis. As stated in section 6.2 above, the parameters used for these analysis correspond to the parameters used for the GE-06 agreement.

The parameters used for the calculation of the analysis metrics are detailed in table 6.2. The protection requirements for the analogue service are calculated using equation 5.1. The protection requirements for the fixed DTT and mobile DTT service are calculated using the input parameters as defined for E_{min_f} and E_{min_p} in section 5.2.2. The protected contour in equation 5.5 is determined by setting the erosion margin, ψ as specified. A motivation for the value of ψ was provided in section 5.3. From using these parameters the co-channel and adjacent channel availability decisions in equation 5.6 and 5.7 can be applied and the necessary SO metrics can be determined.

Table 6.2: Parameters for calculation of analysis metrics

Parameter	Value
Analogue protection	E_{min_a}
Fixed DTT protection	E_{min_f}
Mobile DTT protection	E_{min_p}
Erosion margin	$\psi = 0.1$ dB

6.3.1 Analysis region exclusions

In addition to the protection requirements of the PU transmitter and receivers, there are secondary services also operating in the terrestrial TV frequency bands that warrant protection. The radio astronomy service and, in particular, the SKA is afforded protection from harmful RFI by other services through the Astronomy Geographic Advantage Act [51]. The SKA will have an influence on the SO available in the terrestrial TV bands pending the outcome of regulatory decisions made in line with the act.

PMSE equipment may also operate in some parts of the band on a secondary basis. This was discussed in section 2.3. The results presented excludes the effect of PMSE equipment on the availability of SOs as the occurrence of PMSE equipment can not be accurately determined. To the best knowledge of the author information on PMSE equipment is not available in a database.

The SKA core, central and coordinated astronomy advantage areas were discussed in section 2.3 and illustrated in figure 2.1. At the time of writing, use of any RF equipment without the necessary permissions in the core advantage area is prohibited by law [54]. However, regulations on acceptable RFI in the central and coordinated astronomy advantage areas are at the time of writing not yet in effect [56], [57].

For completeness of the analysis results, the effects of excluding the core and central astronomy advantage areas from the analysis region are considered. With exclusion, it is meant that the area and the population within the excluded region, are not counted towards the totals for the results. The analysis results of the Northern Cape, Western Cape and South Africa are affected by the astronomy advantage areas. In these cases, the analysis results are reported separately for the core and central astronomy advantage area exclusions.

6.3.2 Analysis flow

The process to progress from propagation prediction to the analysis of SO results is now briefly discussed for the analyses at hand. The system model is used to analyse the region given by the 13° x 17° quadrangle with limits 22° to 35° south latitude and 16° to 33° east longitude. South Africa is bounded in the quadrangle given by abovementioned coordinates. This quadrangle is visualised in figure 6.1. The figure also details the different province names and locations.

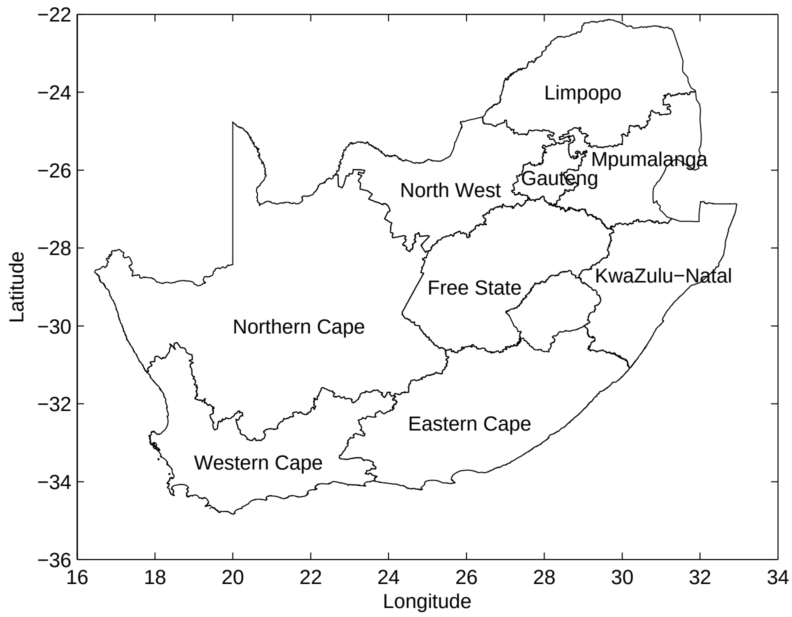


Figure 6.1: Provinces of South Africa

The steps involved in the analysis flow are as follows:

1. The analysis region as described above is defined.
2. The grid spacing, Δx_{degree}, and system model parameters are defined as was discussed in section 6.3.
3. The effect of every entry in PU data structure at a specified temporal time is considered for each channel at every grid cell location.
4. The system model generates the required field strength data tiles as discussed in section 3.6.4.

5. The availability criterion for the co-channel and adjacent channel availability decisions is evaluated for each grid cell in the field strength tiles.

6. The analysis metrics are computed for the analysis region.

6.4 SO in the VHF terrestrial TV frequency band

The analysis results for the SO in the VHF terrestrial TV frequency bands are now discussed and elaborated upon for each of the nine provinces of South Africa and also for the country as a whole. As discussed in section 6.1, the channels considered for VHF are ITU region 1, band III, hence channels 4-11 and 13, corresponding to 174 MHz - 238 MHz and 246 MHz - 254 MHz respectively.

6.4.1 Gauteng

The mean values for the SO weighted by area ($\bar{s}_a$, $\bar{s}_a^{'}$) and SO weighted by population ($\bar{s}_p$, $\bar{s}_p^{'}$) are respectively reported for the two availability criteria and the three temporal scenarios (t_A, t_{DU} and t_D) in table 6.3. The mean values are also expressed as a fraction of the total number of VHF TV channels in the band. This fraction is expressed as a percentage and reported in brackets next to the actual mean values in table 6.3. The weighted mean values are rounded to the first decimal place, whilst the fractions are rounded to the nearest integer. The convention used to denote the variables is consistent with the syntax defined in sections 5.1.4 and 5.4.

Table 6.3: Weighted mean values for VHF SO in Gauteng

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A	2.7 (30%)	1.9 (21%)	0.0 (0%)	0.0 (0%)
t_{DU}	2.7 (30%)	1.9 (21%)	0.0 (0%)	0.0 (0%)
t_D	9.0 (100%)	9.0 (100%)	6.0 (67%)	6.0 (67%)

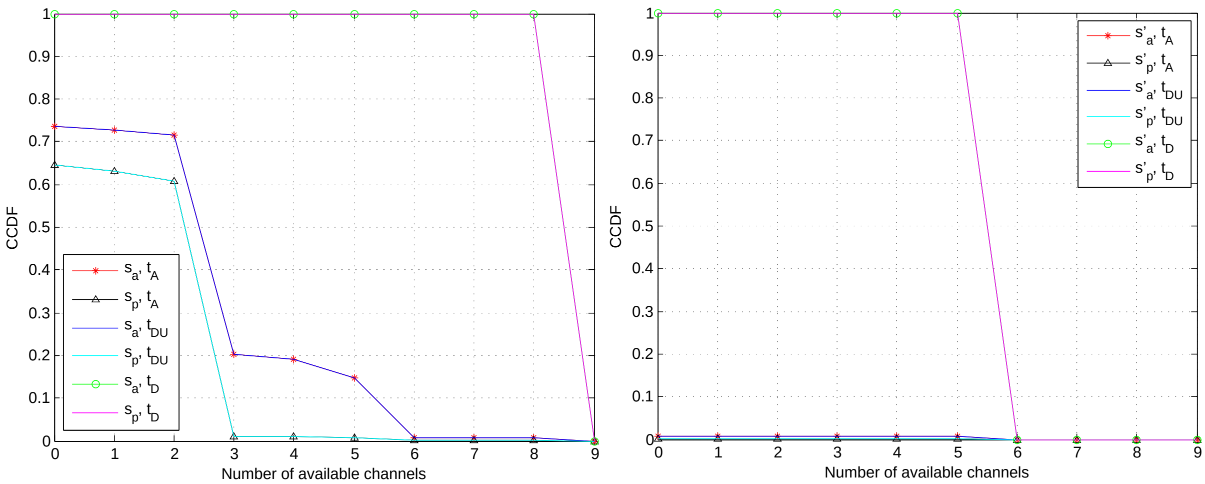
In table 6.3 it can be seen that time t_A and time t_{DU} have the same weighted mean values respectively for the co-channel and adjacent channel criteria. The VHF band is heavily used with, on average, only 2.7 channels available by area and 1.9 channels available by population under the co-channel criterion. For the adjacent channel criterion, no channels are available for the VHF band. The VHF band is therefore heavily used in Gauteng.

From the weighted mean values for time t_D, it can be seen that the entire band is vacant after analogue switch-off. The co-channel criterion reports nine channels available by area and population whilst the adjacent channel criterion reports six channels available by area and population. It was observed above that the VHF band only consists of nine channels in total, of which only six (channels 5 - 10) are eligible channels under the adjacent channel availability criterion due to the upper and lower band edge exclusions and the exclusion of channel 13.

The empirical CCDFs for the number of available channels for Gauteng, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.2a and figure 6.2b respectively. The CCDFs also indicate the distributions for the three temporal scenarios, t_A, t_{DU} and t_D.

The convention used to denote the variables in the CCDF figures are consistent with the syntax defined in sections 5.1.4 and 5.4. Equation 5.10 refers. Let $s_a = s_i$. Similarly, in equation 5.11, let $s_p = s_i$, where s_a and s_p in each instance refer to the number of channels available at each grid cell location for the co-channel criterion by area and by population respectively. In a similar manner, let $s_a^{'}$ and $s_p^{'}$ refer to the number of channels available for the adjacent channel criterion by area and by population respectively.

From figure 6.2a it can be seen that the CCDFs for t_A and t_{DU} are the same for s_a and s_p respectively. The CCDF confirms that the VHF band is heavily used in Gauteng, as four or more channels are only available at 20% of the locations, whilst four or more channels are available to only 1% of the population in Gauteng. However, there seems to be reasonable availability for three or more channels, at 72% of the locations and to 61% of the population.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.2: VHF band: SO for Gauteng

The same trend follows for $s_a^{'}$ and $s_p^{'}$ for t_A and t_{DU} in figure 6.2b, indicating that virtually no SOs are available for secondary reuse. For t_D the vacancy in the band after analogue switch-off is evident for the co-channel and adjacent channel criteria.

From the analysis results for the VHF band in Gauteng it was shown that no DTT entries were assigned to the band for the dual illumination period. The same trend is observed for all the other provinces of South Africa as well. This has the implication that the SO results for time t_A and time t_{DU} are the same, as there are no active digital channels in the band during the dual illumination period. Consequently, for time t_D, after analogue switch-off, the entire VHF band is vacant over the whole country.

For the abovementioned reasons and for clarity of results on the graphs and tables, only the results for time t_A will be discussed in the following sections, as the results for t_{DU} are the same as for t_A. Furthermore, the CCDFs and weighted mean values for time t_D for each province, and South Africa as a whole, will be exactly the same as shown in the results discussion of section 6.4.1. In order to avoid unnecessary repetition of the same result, the CCDFs for t_D and the SO metrics will therefore also not be discussed in the succeeding sections.

6.4.2 Mpumalanga

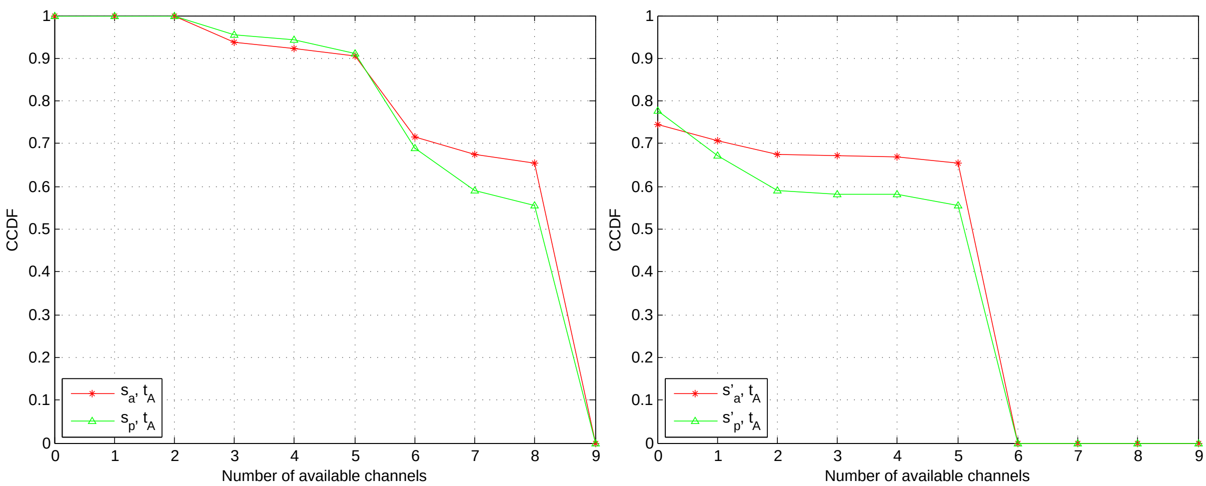
The mean values for the SO weighted by area and population are respectively shown for time t_A and the two availability criteria for Mpumalanga in table 6.4. The mean values are also expressed as a fraction of the total number of VHF TV channels as shown in brackets next to the actual mean values.

Table 6.4: Weighted mean values for VHF SO in Mpumalanga

Time	$\overline{s}_a$	$\overline{s}_p$	$\overline{s}_a^{'}$	$\overline{s}_p^{'}$
t_A	7.8 (87%)	7.6 (85%)	4.1 (46%)	3.8 (42%)

In table 6.4 it can be seen for time t_A that the VHF band is not heavily used, with 7.8 channels by area and 7.6 channels by population available as SOs under the co-channel criterion, corresponding to 87% and 85% of the band respectively. The adjacent channel criterion reports 4.1 channels by area and 3.8 channels by population, corresponding to 87% and 85% of the band respectively.

The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.3a and figure 6.3b respectively.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.3: VHF band: SO for Mpumalanga

Figure 6.3a shows that for the co-channel criterion, at least two channels are available at 100% of the locations and to 100% of the population in Mpumalanga. Furthermore, six or more channels are available at 91% locations, and to 90% of the population in Mpumalanga.

Figure 6.3b shows that for the adjacent channel criterion, at least two channels are available at 71% of the locations and to 67% of the population, whilst at least six channels are available at 65% of locations and to 56% of the population in the province.

6.4.3 Limpopo

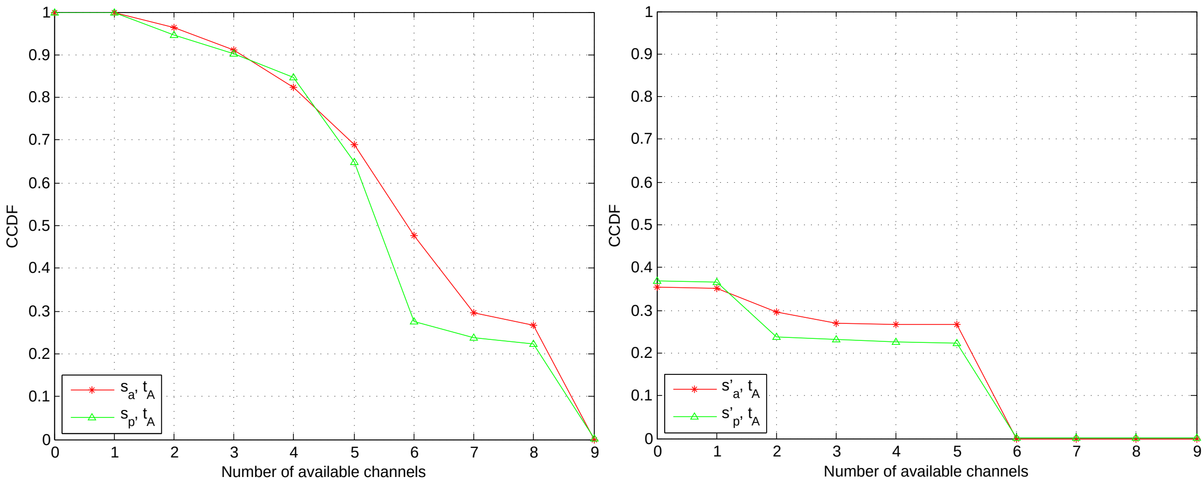
The mean values for the SO weighted by area and population are shown for the two availability criteria for Limpopo in table 6.5. According to the co-channel availability criterion, the VHF band is not heavily used, with 6.4 channels by area and 6.1 channels by population available as SOs, corresponding to 71% and 68% of the band respectively. The adjacent channel criterion reports significantly less SO, with 1.8 channels by area and 1.7 channels by population, corresponding to 20% and 18% of the band respectively.

Table 6.5: Weighted mean values for VHF SO in Limpopo

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A	6.4 (71%)	6.1 (68%)	1.8 (20%)	1.7 (18%)

The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.4a and figure 6.4b respectively.

Figure 6.4a shows that for the co-channel criterion, at least two channels are available at 100% of the locations and to 100% of the population in Limpopo. Furthermore, four or more channels are available at 91% of the locations, and to 90% of the population in the province. Figure 6.4b indicates significantly fewer available channels for the adjacent channel criterion, with at least two channels only available at 35% of the locations and to 36% of the population in the province.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.4: VHF band: SO for Limpopo

6.4.4 Free State

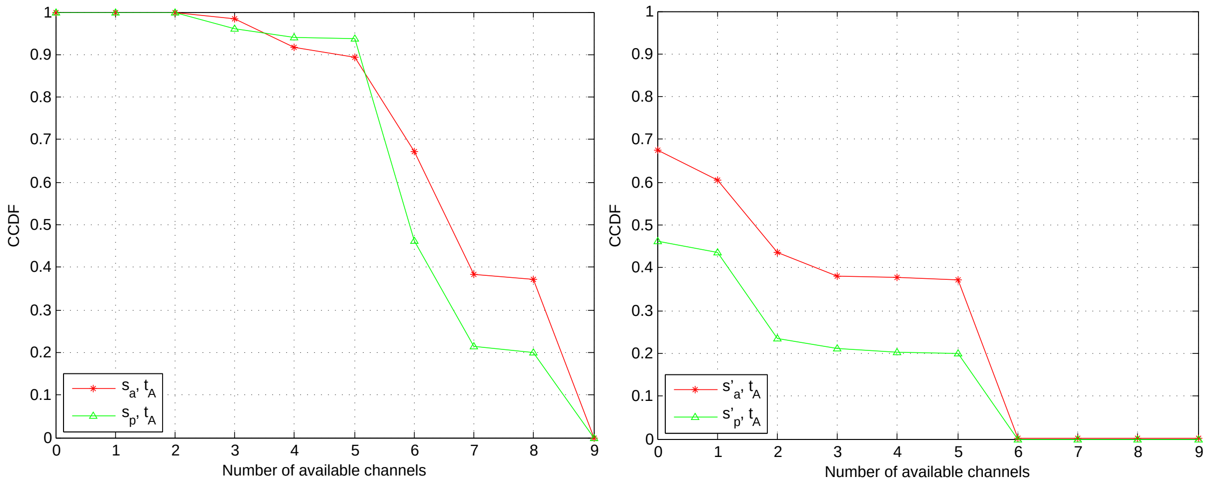
The mean values for the SO weighted by area and population are shown for the two availability criteria for the Free State in table 6.6. The co-channel availability criterion shows low utilisation of the VHF band, with 7.2 channels by area and 6.7 channels by population available as SOs, corresponding to 80% and 75% of the band respectively. The adjacent channel criterion reports less SO, with 2.8 channels by area and 1.7 channels by population, corresponding to 32% and 19% of the band respectively.

Table 6.6: Weighted mean values for VHF SO in the Free State

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a'$	$\bar{s}_p'$
t_A	7.2 (80%)	6.7 (75%)	2.8 (32%)	1.7 (19%)

The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.5a and figure 6.5b respectively.

Figure 6.5a indicates that at least three channels are available at 100% of the locations and to 100% of the population, while six or more channels are available at 90% of the locations, and to 94% of the population in the province. Figure 6.5b indicates significantly fewer available channels for the adjacent channel criterion with at least three channels only available at 44% of the locations and to 23% of the population in the province.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.5: VHF band: SO for the Free Sate

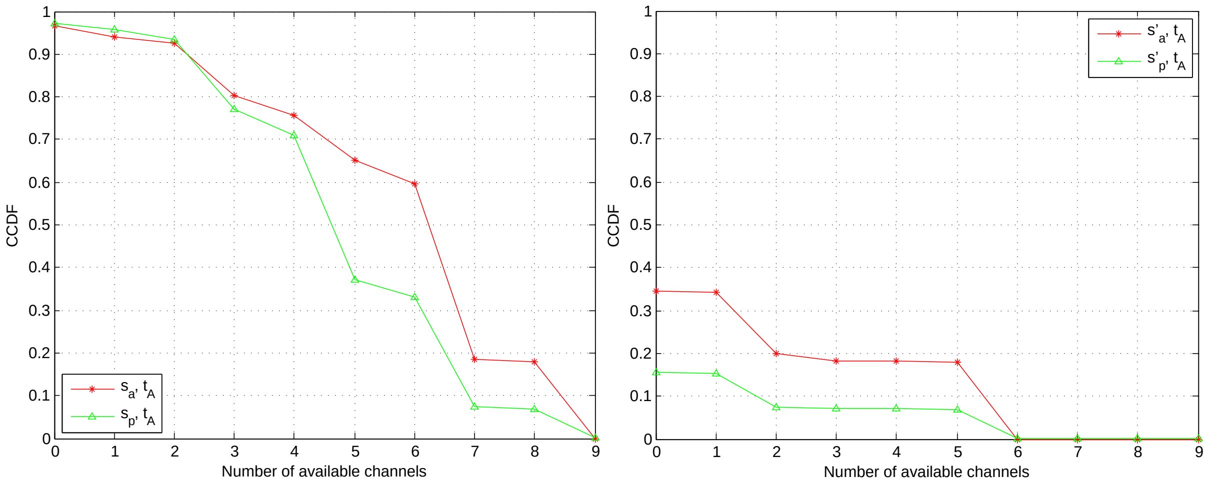
6.4.5 KwaZulu-Natal

Table 6.7 details the mean values for the SO weighted by area and population, for KwaZulu-Natal. The co-channel availability criterion reports 6.0 channels by area and 5.2 channels by population available as SOs, corresponding to 67% and 58% of the band respectively. The adjacent channel criterion reports 1.4 channels by area and 0.6 channels by population, corresponding to 16% and 7% of the band respectively.

Table 6.7: Weighted mean values for VHF SO in KwaZulu-Natal

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a'$	$\bar{s}_p'$
t_A	6.0 (67%)	5.2 (58%)	1.4 (16%)	0.6 (7%)

The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.6a and figure 6.6b respectively.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.6: VHF band: SO for KwaZulu-Natal

Figure 6.6a indicates that at least three channels are available at 94% of the locations and to 94% of the population. The adjacent channel criterion indicates very little SO in figure 6.6b, with three or more channels only available at 20% of the locations and to 7.5% of the population in the province.

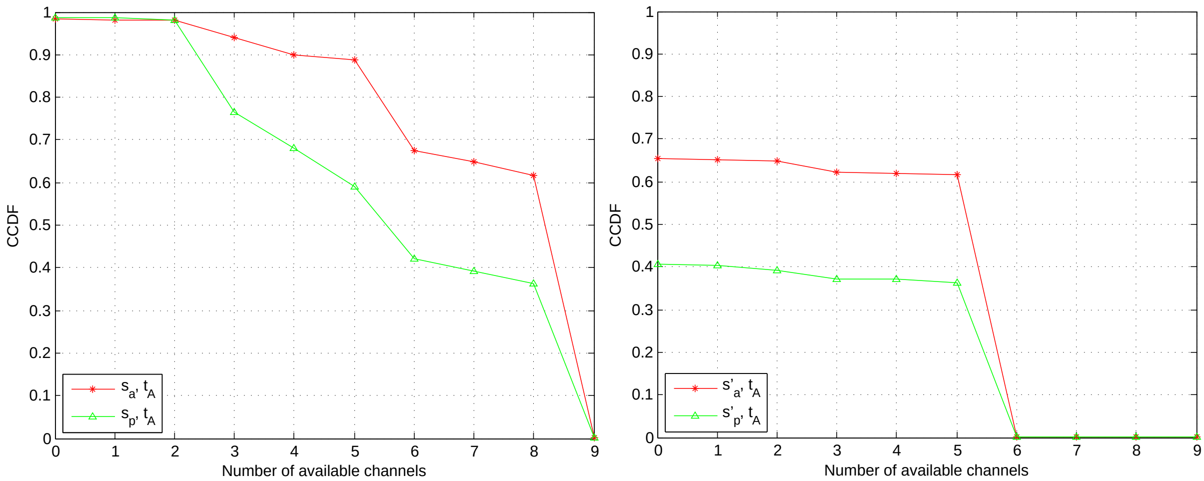
6.4.6 North West

Table 6.8 details the mean values for the SO weighted by area and population, for the North West province. The co-channel availability criterion reports 7.6 channels by area and 6.2 channels by population available as SOs, corresponding to 85% and 69% of the band respectively. The adjacent channel criterion reports 3.8 channels by area and 2.3 channels by population, corresponding to 42% and 26% of the band respectively.

Table 6.8: Weighted mean values for VHF SO in the North West

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
t_A	7.6 (85%)	6.2 (69%)	3.8 (42%)	2.3 (26%)

The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.7a and figure 6.7b respectively.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.7: VHF band: SO for the North West

Figure 6.7a indicates that at least three channels are available at 98% of the locations and to 98% of the population, whilst at least five channels are available at 90% of the locations and to 68% of the population.

Figure 6.7b indicates that three or more channels at 65% of the locations and to 39% of the population are available for the adjacent channel criterion. The CCDF curve remains relatively parallel, with five or more channels available at 62% of the locations and to 37% of the population.

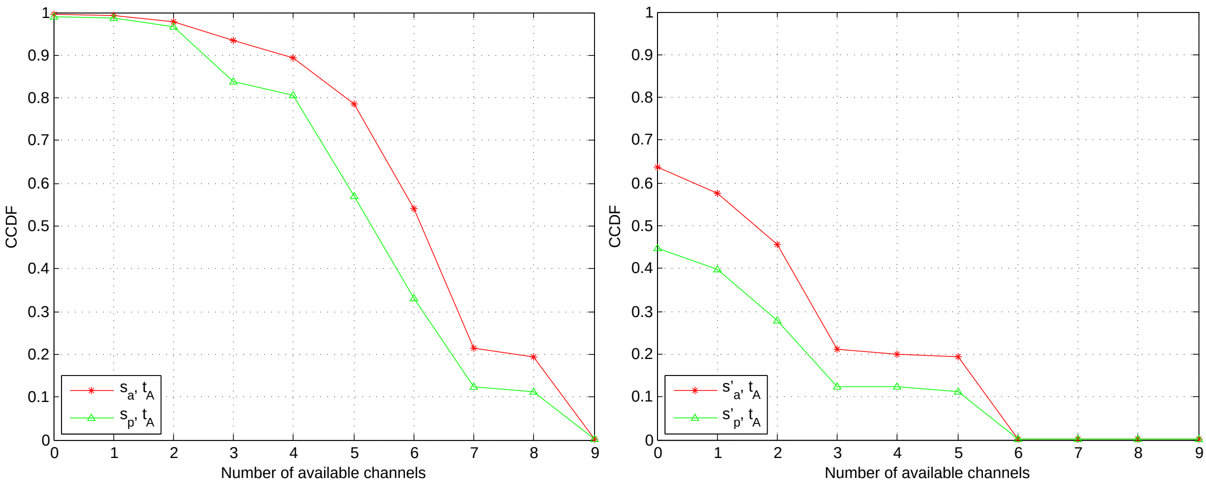
6.4.7 Eastern Cape

Table 6.9 details the mean values for the SO weighted by area and population, for the Eastern Cape. The co-channel availability criterion reports 6.5 channels by area and 6.5 channels by population available as SOs, corresponding to 73% and 64% of the band respectively. The adjacent channel criterion reports 2.3 channels by area and 1.5 channels by population, corresponding to 64% and 16% of the band respectively.

Table 6.9: Weighted mean values for VHF SO in the Eastern Cape

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
t_A	6.5 (73%)	5.7 (64%)	2.3 (25%)	1.5 (16%)

The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.8a and figure 6.8b respectively.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.8: VHF band: SO for the Eastern Cape

Figure 6.8a shows at least two channels are available at 99% of the locations and to 99% of the population, whilst at least five channels are available at 89% of the locations and to 81% of the population. Figure 6.8b indicates significantly less SO, with two or more channels only available at 58% of the locations and to 40% of the population.

6.4.8 Western Cape

In section 6.3.1 it was pointed out that the SO in the Western Cape is subject to the protection of the SKA against harmful interference. Table 6.10 details the mean values for the SO weighted by area and population, for the Western Cape, for time t_A, considering the mean values with and without the additional exclusion of the central advantage area from the analysis region. The co-channel availability criterion reports 5.6 channels by area and 4.5 channels by population available as SOs, corresponding to 62% and 50% of the band respectively. It seems from the weighted mean values that the exclusion of the additional central astronomy advantage area does not have a significant effect (larger than the rounding bias to one decimal) on the results.

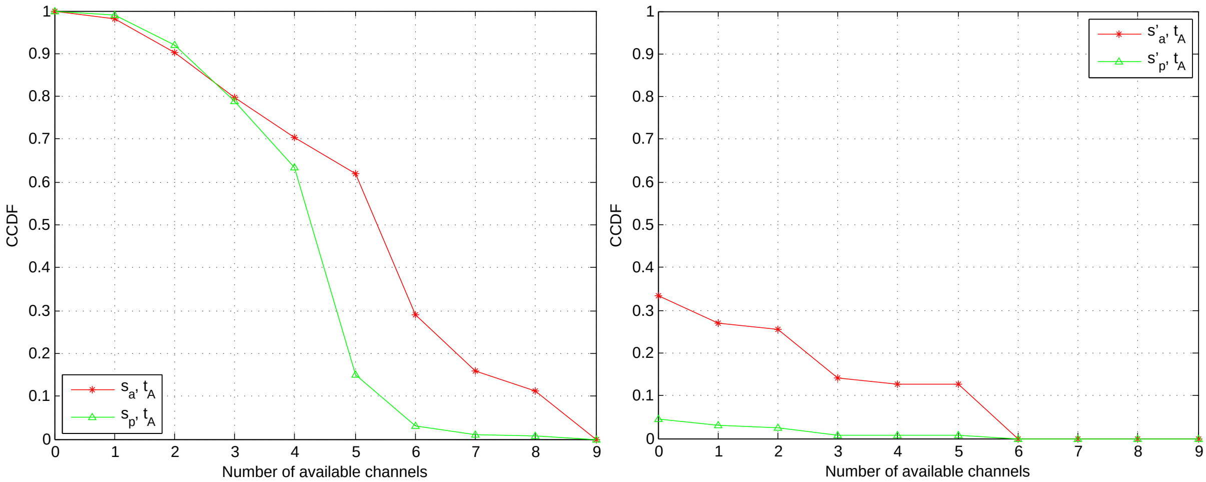
The adjacent channel criterion reports very little SO, with 1.2/1.3 channels by area and 0.1 channels by population, corresponding to 14% and 1% of the band respectively. Once again exclusion of the central area is seen not to have a immense impact on the adjacent channel results. The additional area excluded in the Western Cape due to the central astronomy advantage area is visualised in figure 2.1 (section 2.3). The area excluded from the analysis for the central advantage area is the intersect of the Western Cape province and the central advantage area 1 as depicted in green in the figure.

Table 6.10: Weighted mean values for VHF SO in the Western Cape

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A	5.6 (62%)	4.5 (50%)	1.2 (14%)	0.1 (1%)
t_A (Central advantage area excluded)	5.6 (62%)	4.5 (50%)	1.3 (14%)	0.1 (1%)

Because the effect of the additional area exclusion is not significant, only the empirical CCDFs for the Western Cape without the central advantage area exclusion are shown for the co-channel and adjacent channel availability criterion in figure 6.9a and figure 6.9b respectively.

Figure 6.9a indicate that at least three channels are available at 90% of the locations and to 92% of the population for the co-channel criterion. Figure 6.9b indicates that very little SO abounds, with two or more channels only available at 27% of the locations and to 3% of the population for the adjacent channel criterion.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.9: VHF band: SO for the Western Cape

6.4.9 Northern Cape

The SO in the Northern Cape is also subject to the protection of the SKA against harmful interference, as this is the province affected to the largest extent by the SKA developments. Table 6.11 details the mean values for the SO weighted by area and population, for the Northern Cape, for time t_A, considering the mean values respectively for the additional exclusion of the core and central advantage area from the analysis region.

Table 6.11: Weighted mean values for VHF SO in the Northern Cape

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
t_A (Core advantage area excluded)	7.6 (84%)	6.7 (75%)	3.3 (36%)	1.6 (17%)
t_A (Central advantage area excluded)	7.3 (81%)	6.7 (74%)	2.7 (30%)	1.4 (16%)

The area excluded from analysis when disregarding the core advantage is area is shown in red in figure 2.1 (section 2.3). The co-channel availability criterion reports 7.6 channels by area and 6.7 channels by population available as SOs, whilst the adjacent channel criterion reports 3.3 channels by area and 1.6 channels by population.

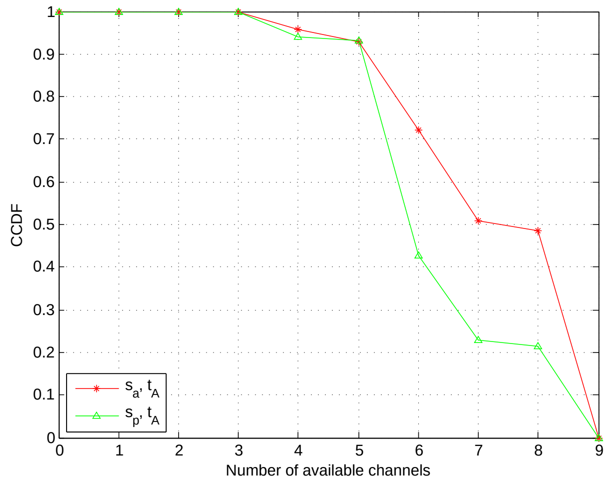
The area excluded from analysis when the central advantage area is disregarded is the intersection of the green area and the borders of the Northern Cape province in figure 2.1. The co-channel availability criterion reports 7.3 channels by area and 6.7 channels by population available as SOs, whilst the adjacent channel criterion reports 2.7 channels by area and 1.4 channels by population.

Comparison of the mean values for the case of the central advantage area and the case of the core advantage area exclusions yields the following observation. The population mean values remain largely unchanged, while the area mean values are influenced more by the central area exclusion. This indicates that the central area is not densely populated, as the exclusion of this area does not have a big impact on the population mean values.

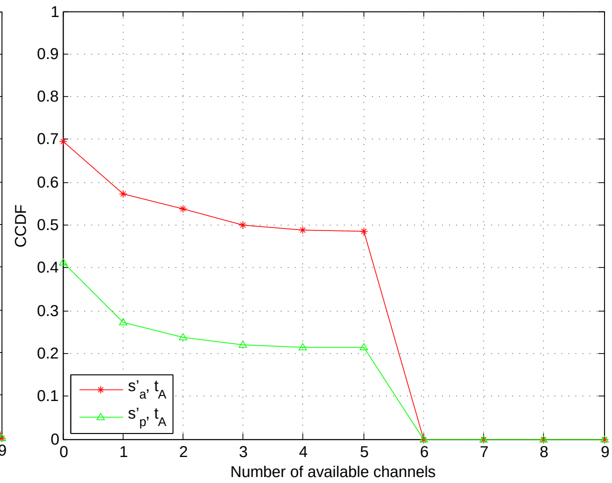
The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion for the core area (figure 6.10a and 6.10b) and the central area exclusions (figure 6.10c and 6.10d) respectively.

Comparison of figure 6.10a and figure 6.10c reveals that the CCDF curves follow the same trend, albeit with different probabilities for a given number of channels available. For the core area exclusion at least four channels are available at 100% of the locations and to 100% of the population, whilst the central area exclusion indicates at least four channels available for 100% of the locations and to 99.8% of the population.

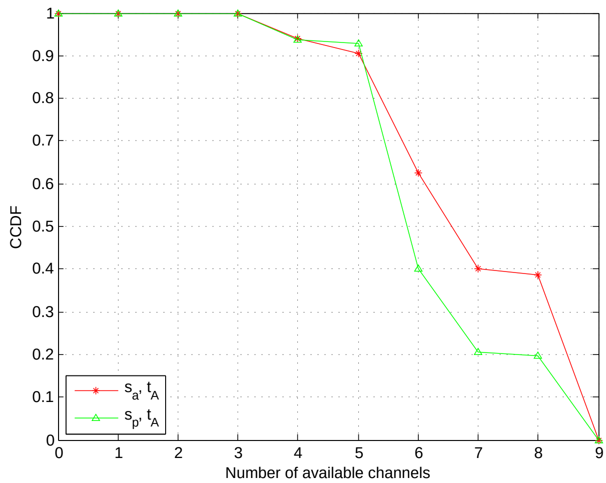
Figure 6.10b and figure 6.10d also follow the same trend, with the case for the core area exclusion having at least two channels available at 57% of the locations and to 27% of the population, whilst the case of the central area exclusion has at least two channels available at 48% of the locations and to 25% of the population.



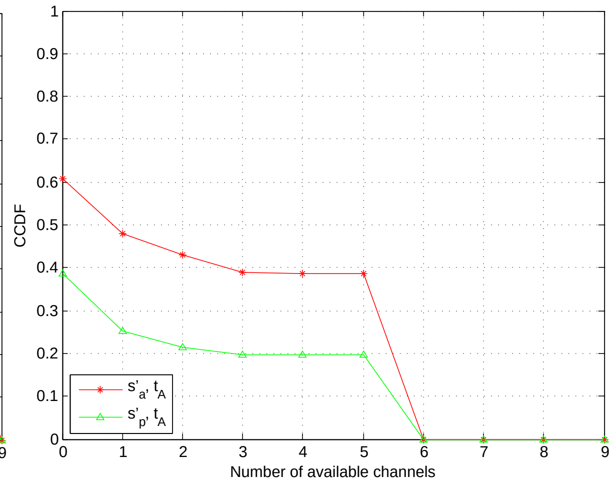
(a) CCDF: co-channel (Core area excluded)



(b) CCDF: adjacent channel (Core area excluded)



(c) CCDF: co-channel (Central area excluded)



(d) CCDF: adjacent channel (Central area excluded)

Figure 6.10: VHF band: SO for the Northern Cape

6.4.10 South Africa

The mean values for the SO weighted by area and population are shown for South Africa in table 6.12, for the exclusion of the SKA core and central advantage area from the analysis region respectively. Values for the case of the core and the case of the central area exclusions are both favourable, indicating that on average 6.9/6.8 channels channels by area and five channels by population are available under the co-channel availability criterion. For the adjacent channel availability criterion, 2.7/2.5 channels by area and 1.1 channels by population, are on average available as SOs.

Table 6.12: Weighted mean values for VHF SO in South Africa

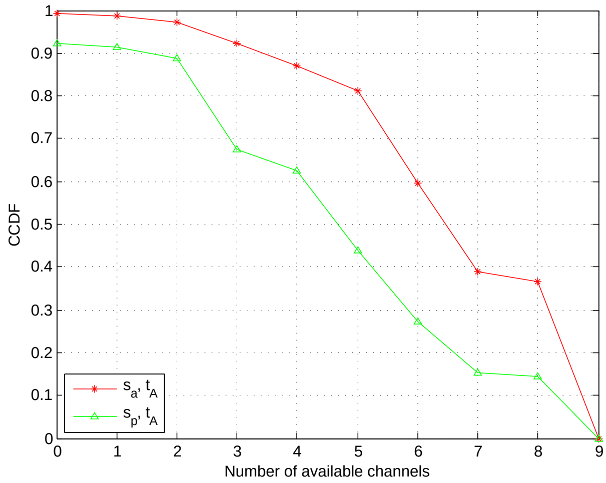
Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A (Core advantage area excluded)	6.9 (77%)	5.0 (56%)	2.7 (29%)	1.1 (13%)
t_A (Central advantage area excluded)	6.8 (75%)	5.0 (56%)	2.5 (27%)	1.1 (13%)

Once again, the additional area excluded by the central advantage area is seen to not influence the population mean values as much as the area mean values, once again pointing to the low population density, and hence the small contribution the central advantage area makes to the calculation of the mean SO weighted by population.

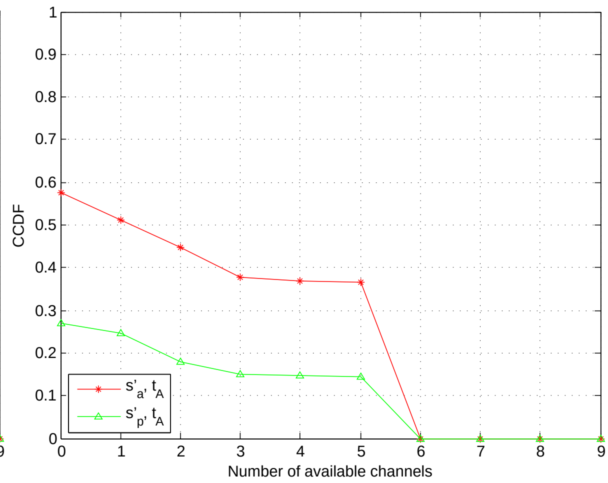
The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion for the core area (figures 6.11a and 6.11b) and the central area exclusions (figure 6.11c and 6.11d) respectively.

Figure 6.11a and figure 6.11c are seen to follow the same trend, although small differences in probability arise for a given number of channels. For the core area exclusion at least four channels are available at 93% of the locations and at least three channels are available for 89% of the population, whilst the central area exclusion indicates that there are at least four channels available for 92% of the locations and at least three channels available for 89% of the population in South Africa.

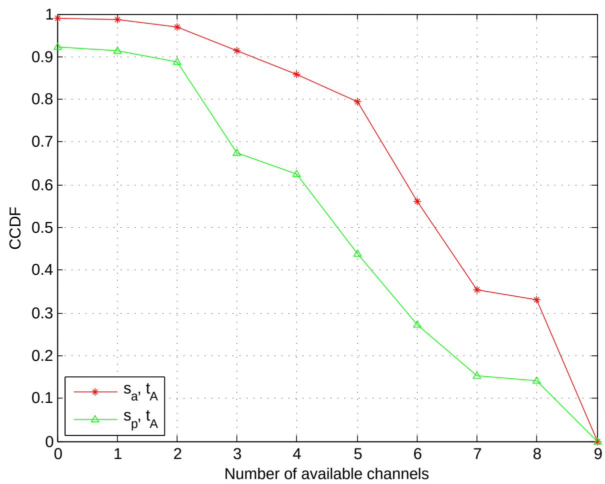
Figure 6.11b and figure 6.11d also follow the same trend, with the core area exclusion having at least two channels available at 51% of the locations and to 25% of the population, whilst the central area exclusion indicates at least two channels available at 49% of the locations and to 25% of the population in South Africa.



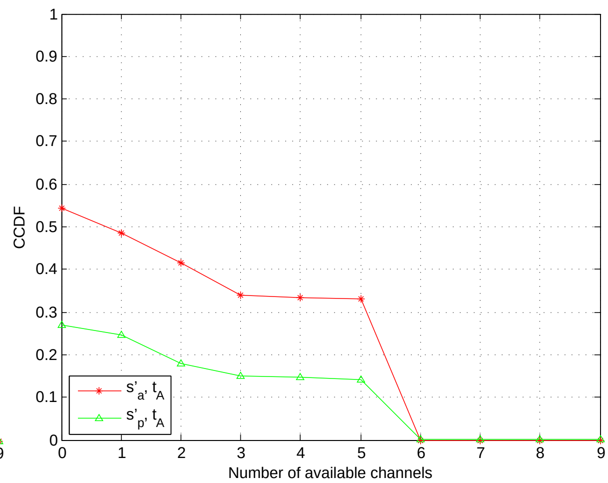
(a) CCDF: co-channel (Core area excluded)



(b) CCDF: adjacent channel (Core area excluded)



(c) CCDF: co-channel (Central area excluded)



(d) CCDF: adjacent channel (Central area excluded)

Figure 6.11: VHF band: SO for South Africa

6.4.11 Summary of VHF SO results

The results for SO in the VHF band for each of the provinces and South Africa as a whole, are aggregated into table 6.13 and table 6.14 for the core and central advantage area exclusions respectively. The province area and population figures as used in the analysis are displayed for each province. Recall that the area and population figures used are from Census 2001, with provincial borders as at 10 October 2001. The weighted mean values are summarised for the three discrete time periods that were evaluated in each case.

Table 6.13: Summary of VHF SO results, core advantage area excluded

Province	Area (km^2)	Population	t_A/t_{DU}			
			$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
Gauteng	17 010	8 837 178	2.7 (30%)	1.9 (21%)	0.0 (0%)	0.0 (0%)
Mpumalanga	79 490	3 122 990	7.8 (87%)	7.6 (85%)	4.1 (46%)	3.8 (42%)
Limpopo	123 910	5 273 642	6.4 (71%)	6.1 (68%)	1.8 (20%)	1.7 (18%)
Free State	129 480	2 706 775	7.2 (80%)	6.7 (75%)	2.8 (32%)	1.7 (19%)
Kwazulu-Natal	92 100	9 426 017	6.0 (67%)	5.2 (58%)	1.4 (16%)	0.6 (7%)
North West	116 320	3 669 349	7.6 (85%)	6.2 (69%)	3.8 (42%)	2.3 (26%)
Eastern Cape	169 580	6 436 763	6.5 (73%)	5.7 (64%)	2.3 (25%)	1.5 (16%)
Western Cape	129 370	4 524 335	5.6 (62%)	4.5 (50%)	1.2 (14%)	0.1 (1%)
Northern Cape	361 830	822 727	7.6 (84%)	6.7 (75%)	3.3 (36%)	1.6 (17%)
All provinces	1 219 090	44 819 778	6.9 (77%)	5.0 (56%)	2.7 (29%)	1.1 (13%)

Table 6.14: Summary of VHF SO results, central advantage area excluded

Province	Area (km^2)	Population	t_A/t_{DU}			
			$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
Gauteng	17 010	8 837 178	2.7 (30%)	1.9 (21%)	0.0 (0%)	0.0 (0%)
Mpumalanga	79 490	3 122 990	7.8 (87%)	7.6 (85%)	4.1 (46%)	3.8 (42%)
Limpopo	123 910	5 273 642	6.4 (71%)	6.1 (68%)	1.8 (20%)	1.7 (18%)
Free State	129 480	2 706 775	7.2 (80%)	6.7 (75%)	2.8 (32%)	1.7 (19%)
Kwazulu-Natal	92 100	9 426 017	6.0 (67%)	5.2 (58%)	1.4 (16%)	0.6 (7%)
North West	116 320	3 669 349	7.6 (85%)	6.2 (69%)	3.8 (42%)	2.3 (26%)
Eastern Cape	169 580	6 436 763	6.5 (73%)	5.7 (64%)	2.3 (25%)	1.5 (16%)
Western Cape	129 370	4 524 335	5.6 (62%)	4.5 (50%)	1.3 (14%)	0.1 (1%)
Northern Cape	361 830	822 727	7.3 (81%)	6.7 (74%)	2.7 (30%)	1.4 (16%)
All provinces	1 219 090	44 819 778	6.8 (75%)	5.0 (56%)	2.5 (27%)	1.1 (13%)

6.4.12 Analysis remarks

As was pointed out above, the results presented in section 6.4.1 to section 6.4.10 are applicable for time t_A and time t_{DU}. It was also shown that for time t_D the entire VHF band will be vacant. In particular, the following remarks can be made about the VHF SO results:

- Consider national SO availability for the case of the core advantage area and co-channel availability criterion. On average, 77% of the VHF band is available when weighted by area and 56% of the band is available when weighted by population. The CCDFs indicate available channels with good location probability and good population probability.

- The provincial analysis results illustrate that the distribution of VHF SO across the country is not uniform, as some provinces have high SO availability, whilst others have little or no SO availability.
- The availability criterion has a significant impact on the SOs available. The adjacent channel requirement reduces the amount of SO significantly for all provinces. This is in part due to the short length of the band (nine channels) and the requirement to have three contiguous channels available, for a channel to qualify as an SO under the current formulation of the adjacent channel criterion. Modification to the adjacent channel requirements and the less conservative treatment of band edges (channels 4 and 11) will allow for the recovery of more available channels.
- In contrast, the co-channel criterion recovers more channels with good location and population probability, suggesting that the band presents good SO for secondary devices that can adhere to the co-channel emission criteria.
- A new service currently planned for the VHF band is Digital Audio Broadcast (DAB). This will come into effect after analogue switch-off, i.e. time t_D. Channels 9 and 10 are earmarked for this service [13].

Taking the above remarks into account, it can be concluded that the VHF band shows current and future promise for the availability of SOs.

6.5 SO in the UHF terrestrial TV frequency band

The analysis results for the SO in the UHF terrestrial TV frequency bands are now discussed and elaborated upon for each of the nine provinces of South Africa and also for the country as a whole. As discussed in section 6.1, the channels considered for UHF are ITU region 1 bands IV and V, hence channels 21 - 68, corresponding to 470 MHz - 854 MHz. The analysis parameters as defined in section 6.3 were used to derive the results.

6.5.1 Gauteng

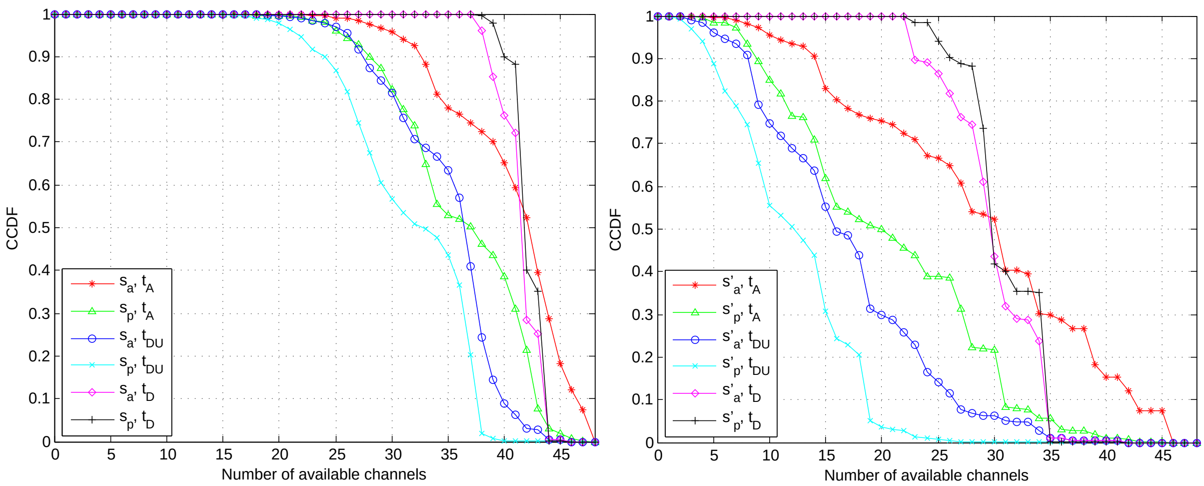
The mean values for the SO weighted by area ($\overline{s}_a$, $\overline{s}_a^{'}$) and population ($\overline{s}_p$, $\overline{s}_p^{'}$) are respectively divulged for the two availability criteria and the three temporal scenarios (t_A, t_{DU} and t_D) in table 6.15. The mean values are also expressed as a fraction of the total number of UHF TV channels in the band. This fraction is expressed as a percentage and reported in brackets next to the actual mean values in table 6.15. The convention used to denote the variables is consistent with the syntax defined in section 5.1.4 and 5.4.

Table 6.15: Weighted mean values for UHF SO in Gauteng

Time	$\overline{s}_a$	$\overline{s}_p$	$\overline{s}_a^{'}$	$\overline{s}_p^{'}$
t_A	41.0 (85%)	36.6 (76%)	29.1 (61%)	20.9 (44%)
t_{DU}	35.3 (74%)	32.0 (67%)	17.2 (36%)	12.5 (26%)
t_D	41.8 (87%)	42.5 (89%)	30.2 (63%)	31.2 (65%)

The mean values in table 6.15 follow the same general trend. For time t_A, the mean SO is at a given level, the SO then decreases during time t_{DU} due to the dual illumination of the analogue and DTT service. Then for time t_D, the analogue transmitters are switched off and only the DTT transmissions remain active. It can be seen that the mean number of channels recovered after analogue switch-off is more than for t_A.

The empirical CCDFs of the number of available channels for Gauteng, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.12a and figure 6.12b respectively. The CCDFs also indicate the distributions for the 3 temporal scenarios, t_A, t_{DU} and t_D. Variables s_a and s_p in each instance refer to the number of channels available at each grid cell location for the co-channel criterion as weighted by area or by population. In a similar manner, $s_a^{'}$ and $s_p^{'}$ refer to the number of channels available for the adjacent channel criterion as weighted by area or by population. The convention used to denote the variables is consistent with the syntax definition given in section 6.4.1.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.12: UHF band: SO for Gauteng

Co-channel criterion

From figure 6.12a is can be seen that for time t_A, at least 16 channels are available at 100% of the locations and to 100% of the population. At least 34 channels are available at 88% of the locations and at least 29 channels are available to 90% of the population in Gauteng.

For time t_{DU}, the SO decreases to at least 14 channels for 100% of the locations and the population. At least 25 channels are available to 90% of the population, whilst at least 28 channels are available at 91% of the locations.

For time t_D the SO increases, with at least 36 channels available for 100% of the locations and 38 or more channels for 100% of the population. At least 41 channels are available to 90% of the population and at 76% of the locations.

Adjacent channel criterion

From figure 6.12b it can be seen for time t_A at least four channels are available at 100% of the locations and available to 100% of the population. For 90% of the locations at least 15 channels are available, whilst ten channels are available to 90% of the population.

The SO decreases for t_{DU} to at least two channels for 100% of the population and locations. At least nine channels are available at 90% of the locations and at least six channels are available to 89% of the population.

Time t_D shows an significant increase in the number of channels available, with at least 21 channels available at 100% of the locations and 23 channels available to 100% of the population. At least 24 channels are available at 90% of the locations and 27 channels are available to 90% of the population.

6.5.2 Mpumalanga

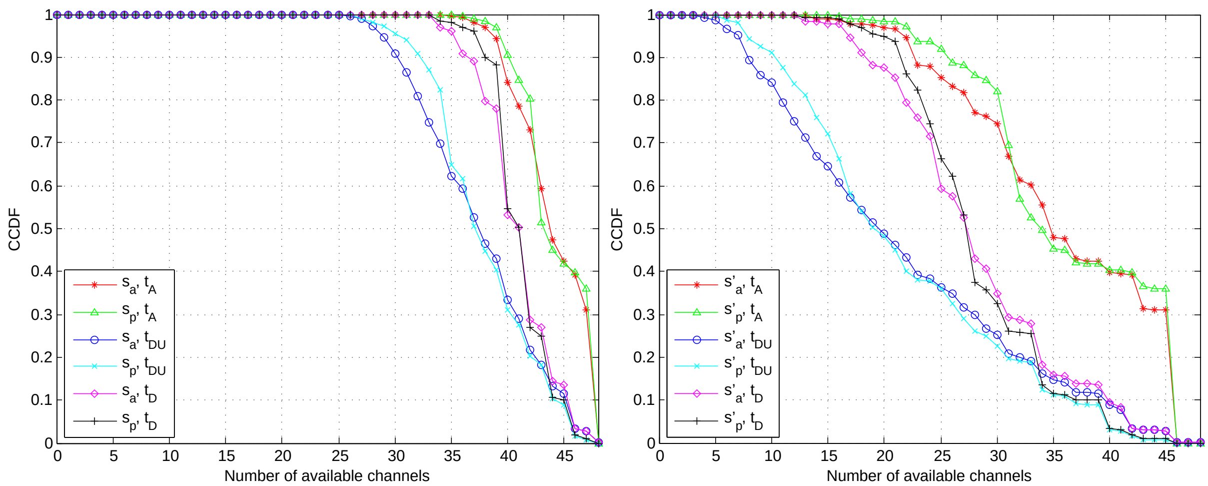
The mean values for the SO weighted by area and population are respectively shown for the two availability criteria and the three temporal scenarios in table 6.16. The mean values are also expressed as a fraction of the total number of UHF TV channels in brackets.

Table 6.16: Weighted mean values for UHF SO in Mpumalanga

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
t_A	44.4 (93%)	44.6 (93%)	36.1 (75%)	36.7 (77%)
t_{DU}	37.9 (79%)	38.3 (80%)	22.0 (46%)	22.1 (46%)
t_D	41.2 (86%)	41.5 (86%)	28.6 (60%)	28.6 (60%)

The mean values in table 6.16 follow the same general trend: for t_A, the mean SO is at a given level, the SO then decreases during time t_{DU} and then increases for time t_D. Interestingly, the number of channels recovered after analogue switch-off is less than for t_A. This could be due to the lower minimum field strength requirements of the digital service, compared to the protection requirements of the analogue service.

The empirical CCDFs of the number of available channels for Mpumalanga, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.13a and figure 6.13b respectively. The CCDFs also indicate the distributions for the three temporal scenarios, which will now be discussed accordingly.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.13: UHF band: SO for Mpumalanga

Co-channel criterion

From figure 6.13a it can be seen that for time t_A, at least 33 channels are available at 100% of the locations and to 100% of the population. Also, 41 or more channels are available at 84% of the locations and to 90% of the population in Mpumalanga.

For time t_{DU}, the SO decreases to at least 24 channels for 100% of the population and locations. At least 33 channels are available to 91% of the population and 31 channels are available at 91% of the locations.

For time t_D the SO increases, with at least 34 channels available to 100% of the population and locations. At least 39 channels are available to 90% of the population and at 80% of the locations.

Adjacent channel criterion

From figure 6.13b it can be seen for time t_A at least ten channels are available to 100% of the population and locations. For 88% of the locations at least 24 channels are available, whilst 27 channels are available to 89% of the population.

The SO decreases for t_{DU} to at least two channels for 100% of the population and locations. At least nine channels are available at 90% of the locations and at least 11 channels are available to 91% of the population.

Time t_D shows an increase in the number of channels available but not more than for time t_A, with at least 13 channels available to 100% of the population and locations. At least 19 channels are available at 90% of the locations and to 97% of the population.

6.5.3 Limpopo

The mean values for the SO weighted by area and population are respectively shown for the two availability criteria and the three temporal scenarios in table 6.17. The mean values are expressed as a fraction of the total number of UHF TV channels in brackets next to the mean value.

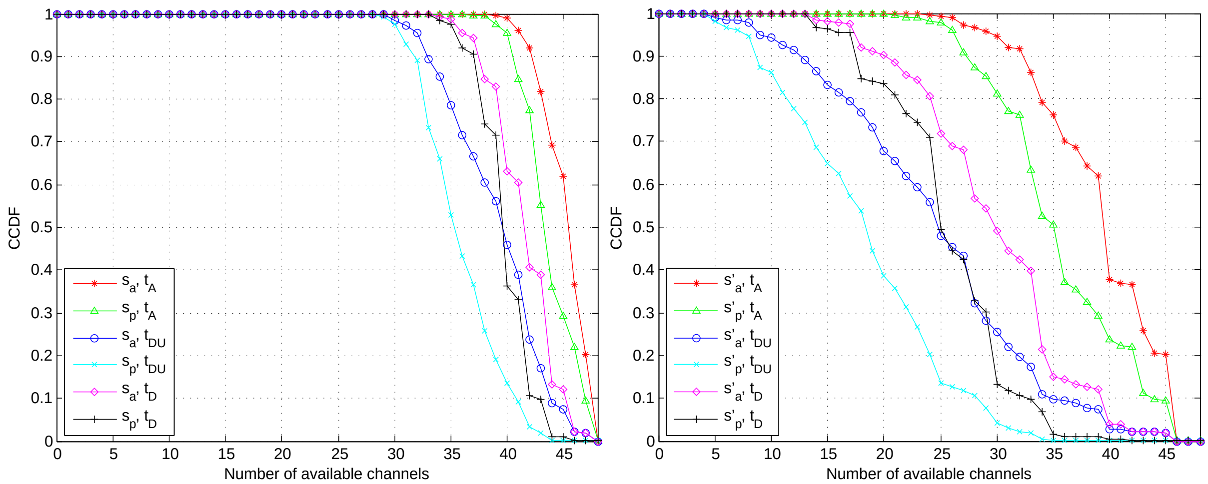
Table 6.17: Weighted mean values for UHF SO in Limpopo

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A	45.6 (95%)	44.1 (92%)	39.5 (82%)	35.9 (75%)
t_{DU}	39.5 (82%)	36.2 (75%)	25.0 (52%)	18.7 (39%)
t_D	41.9 (87%)	40.2 (84%)	30.0 (63%)	26.0 (54%)

The mean values in table 6.17 follow the same trend as was the case for Mpumalanga:

The SO decreases during time t_{DU} and then increases for time t_D; however, the SO recovered after analogue switch-off is less than for t_A.

The empirical CCDFs of the number of available channels for Limpopo, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.14a and figure 6.14b respectively. The CCDFs indicate the distributions for the three temporal scenarios, which will now be discussed accordingly.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.14: UHF band: SO for Limpopo

Co-channel criterion

From figure 6.14a is can be seen that for time t_A, at least 36 channels are available at 100% of the locations and at least 35 channels are available to 100% of the population. At least 43 channels are available at 92% of the locations and to 77% of the population in Limpopo.

For time t_{DU}, the SO decreases to at least 27 channels for 100% of the population and locations. At least 34 channels are available at 90% of the locations and to 73% of the population.

For time t_D the SO increases, with at least 34 channels available to 100% of the population and locations. At least 38 channels are available to 91% of the population and at

94% of the locations.

Adjacent channel criterion

From figure 6.14b it can be seen for time t_A, that at least 11 channels are available to 100% of the population and at least 14 channels are available at 100% of the locations. For 92% of the locations at least 33 channels are available, whilst 28 channels are available to 91% of the population.

The SO decreases for t_{DU} to at least five channels available for 100% of the population and locations. At least 13 channels are available at 92% of the locations and to 78% of the population.

Time t_D shows an increase in the number of channels available but not more than for time t_A, with at least 14 channels available to 100% of the population and locations. At least 21 channels are available at 90% of the locations and to 84% of the population.

6.5.4 Free State

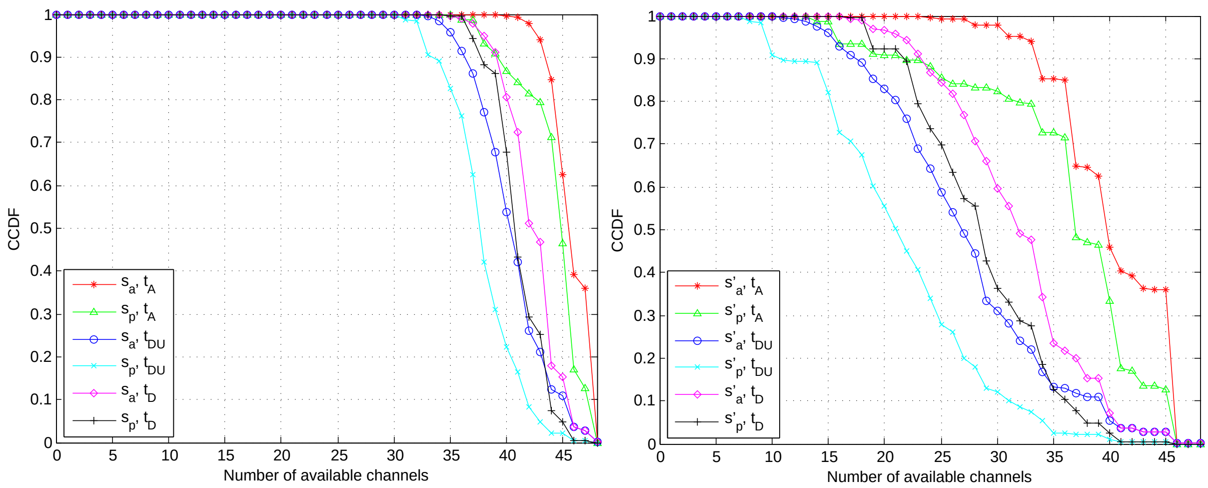
The mean values for the SO weighted by area and population are respectively shown for the two availability criteria and the three temporal scenarios in table 6.18. The mean values are expressed as a fraction of the total number of UHF TV channels in brackets next to the mean value.

Table 6.18: Weighted mean values for UHF SO in the Free State

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A	46.1 (96%)	44.6 (93%)	40.5 (84%)	36.3 (76%)
t_{DU}	40.9 (85%)	38.3 (80%)	27.6 (58%)	21.9 (46%)
t_D	42.7 (89%)	41.5 (86%)	32.0 (67%)	29.0 (60%)

The mean values in table 6.18 follow the same trend as was the case for Mpumalanga and Limpopo: the SO decreases during time t_{DU} and then increases for time t_D; however, the SO recovered after analogue switch-off is less than for t_A.

The empirical CCDFs of the number of available channels for the Free State, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.15a and figure 6.15b respectively. The CCDFs indicate the distributions for the three temporal scenarios which will now be discussed accordingly.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.15: UHF band: SO for the Free State

Co-channel criterion

From figure 6.15a it can be seen that for time t_A, at least 36 channels are available to 100% of the population and locations. At least 44 channels are available at 94% of the locations and to 80% of the population in the Free State.

For time t_{DU}, the SO decreases to at least 31 channels for 100% of the population and locations. At least 37 channels are available at 91% of the locations and to 76% of the population.

For time t_D the SO increases, with at least 35 channels available to 100% of the population and locations. At least 40 channels are available at 91% of the locations and to 86% of the population.

Adjacent channel criterion

From figure 6.15b it can be seen for time t_A, that at least 14 channels are available to 100% of the population and locations. For 94% of the locations at least 34 channels are available, whilst 22 channels are available to 90% of the population.

The SO decreases for t_{DU} to at least eight channels available for 100% of the population and locations. At least 18 channels are available at 91% of the locations whilst at least 11 channels are available to 91% of the population.

Time t_D shows an increase in the number of channels available but not more than for time t_A, with at least 16 channels available to 100% of the population and at least 13 channels available at 100% of the locations. At least 24 channels are available at 91% of the locations and to 79% of the population.

6.5.5 KwaZulu-Natal

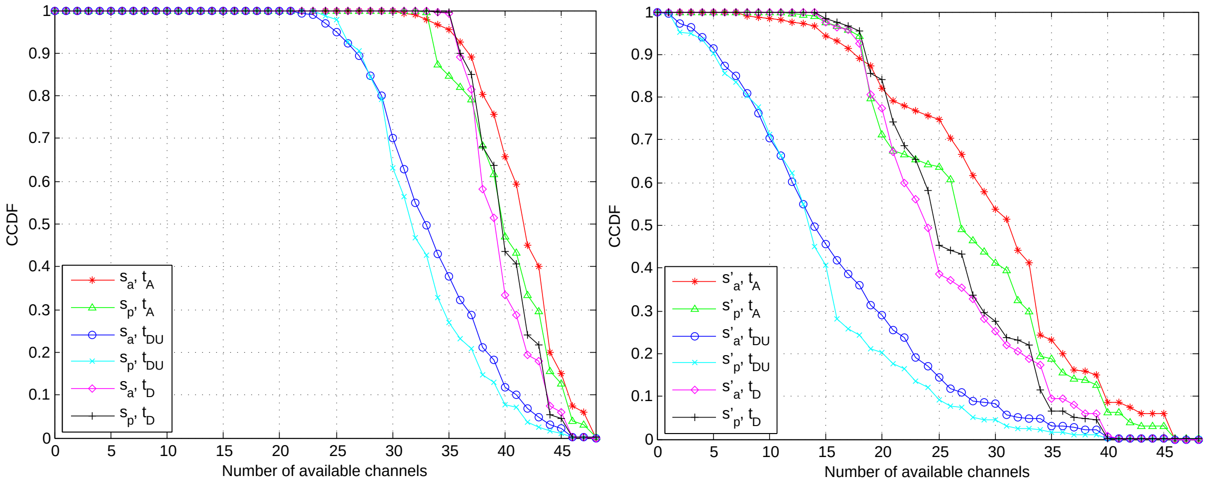
The mean values for the SO weighted by area and population are respectively shown for the two availability criteria and the three temporal scenarios in table 6.19. The mean values are expressed as a fraction of the total number of UHF TV channels in brackets next to the mean value.

Table 6.19: Weighted mean values for UHF SO in KwaZulu-Natal

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A	41.8 (87%)	40.5 (84%)	30.1 (63%)	28.2 (59%)
t_{DU}	33.9 (71%)	33.1 (69%)	16.2 (34%)	14.8 (31%)
t_D	39.9 (83%)	40.5 (84%)	25.9 (54%)	26.6 (55%)

The mean SO values in table 6.19 decrease during time t_{DU} and then increases for time t_D; however, the SO recovered after analogue switch-off is less than for t_A. This is consistent with the trend identified in all the other provinces this far, except Gauteng.

The empirical CCDFs of the number of available channels for the KwaZulu-Natal, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.16a and figure 6.16b respectively. The CCDFs indicate the distributions for the three temporal scenarios, which will now be discussed accordingly.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.16: UHF band: SO for KwaZulu-Natal

Co-channel criterion

Figure 6.16a indicates for time t_A, that at least 30 channels are available to 100% of the population and locations. At least 28 channels are available at 89% of the locations and to 79% of the population in KwaZulu-Natal.

For time t_{DU}, the SO decreases to at least 20 channels for 100% of the population and locations. At least 28 channels are available at 89% of the locations and to 91% of the population.

For time t_D the SO increases, with at least 34 channels available to 100% of the population and locations. At least 37 channels are available at 89% of the locations and to 90% of the population.

Adjacent channel criterion

Figure 6.16b indicates for time t_A, that at least seven channels are available to 100% of the population and locations. For 89% of the locations at least 19 channels are available, whilst 19 channels are available to 94% of the population.

The SO decreases drastically for t_{DU} to 1 channel available for 100% of the population and locations. At least six channels are available at 91% of the locations and to 90% of the population.

Time t_D shows an increase in the number of channels available, with at least 15 channels available to 100% of the population and at least 14 channels available at 100% of the locations. At least 19 channels are available at 93% of the locations and to 96% of the population.

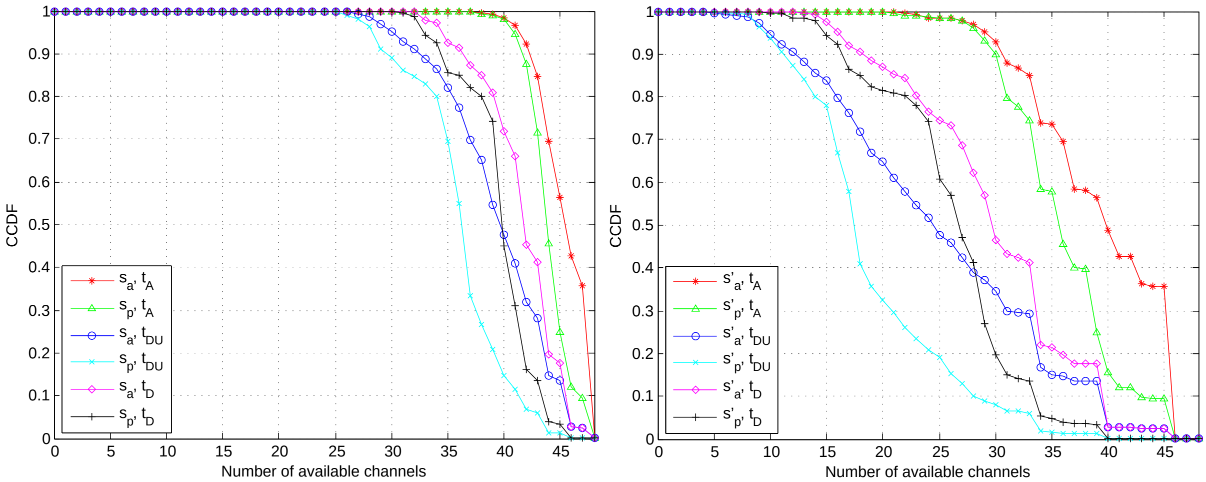
6.5.6 North West

The mean values for the SO weighted by area and population are respectively shown for the two availability criteria and the three temporal scenarios in table 6.20. The mean values are expressed as a fraction of the total number of UHF TV channels in brackets next to the mean value. It can be seen from the table that the SO recovered after analogue switch-off (t_D) is less than the SO before dual illumination (t_A). This trend is consistent with that of the other provinces, except for Gauteng.

Table 6.20: Weighted mean values for UHF SO in the North West

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a'$	$\bar{s}_p'$
t_A	45.8 (95%)	44.4 (93%)	39.7 (83%)	36.4 (76%)
t_{DU}	39.8 (83%)	36.6 (76%)	25.5 (53%)	19.4 (41%)
t_D	42.0 (87%)	40.1 (83%)	30.2 (63%)	26.5 (55%)

The empirical CCDFs of the number of available channels for the North West, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.17a and figure 6.17b respectively. The CCDFs indicate the distributions for the three temporal scenarios, which will now be discussed accordingly.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.17: UHF band: SO for the North West

Co-channel criterion

Figure 6.17a indicates for time t_A, that at least 36 channels are available to 100% of the population and locations. At least 43 channels are available at 92% of the locations and to 88% of the population in the North West.

For time t_{DU}, the SO decreases to at least 25 channels for 100% of the population and locations. At least 33 channels are available at 91% of the locations and at least 30 channels are available to 91% of the population.

For time t_D the SO increases, with at least 31 channels available to 100% of the population and locations. At least 37 channels are available at 91% of the locations and to 85% of the population.

Adjacent channel criterion

Figure 6.17b indicates for time t_A, that at least 18 channels are available to 100% of the population and locations. At least 31 channels are available at 93% of the locations and to 90% of the population.

The SO decreases for t_{DU} to at least three channels available for 100% of the population and locations. At least 13 channels are available at 90% of the locations, whilst at least 12 channels are available to 90% of the population.

Time t_D shows an increase in the number of channels available, but not more than for time t_A, with at least nine channels available to 100% of the population and locations. At least 19 channels are available at 90% of the locations and to 85% of the population.

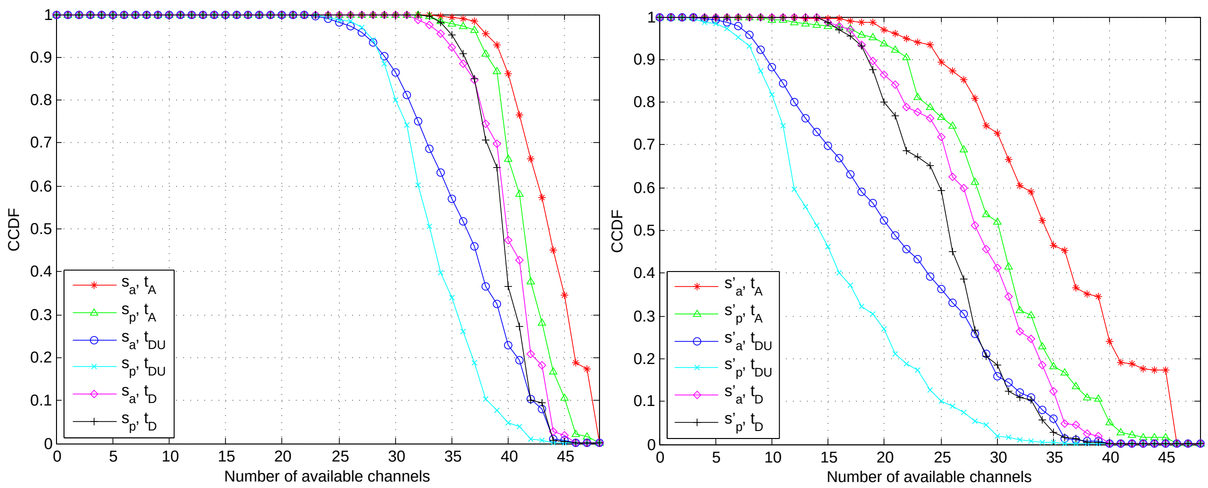
6.5.7 Eastern Cape

The mean values for the SO weighted by area and population are respectively shown for the two availability criteria and the three temporal scenarios in table 6.21. The mean values are expressed as a fraction of the total number of UHF TV channels in brackets next to the mean value. The SO recovered after analogue switch-off is seen to be less than the SO before dual illumination. This trend is consistent with that of the other provinces, except for Gauteng.

Table 6.21: Weighted mean values for UHF SO in the Eastern Cape

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A	43.9 (91%)	41.9 (87%)	35.1 (73%)	30.1 (63%)
t_{DU}	36.3 (76%)	33.9 (71%)	21.5 (45%)	16.2 (34%)
t_D	40.4 (84%)	39.9 (83%)	28.4 (59%)	25.8 (54%)

The empirical CCDFs of the number of available channels for the Eastern Cape, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion in figure 6.18a and figure 6.18b respectively. The CCDFs indicate the distributions for the three temporal scenarios, which will now be discussed accordingly.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.18: UHF band: SO for the Eastern Cape

Co-channel criterion

Figure 6.18a indicates for time t_A, that at least 31 channels are available to 100% of the population and locations. At least 39 channels are available at 96% of the locations and to 91% of the population in the Eastern Cape.

For time t_{DU}, the SO decreases to at least 21 channels for 100% of the population and locations. At least 30 channels are available at 90% of the locations and to 89% of the population.

For time t_D the SO increases again, with at least 31 channels available to 100% of the population and locations. At least 37 channels are available at 88% of the locations and to 91% of the population.

Adjacent channel criterion

Figure 6.18b indicates for time t_A, that at least eight channels are available to 100% of the population and locations. At least 26 channels are available at 90% of the locations, whilst at least 23 channels are available to 90% of the population.

The SO decreases for t_{DU} to at least two channels available for 100% of the population and locations. At least 11 channels are available at 88% of the locations, whilst at least ten channels are available to 87% of the population.

Time t_D shows an increase in the number of channels available, with at least 14 channels available to 100% of the population and locations. At least 20 channels are available at 90% of the locations and to 88% of the population.

6.5.8 Western Cape

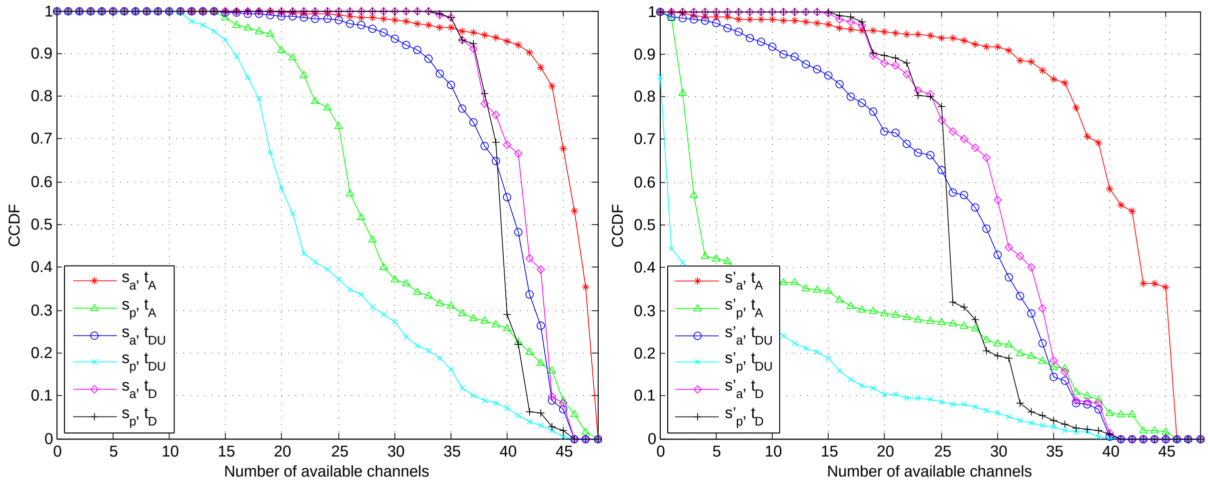
The mean values for the SO weighted by area and population are respectively shown for the two availability criteria and the three temporal scenarios in table 6.22, considering the mean values with and without the additional exclusion of the central advantage area from the analysis region. It follows from the weighted mean values that the exclusion of the additional central astronomy advantage area does not have a significant effect (larger than the rounding bias to one decimal) on the results. Furthermore, the SO recovered after analogue switch-off is also seen to be less than the SO before dual illumination. This trend is consistent with that of the other provinces, except for Gauteng.

Table 6.22: Weighted mean values for UHF SO in the Western Cape

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A	45.5 (95%)	31.0 (65%)	40.0 (83%)	13.7 (29%)
t_{DU}	39.7 (83%)	24.9 (52%)	26.6 (55%)	7.0 (15%)
t_D	41.7 (87%)	40.0 (83%)	30.3 (63%)	26.7 (56%)
t_A (Central advantage area excluded)	45.5 (95%)	31.0 (65%)	40.0 (83%)	13.7 (29%)
t_{DU} (Central advantage area excluded)	39.7 (83%)	24.9 (52%)	26.5 (55%)	7.0 (15%)
t_D (Central advantage area excluded)	41.7 (87%)	40.0 (83%)	30.2 (63%)	26.7 (56%)

From the figures in table 6.22 it can be seen that the effect of the additional central area exclusion is not significant. Therefore, only the empirical CCDFs for the Western Cape without the central advantage area exclusion are shown for the co-channel and adjacent channel availability criterion in figure 6.19a and figure 6.19b respectively. The

CCDFs indicate the distributions for the three temporal scenarios, which will now be discussed accordingly.



(a) CCDF: co-channel availability criterion (b) CCDF: adjacent channel availability criterion

Figure 6.19: UHF band: SO for the Western Cape

Co-channel criterion

Figure 6.19a indicates for time t_A, that at least 13 channels are available to 100% of the population and at least 15 channels are available at 100% of the locations. At least 43 channels are available at 90% of the locations while at least 22 channels are available to 90% of the population in the Western Cape.

For time t_{DU}, the SO decreases to at least ten channels for 100% of the population at at least 11 channels for 100% of the locations. At least 34 channels are available at 90% of the locations whilst at least 17 channels are available to 89% of the population. The CCDF curves for t_A and t_{DU} are seen to show a great difference between the number of channels available by area and population.

For time t_D the SO increases again, with at least 32 channels available to 100% of the population and locations. At least 38 channels are available at 91% of the locations and to 92% of the population.

Adjacent channel criterion

Figure 6.19b indicates for time t_A, that at least 32 channels are available at 90% of the locations, whilst only being available to 22% of the population. For time t_A, the CCDF curves show that there are no vacant channels for 100% of the population or locations.

No channels are available for 100% of the population or locations for time t_{DU} as well. At least 12 channels are available at 90% of the locations and to 37% of the population. The CCDF curves for t_A and t_{DU} are seen to show a great difference between the number of channels available by area and population. This is due to the distribution characteristics of the population within the land area of the Western Cape. Refer back to figure 5.5 for a visualisation of the population density.

Time t_D shows a dramatic increase in the number of channels available to 100% of the population and locations, with at least 14 channels available. At least 20 channels are available at 90% of the locations and to 90% of the population.

6.5.9 Northern Cape

The Northern Cape is the province that is affected to the largest extent by the SKA developments. Table 6.23 details the mean SO weighted by area and population for the two availability criteria and the three temporal scenarios, excluding the core and central advantage area, respectively. The additional area excluded by the central advantage area does not seem to influence the population mean values as much as the area mean values, indicating that the area excluded is not as densely populated, and therefore does not have such a big impact on the population weighted mean values. The SO recovered after analogue switch-off is also seen to be less than the SO before dual illumination. This trend is consistent with that of the other provinces, except for Gauteng.

The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion for

Table 6.23: Weighted mean values for UHF SO in the Northern Cape

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A (Core advantage area excluded)	47.7 (99%)	45.9 (96%)	45.1 (94%)	40.0 (83%)
t_{DU} (Core advantage area excluded)	44.7 (93%)	42.6 (89%)	37.2 (78%)	31.6 (66%)
t_D (Core advantage area excluded)	45.1 (94%)	44.5 (93%)	38.0 (79%)	36.3 (76%)
t_A (Central advantage area excluded)	47.7 (99%)	45.9 (96%)	45.1 (94%)	40.0 (83%)
t_{DU} (Central advantage area excluded)	44.2 (92%)	42.5 (89%)	35.9 (75%)	31.4 (65%)
t_D (Central advantage area excluded)	44.5 (93%)	44.4 (93%)	36.6 (76%)	36.1 (75%)

the core area (figures 6.20a and 6.20b) and the central area exclusions (figures 6.20c and 6.20d) respectively. The CCDFs indicate the distributions for the three temporal scenarios which will now be discussed accordingly.

Co-channel criterion

Comparison of figure 6.20a and figure 6.20c reveals that the CCDF curves follow the same trend, albeit with different probabilities for a given number of channels available.

Figure 6.20a indicates for time t_A, that at least 35 channels are available to 100% of the population and at least 38 channels are available at 100% of the locations. At least 44 channels are available to 90% of the population and at 99.78% of the locations. For time t_{DU}, the SO decreases to at least 29 channels for 100% of the population and at least 32 channels for 100% of the locations. At least 42 channels are available at 96% of the locations and to 80% of the population. For time t_D the SO increases, with at least 40 channels available to 100% of the population and locations. At least 43 channels are available at 87% of the locations and to 85% of the population.

Figure 6.20c indicates for time t_A, that at least 35 channels are available to 100% of the population and at least 38 channels are available at 100% of the locations. At least 44 channels are available to 90% of the population and at 99.7% of the locations. For time t_{DU}, the SO decreases to at least 29 channels for 100% of the population and locations. At least 42 channels are available at 95% of the locations and to 80% of the population. For time t_D the SO increases, with at least 40 channels available to 100% of the population and locations. At least 43 channels are available at 82% of the locations and to 84% of the population.

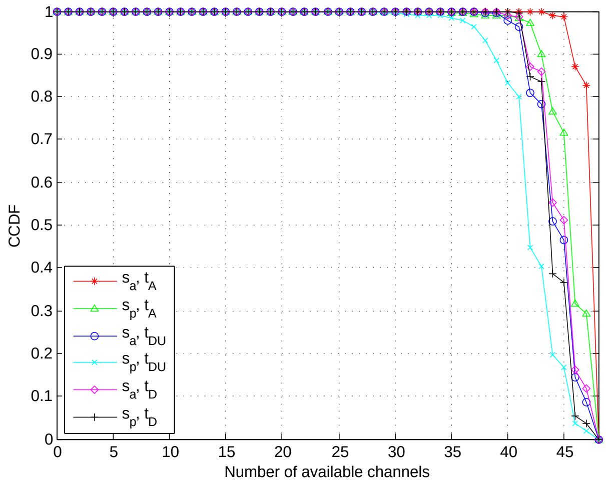
It follows for the co-channel availability criterion that the probability of finding SO in the Northern Cape remains relatively consistent, whether the central advantage area is excluded or not.

Adjacent channel criterion

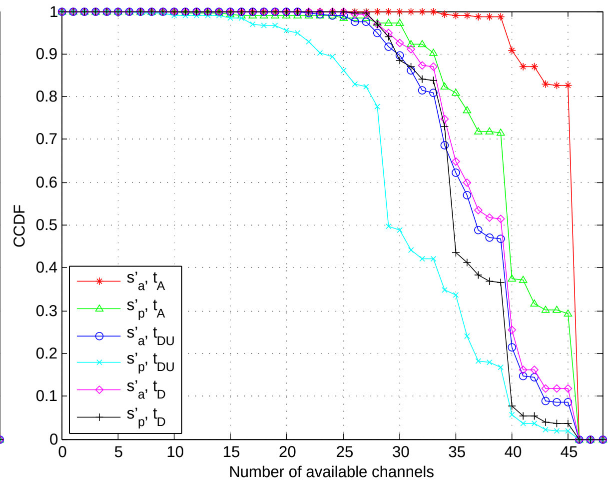
Figure 6.20b and figure 6.20d are seen to also follow the same trend. Figure 6.20b indicates for time t_A, that at least 11 channels are available to 100% of the population and at least 16 channels are available at 100% of the locations. At least 34 channels are available to 90% of the population and at least 41 channels are available at 90% of the locations. For time t_{DU}, the SO decreases to at least seven channels for 100% of the population and at least ten channels for 100% of the locations. At least 31 channels are available at 90% of the locations, whilst at least 24 channels are available to 90% of the population. For time t_D the SO increases, with at least 23 channels available to 100% of the population and locations. At least 32 channels are available at 91% of the locations and to 87% of the population.

Figure 6.20c indicates for time t_A, that at least 11 channels are available to 100% of the population and locations. At least 34 channels are available to 90% of the population and at least 41 channels are available at 90% of the locations. For time t_{DU}, the SO decreases to at least seven channels for 100% of the population and locations. At least 30 channels are available at 89% of the locations whilst at least 24 channels are available to 90% of the population. For time t_D the SO increases, with at least 23 channels available to 100% of the population and locations. At least 31 channels are available at 89% of the locations and to 88% of the population.

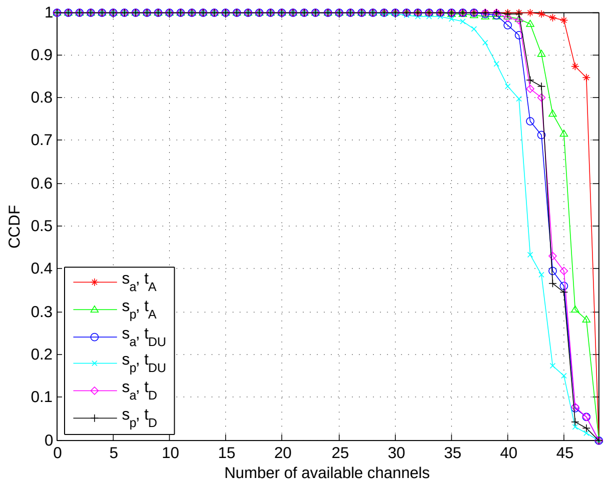
It follows for the adjacent channel availability criterion that the probability of finding SO in the Northern Cape decrease slightly if the central advantage area is excluded from the analysis region.



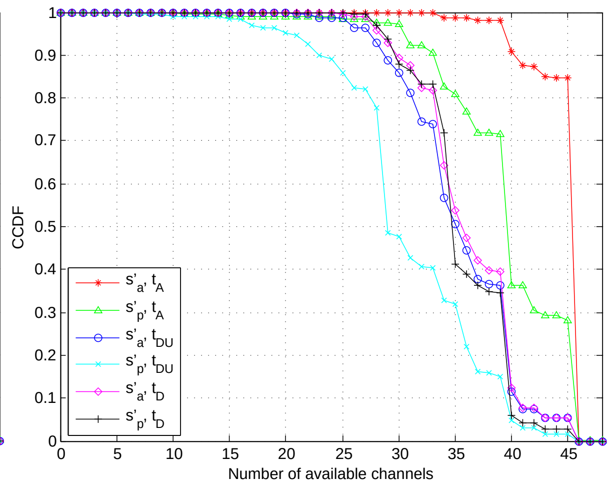
(a) CCDF: co-channel (Core area excluded)



(b) CCDF: adjacent channel (Core area excluded)



(c) CCDF: co-channel (Central area excluded)



(d) CCDF: adjacent channel (Central area excluded)

Figure 6.20: UHF band: SO for the Northern Cape

6.5.10 South Africa

Table 6.24 details the mean SO weighted by area and population for the two availability criteria and the three temporal scenarios, excluding the core and central advantage area from the analysis region. The mean values reported in each instance for the whole of South Africa appear promising. On national level, the additional area excluded by the central advantage area is seen to not influence the population mean values as much as the area mean values, indicating that the area excluded has a low population density, relative to the rest of the country.

Table 6.24 indicates that the mean SO recovered after analogue switch-off is in each instance less than before the commencement of dual illumination. Interestingly, the population weighted mean values suggest that the SOs recovered after analogue switch-off by the co-channel criterion is more than before the commencement of dual illumination. For the adjacent channel criterion, the SO recovered after analogue switch-off is less than for time t_A.

Table 6.24: Weighted mean values for UHF SO in South Africa

Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a^{'}$	$\bar{s}_p^{'}$
t_A (Core advantage area excluded)	45.6 (95%)	40.4 (84%)	39.6 (83%)	28.5 (59%)
t_{DU} (Core advantage area excluded)	40.2 (84%)	33.7 (70%)	27.7 (58%)	15.8 (33%)
t_D (Core advantage area excluded)	42.5 (89%)	40.9 (85%)	32.0 (67%)	27.8 (58%)
t_A (Central advantage area excluded)	45.4 (95%)	40.4 (84%)	39.1 (82%)	28.5 (59%)
t_{DU} (Central advantage area excluded)	39.7 (83%)	33.7 (70%)	26.4 (55%)	15.8 (33%)
t_D (Central advantage area excluded)	42.1 (88%)	40.9 (85%)	31.1 (65%)	27.8 (58%)

The empirical CCDFs for the number of available channels, weighted by area and population, are shown for the co-channel and adjacent channel availability criterion for the core area (figure 6.21a and 6.21b) and the central area exclusions (figure 6.21c and 6.21d) respectively. The CCDFs indicate the distributions for the three temporal scenarios, which will now be discussed accordingly.

Co-channel criterion

Comparison of figure 6.21a and figure 6.21c reveals that the CCDF curves follow the same trend, albeit with different probabilities for a given number of channels available.

Figure 6.21a indicates for time t_A, that at least 13 channels are available to 100% of the population and at least 15 channels are available at 100% of the locations. At least 31 channels are available to 90% of the population, whilst at least 42 channels are available at 90% of the locations.

For time t_{DU}, the SO decreases to at least ten channels for 100% of the population and at least 12 channels for 100% of the locations. At least 32 channels are available at 92%

of the locations and to 68% of the population. At least 26 channels are available to 90% of the population.

For time t_D the SO increases, with at least 31 channels available to 100% of the population and locations. At least 38 channels are available at 93% of the locations and to 91% of the population.

The results for figure 6.21c follow the same trend and absolute results for the availability for 100% of the population and locations. Availability of channels to the population (s_p) remains the same for time t_A, t_{DU} and t_D as discussed in the preceding paragraph. However, the availability of channels at locations (s_a) is lower.

Refer to figure 6.21c. For time t_A, at least 42 channels are available at 89% of the locations. For time t_{DU}, at least 32 channels are available at 91% of the locations. For time t_D, at least 38 channels are available at 92% of the locations.

Adjacent channel criterion

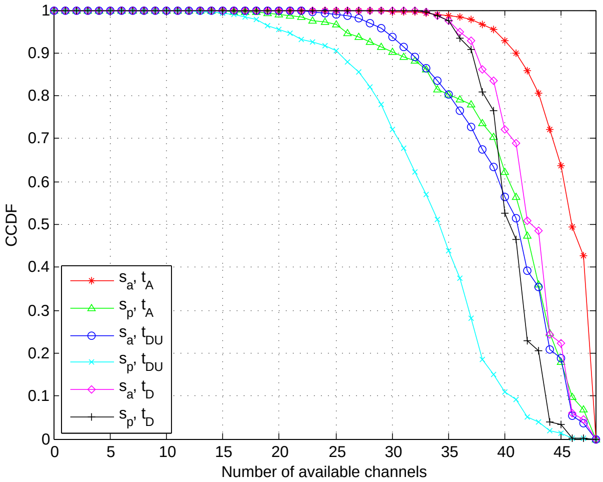
Figure 6.21b and figure 6.21d are seen to also follow the same trend. Figure 6.21b indicates for time t_A, that no channels are available to 100% of the population and locations. However, at least 29 channels are available at 91% of the locations and to 57% of the population. At least 12 channels are available to 90% of the population.

For time t_{DU}, the SO decreases to at least 12 channels are available at 91% of the locations and 68% of the population. At least five channels are available to 90% of the population.

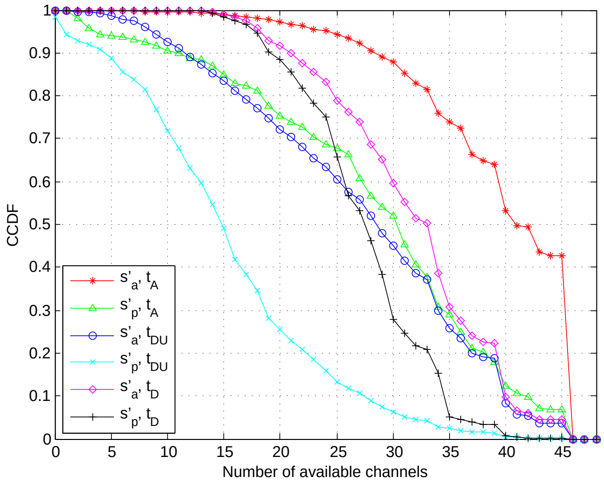
For time t_D the SO increases, with at least ten channels available to 100% of the population and locations. At least 22 channels are available at 90% of the locations and to 85% of the population. At least 20 channels are available to 90% of the population.

The results for figure 6.21d follow the same trend and numerical results for the availability for 100% of the population and locations. Availability of channels to the population ($s_p^{'}$) remains the same for time t_A, t_{DU} and t_D as discussed in the preceding paragraph. However, the availability of channels at locations ($s_a^{'}$) is lower.

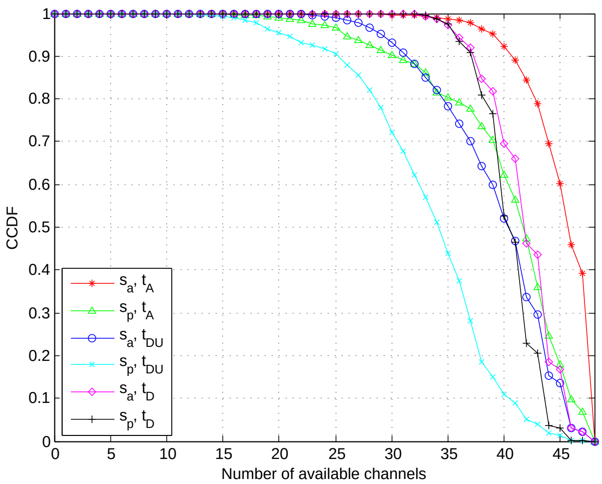
Figure 6.21d refers. For time t_A, at least 29 channels are available at 90% of the locations. For time t_{DU}, at least 12 channels are available at 90% of the locations. For time t_D, at least 22 channels are available at 89% of the locations.



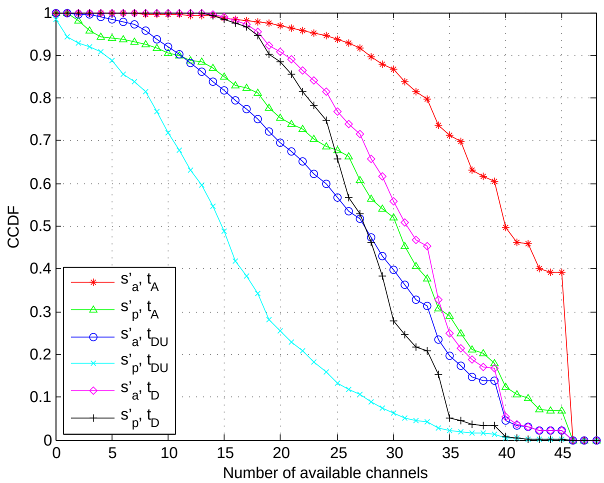
(a) CCDF: co-channel (Core area excluded)



(b) CCDF: adjacent channel (Core area excluded)



(c) CCDF: co-channel (Central area excluded)



(d) CCDF: adjacent channel (Central area excluded)

Figure 6.21: UHF band: SO for South Africa

Effect of future SKA regulations on national SO availability

It follows from comparison of the results discussed above for the SKA core and central advantage area exclusions that the SO on a national level is still significant, even if legislation is put in place to prevent additional RFI from originating within the central advantage area. This is seen to be the case for SO available under the co-channel and adjacent channel availability criteria. It should be emphasised that the draft regulations at the time of writing suggest that additional coordination of RFI in coordinated zone 1, i.e. outside the central advantage area, will only be required from transmitters with an ERP exceeding 60 dBm [57]. This ERP is unlikely to be exceeded by any SU equipment intended for the market.

6.5.11 Summary of UHF SO results

The results for SO in the UHF band for each of the provinces and South Africa as a whole, are aggregated into table 6.25 and table 6.26 for the core and central advantage area exclusions respectively. The province area and population figures as used in the analysis are displayed for each province. Recall that the area and population figures used are from Census 2001, with provincial borders as at 10 October 2001. The weighted mean values are summarised for the three discrete time periods that were evaluated in each case.

Table 6.25: Summary of UHF SO results, core advantage area excluded

			t_A				t_{DU}				t_D			
Province	Area (km^2)	Population	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a'$	$\bar{s}_p'$	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a'$	$\bar{s}_p'$	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}_a'$	$\bar{s}_p'$
Gauteng	17 010	8 837 178	41.0 (85%)	36.6 (76%)	29.1 (61%)	20.9 (44%)	35.3 (74%)	32.0 (67%)	17.2 (36%)	12.5 (26%)	41.8 (87%)	42.5 (89%)	30.2 (63%)	31.2 (65%)
Mpumalanga	79 490	3 122 990	44.4 (93%)	44.6 (93%)	36.1 (75%)	36.7 (77%)	37.9 (79%)	38.3 (80%)	22.0 (46%)	22.1 (46%)	41.2 (86%)	41.5 (86%)	28.6 (60%)	28.6 (60%)
Limpopo	123 910	5 273 642	45.6 (95%)	44.1 (92%)	39.5 (82%)	35.9 (75%)	39.5 (82%)	36.2 (75%)	25.0 (52%)	18.7 (39%)	41.9 (87%)	40.2 (84%)	30.0 (63%)	26.0 (54%)
Free State	129 480	2 706 775	46.1 (96%)	44.6 (93%)	40.5 (84%)	36.3 (76%)	40.9 (85%)	38.3 (80%)	27.6 (58%)	21.9 (46%)	42.7 (89%)	41.5 (86%)	32.0 (67%)	29.0 (60%)
Kwazulu-Natal	92 100	9 426 017	41.8 (87%)	40.5 (84%)	30.1 (63%)	28.2 (59%)	33.9 (71%)	33.1 (69%)	16.2 (34%)	14.8 (31%)	39.9 (83%)	40.5 (84%)	25.9 (54%)	26.6 (55%)
North West	116 320	3 669 349	45.8 (95%)	44.4 (93%)	39.7 (83%)	36.4 (76%)	39.8 (83%)	36.6 (76%)	25.5 (53%)	19.4 (41%)	42.0 (87%)	40.1 (83%)	30.2 (63%)	26.5 (55%)
Eastern Cape	169 580	6 436 763	43.9 (91%)	41.9 (87%)	35.1 (73%)	30.1 (63%)	36.3 (76%)	33.9 (71%)	21.5 (45%)	16.2 (34%)	40.4 (84%)	39.9 (83%)	28.4 (59%)	25.8 (54%)
Western Cape	129 370	4 524 335	45.5 (95%)	31.0 (65%)	40.0 (83%)	13.7 (29%)	39.7 (83%)	24.9 (52%)	26.6 (55%)	7.0 (15%)	41.7 (87%)	40.0 (83%)	30.3 (63%)	26.7 (56%)
Northern Cape	361 830	822 727	47.7 (99%)	45.9 (96%)	45.1 (94%)	40.0 (83%)	44.7 (93%)	42.6 (89%)	37.2 (78%)	31.6 (66%)	45.1 (94%)	44.5 (93%)	38.0 (79%)	36.3 (76%)
All provinces	1 219 090	44 819 778	45.6 (95%)	40.4 (84%)	39.6 (83%)	28.5 (59%)	40.2 (84%)	33.7 (70%)	27.7 (58%)	15.8 (33%)	42.5 (89%)	40.9 (85%)	32.0 (67%)	27.8 (58%)

Table 6.26: Summary of UHF SO results, central advantage area excluded

			t_A				t_{DU}				t_D			
Province	Area (km^2)	Population	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
Gauteng	17 010	8 837 178	41.0 (85%)	36.6 (76%)	29.1 (61%)	20.9 (44%)	35.3 (74%)	32.0 (67%)	17.2 (36%)	12.5 (26%)	41.8 (87%)	42.5 (89%)	30.2 (63%)	31.2 (65%)
Mpumalanga	79 490	3 122 990	44.4 (93%)	44.6 (93%)	36.1 (75%)	36.7 (77%)	37.9 (79%)	38.3 (80%)	22.0 (46%)	22.1 (46%)	41.2 (86%)	41.5 (86%)	28.6 (60%)	28.6 (60%)
Limpopo	123 910	5 273 642	45.6 (95%)	44.1 (92%)	39.5 (82%)	35.9 (75%)	39.5 (82%)	36.2 (75%)	25.0 (52%)	18.7 (39%)	41.9 (87%)	40.2 (84%)	30.0 (63%)	26.0 (54%)
Free State	129 480	2 706 775	46.1 (96%)	44.6 (93%)	40.5 (84%)	36.3 (76%)	40.9 (85%)	38.3 (80%)	27.6 (58%)	21.9 (46%)	42.7 (89%)	41.5 (86%)	32.0 (67%)	29.0 (60%)
Kwazulu-Natal	92 100	9 426 017	41.8 (87%)	40.5 (84%)	30.1 (63%)	28.2 (59%)	33.9 (71%)	33.1 (69%)	16.2 (34%)	14.8 (31%)	39.9 (83%)	40.5 (84%)	25.9 (54%)	26.6 (55%)
North West	116 320	3 669 349	45.8 (95%)	44.4 (93%)	39.7 (83%)	36.4 (76%)	39.8 (83%)	36.6 (76%)	25.5 (53%)	19.4 (41%)	42.0 (87%)	40.1 (83%)	30.2 (63%)	26.5 (55%)
Eastern Cape	169 580	6 436 763	43.9 (91%)	41.9 (87%)	35.1 (73%)	30.1 (63%)	36.3 (76%)	33.9 (71%)	21.5 (45%)	16.2 (34%)	40.4 (84%)	39.9 (83%)	28.4 (59%)	25.8 (54%)
Western Cape*	129 370	4 524 335	45.5 (95%)	31.0 (65%)	40.0 (83%)	13.7 (29%)	39.7 (83%)	24.9 (52%)	26.5 (55%)	7.0 (15%)	41.7 (87%)	40.0 (83%)	30.2 (63%)	26.7 (56%)
Northern Cape*	361 830	822 727	47.7 (99%)	45.9 (96%)	45.1 (94%)	40.0 (83%)	44.2 (92%)	42.5 (89%)	35.9 (75%)	31.4 (65%)	44.5 (93%)	44.4 (93%)	36.6 (76%)	36.1 (75%)
All provinces*	1 219 090	44 819 778	45.4 (95%)	40.4 (84%)	39.1 (82%)	28.5 (59%)	39.7 (83%)	33.7 (70%)	26.4 (55%)	15.8 (33%)	42.1 (88%)	40.9 (85%)	31.1 (65%)	27.8 (58%)

6.5.12 Analysis remarks

The preceding section quantified the amount of available SO in the UHF band of South Africa on provincial and national level. Recall that the results presented in section 6.5.1 to section 6.5.10 are applicable for time t_A, t_{DU} and t_D.

In particular the following remarks can be made about the UHF SO results:

- The provincial and national results for SO indicate significant amounts of available spectrum. The results presented on national level highlight that there is a significant amount of available channels at 100% of the locations for all three temporal periods. The same can be said about the amount of channels available to 100% of the population.
- It can be seen from the provincial and national results that not all SOs will be equally useful for the same purpose. In many instances SO are available by area, but not by population or vice versa.
- The results are restricted to UHF channel 21-68, since the digital dividend has, at the time of writing, not been released yet.
- The SO results based on the co-channel availability criterion suggest that there are enough SOs during the dual illumination period on a national basis to accommodate the spectrum required for IMT 790, i.e. the digital dividend 1. Section 6.5.10 showed that more than nine channels (72 MHz) are available for 100% of the population and locations. IMT 790 requires 72 MHz contiguous spectrum, of which 64 MHz (eight channels) is currently allocated to the UHF terrestrial TV

(channel 61-68). These channels are however not necessarily contiguous at time t_{DU} for 100% of locations and therefore the digital dividend cannot be released as of yet. Furthermore, the digital dividend will become exploitable only come 17 June 2015 [4].

- The results for time t_D are very optimistic in the sense that it is assumed in the analysis for time t_D that both high and low power analogue transmitters will be switched off and only the DTT and mobile DTT entries in the PU data structure will be active. In reality, only the country's high power analogue sites will need to be switched off to fulfil the mandate of the GE-06 agreement. It is probable that, where required, rural communities will still continue to be serviced by low power, self-help stations for the foreseeable future. At the time of writing, and to the best knowledge of the author, information about which of these stations will remain in use is not available.

- The general trend is observed that the SO after analogue switch-off (t_D) is less than the SO available before the start of the dual illumination period (t_A).

- The analysis parameters chosen and motivated in section 6.3 should be taken into account when evaluating the SO results presented. It is possible that more SOs can be recovered if the protection criteria of the PUs are less stringent.

Taking the above remarks into account, it can be concluded that the UHF band shows significant availability of SOs under the co-channel and adjacent channel availability criteria.

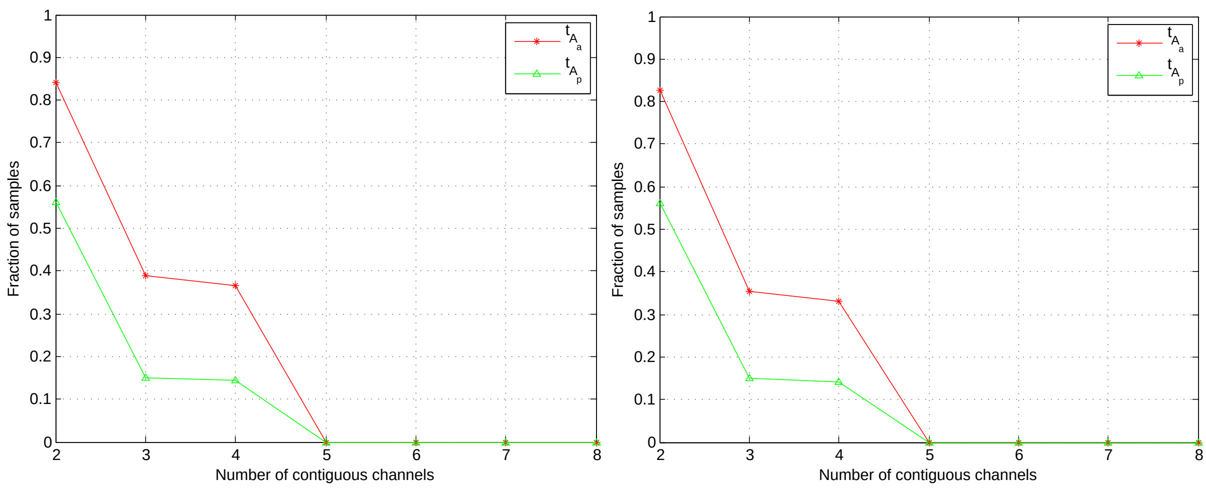
6.6 Probability of finding contiguous SO

Attention is now shifted to the determination of the probability of finding contiguous SO. The resulting probabilities are weighted by area and population, as per previous results. The co-channel availability criterion is used to determine the channels available as SOs. In section 5.2.1 it was noted that the channel bandwidth is 8 MHz. Hence two contiguous channels indicate 16 MHz of contiguous spectrum and so forth.

From the above construct, the fraction of the population and locations that has at least one occurrence of a contiguous channel of a specified length available can be derived. The results for the probabilities of finding contiguous channels are now separately presented for the VHF and UHF band below.

6.6.1 VHF

Figures 6.22a and 6.22b report the fraction of the population and the fraction of locations that have at least one occurrence of a contiguous channel, of a length as given by the x-axis (number of contiguous channels). The fractions are reported, excluding the SKA core and central advantage area from the analysis region respectively for figures 6.22a and 6.22b.



(a) Core area excluded (b) Central area excluded

Figure 6.22: VHF band: Contiguous SO for South Africa

Recall from section 6.4.1 that for the VHF band, $t_A = t_{DU}$ and therefore only t_A is discussed. Also recall that for t_D, the entire VHF band is vacant. For clarity of representation, only the results for t_A are shown in the figure. The fraction weighted by area is denoted by t_{A_a} and the fraction weighted by population is denoted by t_{A_p}.

Figure 6.22a indicates that at least one occurrence of two contiguous channels (16 MHz) are available to 56% of the population and 84% of the locations. At least one occurrence of three contiguous channels (24 MHz) is available to 15% of the population and 39% of the locations.

Figure 6.22b indicates for the central advantage area exclusion that at least one occurrence of two contiguous channels (16 MHz) are available to 56% of the population and 83% of the locations. At least one occurrence of three contiguous channels (24 MHz) are available to 15% of the population and 35% of the locations. As in the previous analyses, the central advantage area exclusion is seen to influence the SO by weighted area more than the SO weighted by population.

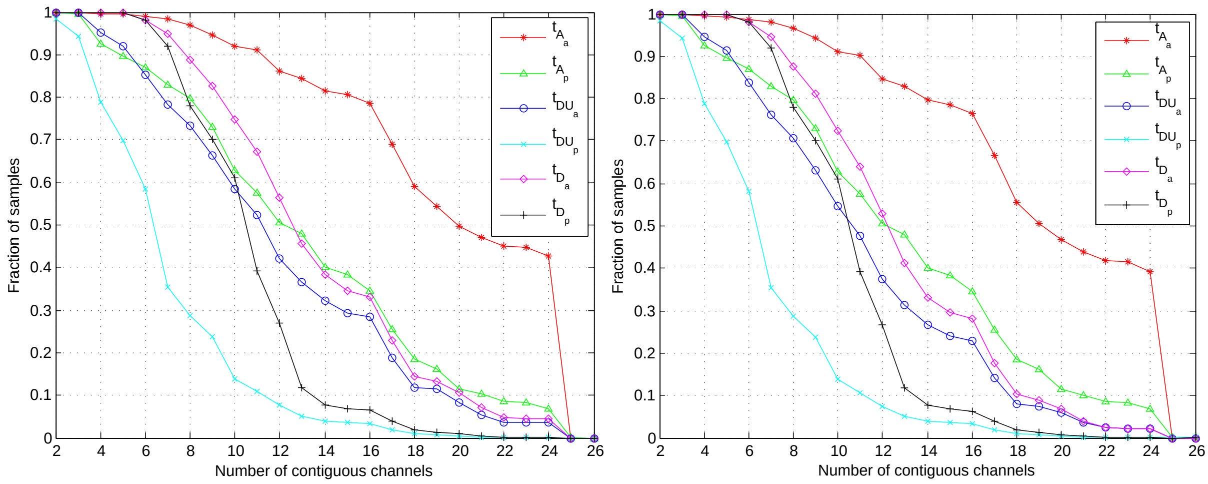
The high utilisation of the VHF band is also evident from relatively low percentage of sampled points that have contiguous channels.

6.6.2 UHF

Figures 6.23a and 6.23b report the fraction of the population and the fraction of locations that have at least one occurrence of a contiguous channel, of a length as given by the x-axis (number of contiguous channels). The fractions are reported, excluding the SKA core and central advantage area from the analysis region respectively for figures 6.23a and 6.23b. The fractions for the three temporal scenarios are shown, wherein each instance the sub-subscript a refers to the fraction weighted by area, and sub-subscript p refers to the fraction weighted by population.

Figure 6.23a indicates for the time t_A that at least one occurrence of five contiguous channels (40 MHz) are available to 90% of the population and 99.4% of locations. At least one occurrence of 11 contiguous channels (88 MHz) is available at 91% of the locations.

For time t_{DU}, the number of contiguous channels drops to five contiguous channels (40 MHz) at 92% of the locations and to 70% of the population. Time t_D indicates an increase to eight contiguous channels (64 MHz) at 89% of the locations whilst seven contiguous channels (56 MHz) are available to 92% of the population.



(a) Core area excluded (b) Central area excluded

Figure 6.23: UHF band: Contiguous SO for South Africa

Figure 6.23b indicates for the central advantage area exclusion that the absolute results for contiguous availability weighted by population stays the same as reported for the core advantage area exclusion above. The location statistics are slightly lower for the central area exclusion. For time t_A at least one occurrence of five contiguous channels are available at 99.4% of locations. For time t_{DU}, the number of contiguous channels drops to five contiguous channels at 91% of the locations. Time t_D indicates an increase to eight contiguous channels at 88% of the locations.

6.6.3 Contiguous SO analysis considerations

From the results in the preceding sections, it can be concluded that significant contiguous SO exists in the UHF and VHF bands. The UHF band in particular was shown to have contiguous channels available with high population and location probability. It is important to interpret the abovementioned results correctly, however. The contiguous SO analysis focused on calculating the fraction of locations and population that will have at least one occurrence of said contiguous channels available. The results therefore do not imply that the contiguous channels are located at the same channel numbers. The geographical extent over which a specific contiguous channel block is available are therefore not quantified by the results. The probability of such a contiguous channel occurring, however, is quantified. Note that the details of the specific contiguous channel blocks are available as output from the system model developed in this thesis.

6.7 Comparison of SO to related work

In this section the SO available in South Africa is compared to related work performed for the quantification of SO in Europe and the USA. The related work discussed in section 2.7 indicated that an SO study for 11 European countries for the UHF band has been done in [10]. Furthermore, the seminal work in this research field was done to quantify SO in the USA [1].

The European study focused on the SO in the UHF band between 470 MHz - 790 MHz (Channel 21-60). The study is done for the channels mentioned because all of the European countries in the study have already completed analogue switch-off in compliance with GE-06 [38]. In many European administrations, channels 61-69 has already been cleared to be re-purposed for IMT 790.

The American study was released in January 2009 and focused on SO in the VHF and UHF bands, available after the analogue switch-off date of June 12, 2009.

6.7.1 Analysis parameters

The analysis parameters as defined in section 6.3 are used to derive the results for this section, with the exception of the erosion margin, the channels evaluated, the adjacent channel protection criteria and the temporal scenarios compared. These parameters are adjusted to allow for direct comparison with the related work.

The erosion margin, ψ, is set at 1 dB for comparison with the European and American studies. The channels considered for comparison with the European study is UHF terrestrial TV channels given by $c = \{21, 22, 23, .., 59, 60\}$, which corresponds to 470 MHz - 790 MHz.

The channels considered for comparison with the American study are the UHF and VHF terrestrial TV frequency channels as defined in section 6.1. Section 2.2.1 pointed out that the USA terrestrial TV channels have a channel bandwidth of 6 MHz. Due to this, the channel numbers and frequency ranges for the corresponding VHF and UHF bands are different than those for South Africa. It is therefore not correct to directly compare the mean values of this study to the South African results. However, the number of available channels, expressed as a fraction of the total number of TV channels in the respective band, can be compared.

For the American study, the authors specified that interference in the the adjacent channels can be 27 dB higher than in the co-channel. This is incorporated into the analysis by rewriting equation 5.5 as follows:

$$E'_{protect} = E_{min_x} + \psi + 27 \tag{6.1}$$

where $E'_{protect}$ is the field strength at the protected contour of the adjacent channel, E_{min_x} is the minimum electrical field strength for the relevant service to be protected with $x = a/f/p$ and ψ is the allowable erosion margin.

The adjacent channel availability criterion can then be evaluated by substituting equation 6.1 into equation 5.7.

The temporal scenario compared with the European and American study is time t_{DU}, as this represents the closest to the current (time of writing) temporal situation in South Africa.

6.7.2 Comparison to SO in Europe

Table 6.27 compares the mean SO weighted by area and population of South Africa with the parameters obtained from the study performed for Europe [10]. The South African results shown are for time t_{DU}, excluding the SKA core astronomy advantage area from the analysis region.

Table 6.27: SO comparison between South Africa and Europe [10] for channel 21-60

Country	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
South Africa	33.2 (83%)	27.8 (70%)	22.1 (55%)	12.5 (31%)
Austria	21.1 (53%)	22.0 (55%)	7.3 (18%)	8.0 (20%)
Belgium	25.6 (64%)	25.2 (63%)	11.1 (28%)	10.5 (26%)
Czech Republic	13.4 (34%)	14.1 (35%)	1.9 (5%)	1.9 (5%)
Denmark	24.4 (61%)	24.1 (60%)	9.7 (24%)	8.7 (22%)
Germany	19.2 (48%)	17.7 (44%)	5.7 (14%)	4.1 (10%)
The Netherlands	23.7 (59%)	23.7 (59%)	9.7 (24%)	9.7 (24 %)
Luxembourg	21.5 (54%)	19.8 (50%)	5.6 (14%)	4.1 (10%)
Slovakia	26.1 (65%)	25.8 (65%)	13.0 (33%)	12.6 (32%)
Sweden	25.6 (64%)	21.4 (54%)	12.4 (35%)	7.5 (19%)
Switzerland	25.3 (63%)	-	12.7 (32%)	-
United Kingdom	23.1 (58%)	20.4 (51%)	13.2 (33%)	10.2 (26%)
Continental Europe	22.5 (56%)	19.8 (49%)	9.8 (25%)	7.1 (18%)

These results are directly comparable due to similar spatial resolutions being used for performing the propagation predictions and analysis. The European study was performed on a Lambert Azimuthal Equal-Area projected analysis surface with a square grid spacing of 2 km [10].

Section 3.6.1 noted that all computations for the analysis in this thesis are done directly in the geographical coordinate system. Section 6.3 also noted that the analysis was done for a grid spacing of 60 arc-seconds, which corresponds to a quadrangle of approximately 1.85 km $\times$ 1.85 km at the equator.

Inspection of table 6.27 indicates that South Africa has the most SOs available in terms of all the evaluated metrics. Comparison with the average SO available in continental Europe shows that South Africa has on average:

- 10.7 more channels weighted by area and eight more channels weighted by population available for the co-channel availability criterion.
- 12.3 more channels weighted by area and 5.4 more channels weighted by population for the adjacent channel availability criterion

It can be concluded that South Africa has significantly more SOs available than Europe, even though South Africa is still in the dual illumination period, identified by time t_{DU}. Additional SO will become available after analogue switch-off.

6.7.3 Comparison to SO in the USA

Table 6.28 provides the SO weighted by area and population, for the co-channel and adjacent channel availability criteria. The results shown are obtained by using the modified adjacent channel protected region ($E'_{protect}$) as discussed in section 6.7.1. The results exclude the core astronomy advantage area from the analysis region. The channels considered for the VHF band, are channels 4-11 and 13 whilst for the UHF band, channels 21-68 are considered.

Table 6.28: SO in South Africa, availability criteria as defined in section 6.7.1

Band & Time	$\bar{s}_a$	$\bar{s}_p$	$\bar{s}'_a$	$\bar{s}'_p$
VHF: t_{DU}	7.0 (78%)	5.1 (57%)	4.3 (47%)	2.4 (27%)
UHF: t_{DU}	40.6 (85%)	34.3 (71%)	36.6 (76%)	27.9 (58%)

Table 6.29 compares the mean SO weighted by area and population for South Africa with the parameters obtained from the study performed for the USA [1]. The SO available is expressed as a fraction of the total number of VHF and UHF TV channels in the band. The results for the USA are taken from row 2 of table II for comparison [1]. The fractional values for the USA for VHF are computed by aggregating the low VHF and high VHF values and then computing the fraction. In a similar manner the fractional values for low UHF and high UHF are aggregated to compute the fractional value for UHF.

Table 6.29: SO comparison between South Africa and the USA [1]

	VHF				UHF			
Country	$\overline{s}_a$	$\overline{s}_p$	$\overline{s}_a^{'}$	$\overline{s}_p^{'}$	$\overline{s}_a$	$\overline{s}_p$	$\overline{s}_a^{'}$	$\overline{s}_p^{'}$
South Africa	78%	57%	47%	27%	85%	71%	76%	58%
USA	73%	63%	50%	35%	79%	63%	58%	37%

Inspection of table 6.29 indicates that for the VHF band under the co-channel criterion, South Africa has more SOs available by area than the USA, while the USA has more SOs available by population. For the VHF adjacent channel criterion, the USA is seen to have more SOs available than South Africa by area and population. This confirms that the VHF band is heavily used in South Africa.

For the UHF band and the both availability criteria, South Africa is seen to have more SOs available than the USA. Note that the results for South Africa are for time t_{DU}, and additional SOs will become available after analogue switch-off.

6.8 SO maps

In order to better visualise the SO in South Africa, a map of the number of available channels at each sampled grid cell location is constructed for the co-channel and adjacent channel availability criterion. Note that the number of channels visualised for each grid cell is the unweighted number of available channels, s_i, as determined using equation 5.8. The maps are projected using the Albers Equal Area Projection to minimise areal distortion, using standard parallels 24° S and 32° S and origin 27 ° E, 0 ° S as recommended in [118]. The core astronomy advantage area is excluded from the SO map, as are the neighbouring countries of Lesotho and Swaziland. The central astronomy advantage area is overlaid on the map together with the provincial border lines.

The number of available channels in the VHF band for time t_A and time t_{DU}, is visualised in figure 6.24a for the co-channel availability criterion and in figure 6.25b for the adjacent channel availability criterion. The SO map for time t_D is omitted, as it was shown that the VHF band is completely vacant after analogue switch-off in section 6.4.1.

The number of available channels in the UHF band for time t_A, before the start of the dual illumination period, is visualised in figure 6.25a for the co-channel availability criterion and in figure 6.25b for the adjacent channel availability criterion. The colour-maps for the UHF SO maps are on the scale to enable visual comparison between the maps for the different temporal scenarios.

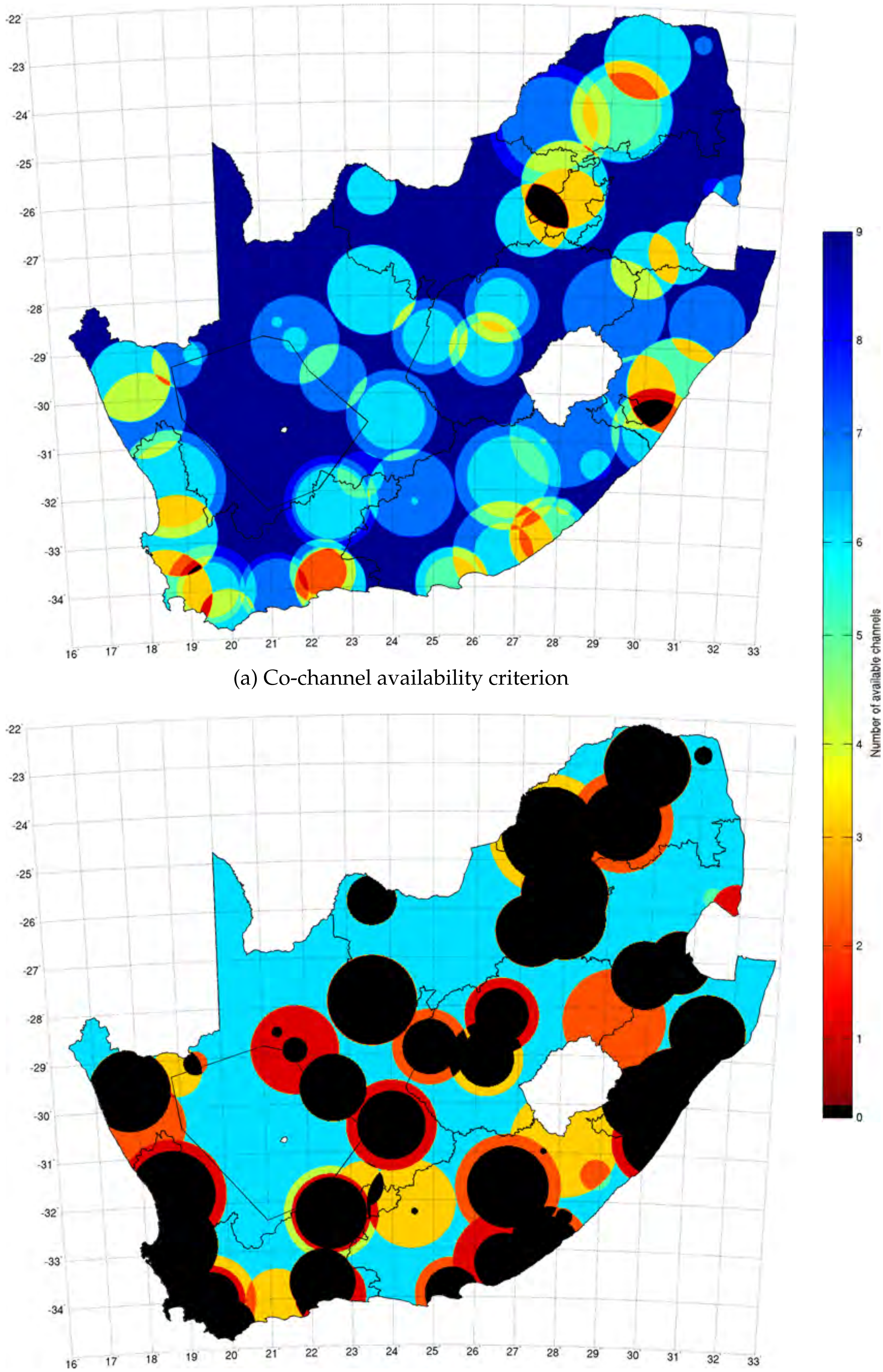
The number of available channels in the UHF band for time t_{DU}, depicting full dual illumination, is visualised in figure 6.26a for the co-channel availability criterion and in figure 6.26b for the adjacent channel availability criterion.

Finally, the number of available channels in the UHF band for time t_D, after analogue switch-off, is visualised in figure 6.27a for the co-channel availability criterion and in figure 6.27b for the adjacent channel availability criterion.

In the abovementioned figures, it is observed that the contours are in many instances close to perfect circles. The reason for this is two-fold. Firstly, recall that the underlying ITU-R P.1546 propagation model is a point to area prediction method and not a path specific propagation model. Propagation predictions therefore tend to change gradually with location. Secondly, the motivation for setting the effective height parameter equal to the maximum effective height, h_{max}, was detailed in section 6.3. It was noted that using h_{max} as the effective height parameter results in overprediction of the field strength coverage area of the PU on the radials for which $h_{eff} < h_{max}$ [4]. The circle shaped contours are due to using h_{max} as the effective height parameter for all radials.

6.9 Summary

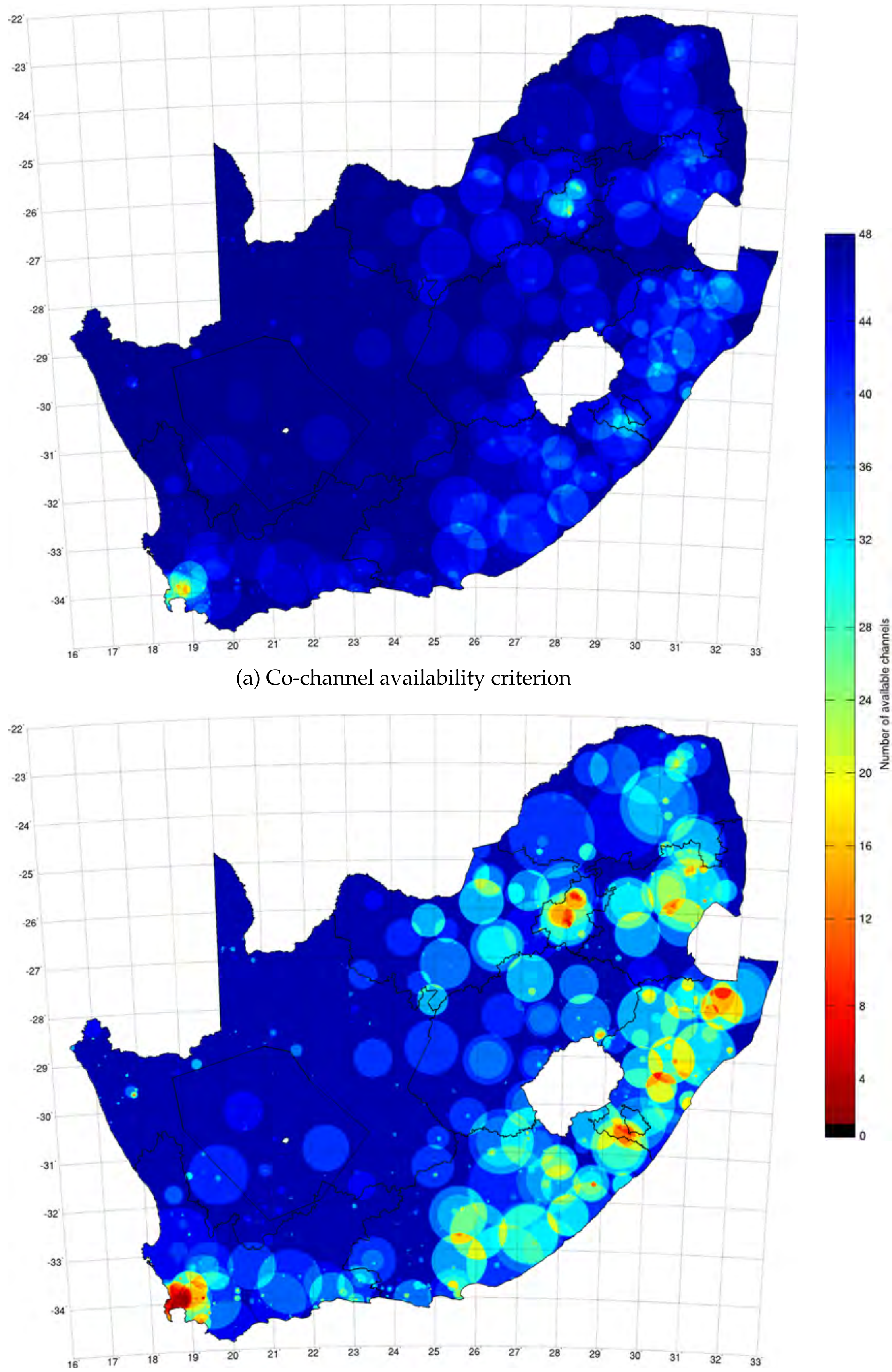
In this chapter the SOs in the VHF and UHF terrestrial TV frequency bands have been analysed. The amount of SO available has been quantified on provincial and national levels. The probability to find contiguous channels of a certain length was quantified. The SO for South Africa was compared to the SO available in Europe and the USA. Finally, maps visualising the SO for South Africa were constructed to aid in understanding the SOs in a qualitative manner.



(a) Co-channel availability criterion

(b) Adjacent channel availability criterion

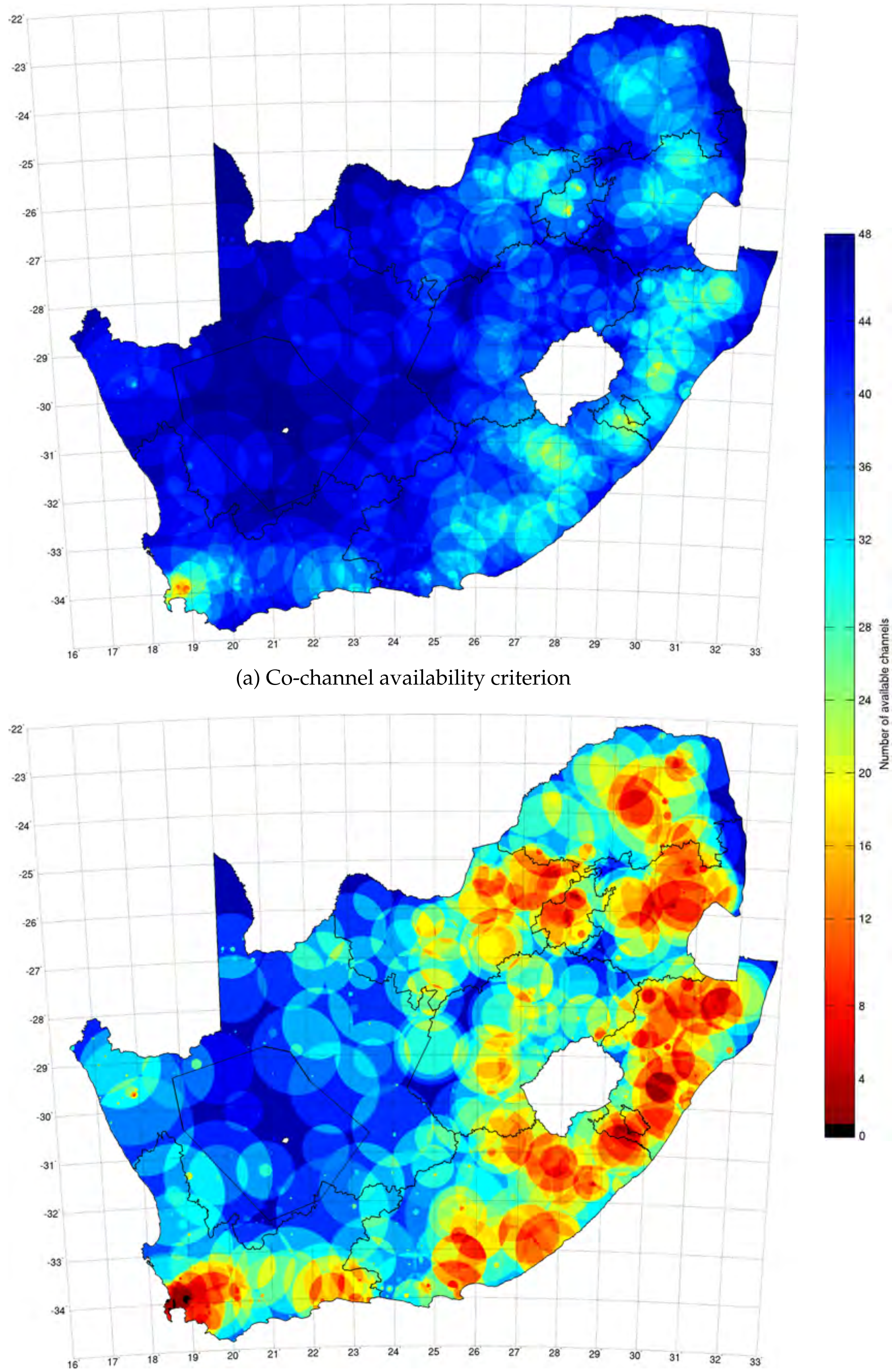
Figure 6.24: VHF SO map for time t_A and t_{DU}



(a) Co-channel availability criterion

(b) Adjacent channel availability criterion

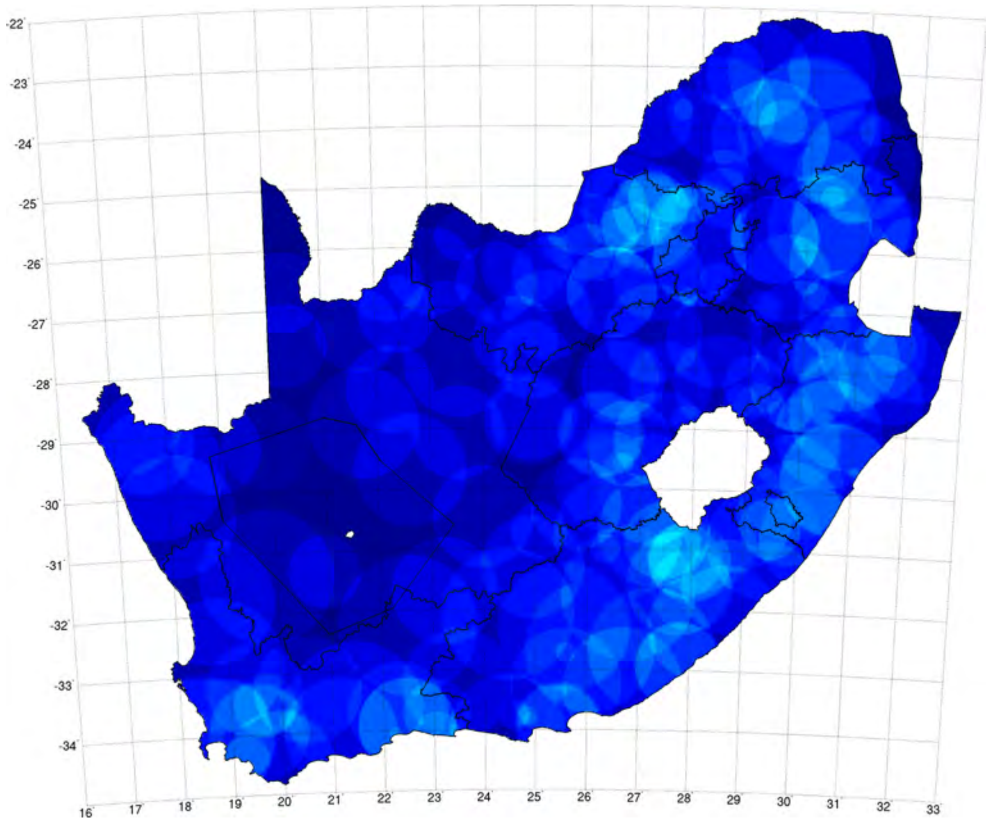
Figure 6.25: UHF SO map for time t_A



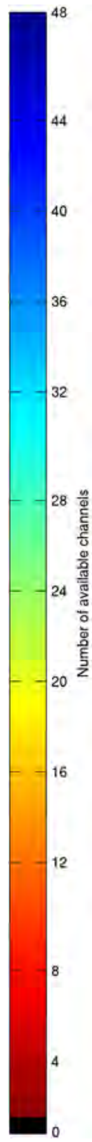
(a) Co-channel availability criterion

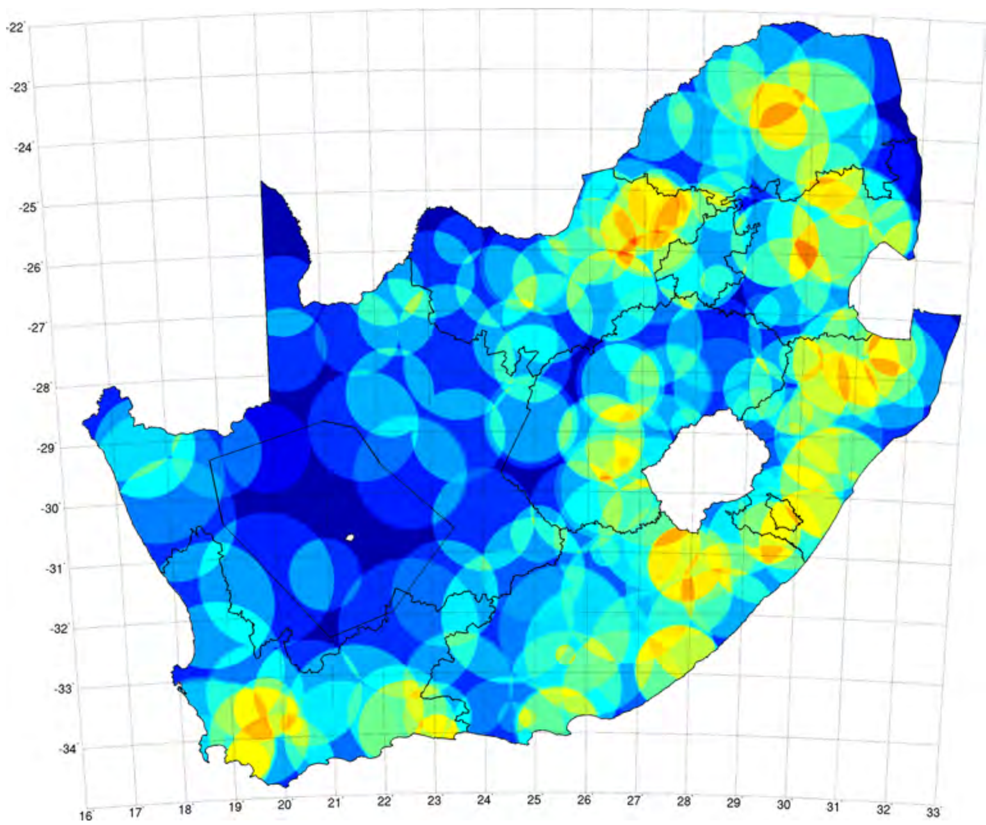
(b) Adjacent channel availability criterion

Figure 6.26: UHF SO map for time t_{DU}



(a) Co-channel availability criterion





(b) Adjacent channel availability criterion

Figure 6.27: UHF SO map for time t_D

Chapter 7

Conclusions and recommendations

In this chapter the context and relevance of the research work conducted is reflected upon by revisiting the original research goal. A summary of the work done is provided, where after the research contributions made are re-emphasised. Finally, recommendations for future improvements and research are presented.

7.1 Summary of work done

The focus of this thesis was on the quantification of SO availability in the terrestrial TV frequency bands of South Africa. The argument and context for a unique contribution was raised in chapter 1. The case for the original contribution was motivated by the investigation into related research work in chapter 2.

A system model that is able to produce the required geo-referenced field strength coverage maps was first conceptualised and then implemented. The system model was described in chapter 3. The ITU-R P.1546 propagation model was incorporated into the model and implemented from the ground up. Similarly, the extraction routines for the elevation database were developed, taking earth curvature into account. Implementation choices were motivated and documented.

The system model was verified and validated in chapter 4. Operational validation was performed by comparing the final outputs of the developed system model with the results of a published SO prediction study for the Netherlands. The system model was shown to be fit for the intended purpose.

The method of analysis was thoroughly discussed in chapter 5. The TV transmitter database as used in the study required extensive processing to obtain a good dataset. The final dataset used is provided in appendices A, B and C for reference. To model the SO available, the entries in the PU transmitter database were accepted as the ground truth.

Furthermore, the protection requirements and availability criteria for the PUs were discussed in detail. Some metrics to analyse and quantify the SO available were developed. To this end, a grid approximation of the population count and population density of South Africa was derived, as no relevant grid raster with the required data could be found in the public domain.

The analysis results of the SO available in the terrestrial TV frequency bands were presented in chapter 6. SOs in the VHF and UHF bands were respectively analysed for time t_A, t_{DU} and t_D. The SO available was determined under the co-channel availability criterion as well as the adjacent channel availability criterion. SO was quantified on provincial and on national level by expressing SO in terms of the number of available channels. The probability of finding a certain number of vacant channels was quantified, weighting the results by area and by population count.

Consideration was also given to the effects that the astronomy advantage areas of the SKA have on SO availability. The probability of finding contiguous channels in the VHF and UHF bands was also quantified. A comparative study, comparing the SO for South Africa with related work in Europe and the USA, was also performed. Finally, maps that visualise the available SO were constructed for all three temporal scenarios.

7.2 Revisiting the research goal

In section 1.2 it was stated that the research undertaken endeavours to provide a quantitative estimate of the SO available in the terrestrial TV frequency bands of South Africa, on provincial and national level, for the following three discrete time periods:

- The SO before the start of the dual illumination period, i.e. the analogue only, denoted by t_A.
- The SO available during the dual illumination period, denoted by t_{DU}.
- The SO available after analogue switch-off, i.e. the digital service only, denoted by t_D.

7.2.1 VHF

The analysis results for the channels in the VHF band (channels 4-11 & 13) highlighted that there is significant SO available under the co-channel availability criterion. The following can be stated for time t_A and time t_{DU}, considering the SO availability for South Africa and excluding the effect of the core astronomy advantage area: on average, 77% of the band is available when weighted by area and 56% of the band is available when weighted by population.

The SO available under the adjacent channel availability criterion is significantly less. This is due to the short length of only eight contiguous channels in the band. On average, 29% of the band is available when weighted by area and 13% of the band is available when weighted by population. Investigation into the contiguous nature of the SOs revealed that at least one occurrence of 16 MHz of contiguous spectrum is available to 56% of the population and at 83% of the locations.

It was also shown that after analogue switch-off (time t_D), the VHF band will be completely vacant, as no digital entries have been assigned to the band. However, section

6.4.12 noted that channels 9 and 10 are earmarked for the DAB service in future.

7.2.2 UHF

The analysis results for the channels in the UHF band suggest that there is significant SO currently available, and even more after analogue switch-off. The SO available in South Africa for channels 21-68, excluding the effect of the core astronomy advantage area, is briefly re-visited for the three temporal scenarios below.

Analogue only (t_A)

For time t_A, it was shown that on average, 95% of the band is available when weighted by area and 84% of the band is available when weighted by population for the co-channel criterion. At least 13 channels are available to 100% of the population and at least 15 channels are available at 100% of the locations. For the adjacent channel criterion, on average, 83% of the band is available by area and 59% of the band is available by population. It was also shown that at least one occurrence of 40 MHz of contiguous spectrum is available at 99.4% of the locations and to 90% of the population.

Dual illumination (t_{DU})

For time t_{DU}, it was shown that, on average, 84% of the band is available when weighted by area and 70% of the band is available when weighted by population for the co-channel criterion. At least ten channels are available to 100% of the population and at least 12 channels are available at 100% of the locations. For the adjacent channel criterion, on average, 58% of the band is available by area and 33% of the band is available by population. It was also shown that at least one occurrence of 40 MHz of contiguous spectrum is available at 92% of the locations and to 70% of the population.

Analogue switch-off (t_D)

For time t_D, it was shown that, on average, 89% of the band is available when weighted by area and 85% of the band is available when weighted by population for the co-channel criterion. At least 31 channels are available to 100% of the population and locations. For the adjacent channel criterion, on average, 67% of the band is available by area and 58% of the band is available by population. At least ten channels are available to 100% of the population and locations. It was also shown that at least one occurrence of 56 MHz of contiguous spectrum is available at 95% of the locations and to 92% of the population.

7.3 Research contributions made

In section 1.3 it was stated that the unique contribution made in this study is through the critical analysis of existing information in a new way. New facts, information and insight are obtained by the critical analyses of existing information available in the form of the Final Terrestrial Broadcasting Plan of 2008 [5] and the ICASA TV transmitter database.

The case for a unique contribution was motivated in chapter 2. It was shown that there is no comparable work currently available for South Africa. Related work was shown to be only from other administrations in the international community.

The work presented is therefore the first of its kind for the South African environment and uncovers new knowledge regarding Spectral Opportunity (SO) in South Africa. The three main contributions claimed to be made in this thesis are:

1. A geographically referenced field strength coverage map for every terrestrial TV channel in South Africa is produced.
2. From the field strength coverage map, a geographically referenced SO map for

every terrestrial TV channel in South Africa is produced.

3. A quantification of the available SO on provincial and national level weighted respectively by land area and population density is presented.

Contribution 1: To the best of the author's knowledge, the field strength coverage maps for the terrestrial TV service are not available in the public domain. These field strength coverage maps needed to be constructed first before the SO could be analysed. Chapter 3 detailed the design choices made to implement this step. The ITU-R P.1546 propagation model was implemented from the ground up to ensure reliable, accurate and standards-compliant results. This was also done to ensure that every model parameter used is described in a transparent manner. Design decisions were motivated, and focused specifically on relevant choices for the South African context.

Contribution 2: The field strength coverage maps of contribution 1 were utilised in conjunction with the availability criteria adopted, to produce a geographically referenced SO map for every terrestrial TV channel in South Africa. The adopted availability criteria are in line with international best practice. The aggregated counts for the number of available channels at each location were visualised in section 6.8. The SO maps provide a qualitative view of the SO available.

Contribution 3: The analysis results set forth in chapter 6 quantified the SO available on provincial and national level, according to land area and population density. This contribution ties up with the core research goal of this study, which was revisited in section 7.2.

7.4 Recommendations for future work

The work presented lays the foundation for further studies on the utility of secondary access to TV white space in South Africa. To this end a few recommendations for improvement of the current work and opportunities for future work are presented.

The next logical step is to consider the secondary use case for the SOs that are available. Case studies for SUs need to be developed and investigated. These studies have to illustrate the utility that the exploitation of SOs yield. The white space capacity available also needs to be investigated from a Shannon information theoretic perspective, as well as a practically achievable SU network capacities. Pointers to such work can be found in [72].

The related work on the secondary use case for SOs focus primarily on the utility of the SOs in the UHF band. For South Africa it may however also be worth exploring the possibilities and scenarios for the utility of SOs in the VHF band, due to the vacancy of this band after dual illumination.

It was seen from comparison of the provincial SO results that not all SOs will be equally useful for the same purpose. In many instances SOs are available by area, but not by population and vica versa. Hence some spectrum may be better for other purposes such as machine-to-machine communications, than what it is for wireless broadband and end-user communication.

The debate of which approach South Africa will adopt to determine SOs has not yet been raised. Therefore it will also be of relevance to calculate the SO available in South Africa by means of the SE43 methodology [43] and weigh up the merits of each method.

The system model and post-processing routines developed through the course of this thesis can be utilised as the basis from which a fully fledged geolocation database solution can be developed. The system model, incorporating the implemented ITU-R P.1546 propagation model and the elevation extraction routines, is also of practical relevance in its own right to any activity involving network planning or propagation prediction.

The basis of a trustworthy geolocation database lies in the reliability and accuracy of the technical parameters with which the database is populated. In this study, the TV transmitter database that was derived from the data sources as detailed, were taken as the ground truth. South Africa is currently in a transition phase with the start of the dual illumination performance period (see section 2.2.3) imminent. The transition phase raises uncertainty about the validity of some of the technical parameters in the database. As the DTT network is deployed, some technical parameters will as a result also change as required. The two erratums to the Final Terrestrial Broadcasting Plan of 2008 that have already been published are testament to this [5], [111], [112].

Before secondary access can become a reality, a verified database of TV transmitter entries with technical parameters will need to be constructed. The verified entries will have to be validated with ground truth spectrum measurements at key sites. After this spectrum audit has been completed, the data should be disseminated in a transparent fashion. An example of how this has been implemented is the REBOOT initiative of the FCC [123]. DSA aims to improve the utilisation of the RF spectrum. However, utilisation can only be improved if it is known what the current utilisation by the incumbent is.

White space field trial networks are also an important factor on the roadmap towards spectrum reform and amendment of regulatory policy. It is vital that more network field trials are conducted in order to demonstrate to the incumbents and regulator that PUs and SUs can co-exist on a non-interfering basis. The white space trial network running in the greater Cape Town area, which was discussed in section 2.2.3, is the first field trial network in South Africa. At the time of writing, the trial network was operational. The network is used to provide 2.5 Mbps broadband internet service to ten schools within a 10 km radius from the base station sites. Graphs of traffic forwarded and performance metrics since the start of the trial are available on the trial network's website [124].

7.5 Closure

Worldwide administrations are under increasing pressure to keep up with demand for licensing more and more spectrum as the requirements for wireless data and communications continues to grow. DSA allows the utility of the spectrum to be raised, whether the spectrum is already licensed to an incumbent or service or is provisioned to be licensed in the near future. In the context of TV white space, DSA will continue to play an important role in maximising spectrum utility, whilst still protecting the interests of the incumbent.

South Africa has a strategic objective to provide broadband access to all citizens of South Africa through the Broadband Policy of South Africa [125]. Development of a knowledge economy through expansion of ICT infrastructure and the liberalisation of spectrum policy are also key agenda points in the National Development Plan for 2030 [126].

The number of SOs in the terrestrial TV frequency bands of South Africa is too vast to ignore. South Africa is positioned uniquely in time to pro-actively incorporate the technological enablers for secondary access to these frequency bands into regulatory policy. May the work presented encourage the debate towards more open and less restrictive spectrum regulations.

Bibliography

[1] M. Mishra and A. Sahai, "How much white space is there?" EECS Technical Report, Tech. Rep. EECS-2009-3, January 2009. [Online]. Available: http://www.eecs.berkeley.edu/Pubs/TechRpts/2009/EECS-2009-3.html

[2] M. Nekovee, T. Irnich, and J. Karlsson, "Worldwide trends in regulation of secondary access to white spaces using cognitive radio," *Wireless Communications, IEEE*, vol. 19, no. 4, pp. 32–40, 2012.

[3] A. Wyglinkski, M. Nekovee, and Y. Hou, Eds., *Cognitive Radio Communications and Networks: Principles and Practice*. Academic Press, 2010.

[4] "Final acts of the regional radiocommunication conference for planning of the digital terrestrial broadcasting service in parts of regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (RRC-06)," in *RRC-06*. ITU, 2006.

[5] "Final terrestrial broadcasting frequency plan, 2008," in *Government Gazette*, Republic of South Africa, 18 Nov 2009, no. 32728, notice 1538.

[6] "Consolidated spectrum audit monitoring report: 450-470 MHz," Electronic, Independant Communications Authority of South Africa (ICASA), May 2010. [Online]. Available: http://www.icasa.org.za

[7] "Consolidated spectrum audit monitoring report: 790-862 MHz," Electronic, Independant Communications Authority of South Africa (ICASA), Mar 2010. [Online]. Available: http://www.icasa.org.za

[8] *Minimum field strenghts for which protection maty be saught in planning an analogue terrestrial television service*, ITU-R Recommendation BT.417-5.

[9] *Planning criteria, including protection ratios, for digital terrestrial television services in the VHF/UHF bands*, ITU-R Recommendation BT.1368-9.

[10] J. van de Beek, J. Riihijarvi, A. Achtzehn, and P. Mahonen, "TV white space in Europe," *Mobile Computing, IEEE Transactions on*, vol. 11, no. 2, pp. 178–188, 2012.

[11] "Second report and order and memorandum opinion and order in the matter of unlicensed operation in the TV broadcast bands," in *Federal Communications Commision (FCC)*, USA, 23 Sep 2010, vol. 10-174, et docket 04-186.

[12] "Draft policy directions on exploiting the digital dividend," in *Government Gazette*, Republic of South Africa, 14 Dec 2011, no. 34848, notice 898.

[13] "Notice inviting comments regarding the 2nd draft frequency migration regulation and radio frequency migration plan," in *Government Gazette*, Republic of South Africa, 24 Dec. 2012, vol. 36031, notice 1064.

[14] M. Lazarus, "The great spectrum famine," *Spectrum, IEEE*, vol. 47, no. 10, pp. 26 –31, oct. 2010.

[15] M. Cave, C. Doyle, and W. Webb, *Essentials of Modern Spectrum Management*. Cambridge , UK : Cambridge University Press, 2007.

[16] "Hyperconnectivity and the approaching zettabyte era," White Paper, Cisco, Jun 2010. [Online]. Available: http://www.cisco.com/

[17] (2013, Jan) VNI mobile forecast highlights, 2011 - 2016. Cisco. [Online]. Available: http://www.cisco.com/web/solutions/sp/vni/vni_mobile_forecast_highlights/index.html

[18] L. Berlemann and S. Mangold, *Cognitive Radio and Dynamic Spectrum Access*. Chichester, West Sussex, UK : Wiley, 2009.

[19] L. E. Doyle, *Essentials of Cognitive Radio*. Cambridge, UK : Cambridge University Press, 2009.

[20] "IEEE standard definitions and concepts for dynamic spectrum access: Terminology relating to emerging wireless networks, system functionality, and spectrum management," *IEEE Std 1900.1-2008*, pp. c1 –48, 26 2008.

[21] Q. Zhao and B. Sadler, "A survey of dynamic spectrum access," *Signal Processing Magazine, IEEE*, vol. 24, no. 3, pp. 79 –89, May 2007.

[22] J. Mitola, "Cognitive radio for flexible mobile multimedia communications," in *Mobile Multimedia Communications, 1999. (MoMuC '99) 1999 IEEE International Workshop on*, 1999, pp. 3–10.

[23] J. Peha, "Sharing spectrum through spectrum policy reform and cognitive radio," *Proceedings of the IEEE*, vol. 97, no. 4, pp. 708–719, 2009.

[24] M. Nekovee, "A survey of cognitive radio access to TV white spaces," *Ultra Modern Telecommunications Workshops, 2009. ICUMT '09. International Conference on*, pp. 1 –8, Oct. 2009.

[25] M. Islam, C. Koh, S. Oh, X. Qing, Y. Lai, C. Wang, Y.-C. Liang, B. Toh, F. Chin, G. Tan, and W. Toh, "Spectrum survey in Singapore: Occupancy measurements and analyses," may. 2008, pp. 1 –7.

[26] M. Wellens, J. Wu, and P. Mahonen, "Evaluation of spectrum occupancy in indoor and outdoor scenario in the context of cognitive radio," aug. 2007, pp. 420 –427.

[27] *Spectrum occupancy measurement*, ITU-R Recommendation SM.1880.

[28] T. Dudda, T. Irnich, and J. Karlsson, "How much TV white space is there in Germany?" in *17th ITG-Fachtagung: Technologien und Andwendungen*, Osnabrck, Mai 2012.

[29] *IEEE Standard for Information Technology–Telecommunications and information exchange between systems Wireless Regional Area Networks (WRAN)–Specific requirements Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands*, IEEE Std. 802.22-2011, Jul. 2011.

[30] *Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz*, ITU-R Recommendation P.1546-4.

[31] "Final acts of the world radiocommunication conference (WRC-07)," in *WRC-07*. ITU, 2007.

[32] "Final acts of the world radiocommunication conference (WRC-12)," in *WRC-12*. ITU, 2012.

[33] "Technical considerations regarding harmonisation options for the digital dividend," electronic, CEPT, Report 24, July 2008. [Online]. Available: http://www.erodocdb.dk

[34] M. Nekovee, "Current trends in regulation of secondary access to TV white spaces using cognitive radio," in *Global Telecommunications Conference (GLOBECOM 2011), 2011 IEEE*, 2011, pp. 1–6.

[35] (2012, Nov) Spectrum dashboard. FCC. [Online]. Available: http://reboot.fcc.gov/spectrumdashboard/searchSpectrum.seam

[36] (2012, Dec) Electronic code of federal regulations, title 47, part 15, subpart h. U.S. Government Printing Office. [Online]. Available: http://www.ecfr.gov/

[37] FCC, *Connecting America: The National Broadband Plan*. Federal Communications Commision, 2010, ch. 5.

[38] (2013, Feb) Analogue switch-off dates. Digital Terrestrial Television Action Group (DigiTAG). [Online]. Available: http://www.digitag.org

[39] "The identification of common and minimal (least restrictive) technical conditions for 790 - 862 MHz for the digital dividend in the European

Union," electronic, CEPT, Report 30, Oct 2009. [Online]. Available: http://www.erodocdb.dk

[40] "Frequency (channelling) arrangements for the 790-862 MHz band," electronic, CEPT, Report 31, Oct 2009. [Online]. Available: http://www.erodocdb.dk

[41] H. Karimi, M. Fenton, G. Lapierre, and E. Fournier, "European harmonized technical conditions and band plans for broadband wireless access in the 790-862 MHz digital dividend spectrum," in *New Frontiers in Dynamic Spectrum, 2010 IEEE Symposium on*, 2010, pp. 1–9.

[42] H. Karimi, "Geolocation databases for white space devices in the UHF TV bands: Specification of maximum permitted emission levels," in *New Frontiers in Dynamic Spectrum, 2011 IEEE Symposium on*, 2011.

[43] "Technical and operational requirements for the possible operation of cognitive radio systems in the 'white spaces' of the frequency band 470-790 MHz," electronic, ECC, Report 159, Jan 2011. [Online]. Available: http://www.ecodocdb.dk

[44] "National radio frequency plan, 2010," in *Government Gazette*, Rebuplic of South Africa, 30 Jul 2010, vol. 541, no. 33409, notice 727.

[45] "Meeting with Department of Communications and Sentech on progress of digital migration," Select Committee on Labour and Public Enterprises, 15 Aug 2012. [Online]. Available: http://www.pmg.org.za/report/20120815-meeting-department-communications-and-sentech-progress-digital-migrat

[46] *Strategic Plan: 2011-2014*, Department: Communications, Republic of South Africa, 2011. [Online]. Available: http://www.doc.gov.za/

[47] "Digital migration regulations, 2012," in *Government Gazette*, Republic of South Africa, 14 Dec. 2012, vol. 3600, notice 1070.

[48] "Mobile television regulations, 2010." Republic of South Africa: Government Gazettte, 16 April 2010, vol. 33125, notice R. 318.

[49] M. Masonta, R. Makgothlo, and F. Mekuria, “Setting the scene for TV white space and dynamic spectrum access in South Africa,” in *IST-Africa Conference Proceedings*, 2012.

[50] (2013, Feb) The Cape Town TV white spaces trial. TENET (Tertiary Education and Research Network of South Africa). [Online]. Available: http://www.tenet.ac.za/about-us/the-cape-town-tv-white-spaces-trial

[51] “Astronomy geographic advantage act, 2007,” in *Government Gazette*, Rebuplic of South Africa, 17 Jun 2008, no. 31157, notice 666.

[52] “Astronomy geogrpahic advantage act, 2007 (21 / 2007): Withdrawal of notice number 82: Declaration of areas as astronomy advantage areas,” in *Government Gazette*, Rebuplic of South Africa, 19 Feb 2010, no. 32951, notice 115.

[53] “Declaration of areas to be core astronomy advantage areas in terms of the astronomy geographic advantage act, 2007,” in *Government Gazette*, Rebuplic of South Africa, 20 Aug 2010, no. 33462, notice 723.

[54] “Regulations to prohibit or restrict certain activities in core astronomy advantage areas in terms of the astronomy geographic advantage act, 2007,” in *Government Gazette*, Rebuplic of South Africa, 22 Jun 2012, no. 35450, notice R465.

[55] “Regulations on radio astronomy protection levels in astronomy advantage areas declared for the purposes of radio astronomy,” in *Government Gazette*, Republic of South Africa, 10 Feb 2012, no. 35007, notice R90.

[56] “Notice of intention to declare areas in terms of the astronomy geographic advantage act, 2007 (21/2007) to be astronomy advantage areas.” in *Government Gazette*, Republic of South Africa, 5 Feb 2009, no. 31855, notice 115.

[57] “Notice of intention to make regulations regarding the karoo radio astronomy advantage area for square kilometre array radio telescope,” in *Government Gazette*, Republic of South Africa, 5 Feb 2009, vol. 31855, notice 118.

[58] R. Chiang, G. Rowe, and K. Sowerby, "A quantitative analysis of spectral occupancy measurements for cognitive radio," apr. 2007, pp. 3016 –3020.

[59] M. A. McHenry, P. A. Tenhula, D. McCloskey, D. A. Roberson, and C. S. Hood, "Chicago spectrum occupancy measurements analysis and a long-term studies proposal," vol. 222, Boston, MA, United states, 2006.

[60] T. Taher, R. Bacchus, K. Zdunek, and D. Roberson, "Long-term spectral occupancy findings in Chicago," in *New Frontiers in Dynamic Spectrum, 2011 IEEE Symposium on*, 2011.

[61] G. Petrick, "Radio frequency interference measurements," *EngineerIT Magazine*, no. 8, pp. 32–36, aug. 2006.

[62] G. Patrick, "Radio spectrum occupancy in South Africa," *EngineerIT Magazine*, no. 9, pp. 26–30, sep. 2006.

[63] M. Masonta, D. Johnson, and M. Mzyece, "The white space opportunity in Southern Africa: Measurements with meraka cognitive radio platform," in *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, R. Popescu-Zeletin, K. Jonas, I. Rai, R. Glitho, and A. Villafiorita, Eds. Springer Berlin Heidelberg, 2012, vol. 92, pp. 64–73.

[64] A. Lysko, M. Masonta, D. Johnson, and H. Venter, "FSL based estimation of white space availability in UHF TV bands in Bergvliet, South Africa," in *Southern African Telcommunications and Network Access Conference (SATNAC)*, George, South Africa, Sep 2012.

[65] J. Mitola, "Cognitive radio architecture evolution," *Proceedings of the IEEE*, vol. 97, no. 4, pp. 626 –641, apr. 2009.

[66] R. Tandra, A. Sahai, and S. Mishra, "What is a spectrum hole and what does it take to recognize one?" *Proceedings of the IEEE*, vol. 97, no. 5, pp. 824–848, 2009.

[67] P. Marshall, *Quantitative analysis of Cognitive Radio and Network Performance*. Boston, M.A: Artech House, 2010.

[68] T. Yucek and H. Arslan, “A survey of spectrum sensing algorithms for cognitive radio applications,” *Communications Surveys & Tutorials, IEEE*, vol. 11, no. 1, pp. 116–130, 2009.

[69] D. Gurney, G. Buchwald, L. Ecklund, S. Kuffner, and J. Grosspietsch, “Geo-location database techniques for incumbent protection in the TV white space,” in *New Frontiers in Dynamic Spectrum Access Networks, 2008. DySPAN 2008. 3rd IEEE Symposium on*, 2008, pp. 1–9.

[70] R. Murty, R. Chandra, T. Moscibroda, and P. Bahl, “Senseless: A database-driven white spaces network,” *Mobile Computing, IEEE Transactions on*, vol. 11, no. 2, pp. 189–203, 2012.

[71] T. Dudda and T. Irnich, “Capacity of cellular networks deployed in TV white space,” in *New Frontiers in Dynamic Spectrum Access Networks, 2012 IEEE Symposium on*, 2012.

[72] K. Harrison, S. Mishra, and A. Sahai, “How much white-space capacity is there?” in *New Frontiers in Dynamic Spectrum, 2010 IEEE Symposium on*, 2010, pp. 1–10.

[73] M. Nekovee, “Quantifying the availability of TV white spaces for cognitive radio operation in the UK,” in *Communications Workshops, 2009. ICC Workshops 2009. IEEE International Conference on*, 2009, pp. 1–5.

[74] J. van de Beek, J. Riihijrvi, A. Achtzehn, and P. Mhnen, “UHF white space in Europe - a quantitative study into the potential of the 470790 MHz band,” in *New Frontiers in Dynamic Spectrum, 2011 IEEE Symposium on*, 2011.

[75] D. Makris, G. Gardikis, and A. Kourtis, “Quantifying TV white space capacity: A geolocation-based approach,” *Communications Magazine, IEEE*, vol. 50, no. 9, pp. 145–152, 2012.

[76] M. Barbiroli, C. Caciofi, D. Guiducci, and V. Petrini, “White spaces potentially available in Italian scenarios based on the geo-location database approach,” in *New Frontiers in Dynamic Spectrum Access Networks, 2012 IEEE Symposium on*, 2012.

[77] M. Fitch, M. Nekovee, S. Kawade, K. Briggs, and R. MacKenzie, "Wireless service provision in TV white space with cognitive radio technology: A telecom operator's perspective and experience," *Communications Magazine, IEEE*, vol. 49, no. 3, pp. 64–73, 2011.

[78] R. Jantti, J. Kerttula, K. Koufos, and K. Ruttik, "Aggregate interference with FCC and ECC white space usage rules: Case study in Finland," in *New Frontiers in Dynamic Spectrum Access Networks (DySPAN), 2011 IEEE Symposium on*, 2011, pp. 599–602.

[79] N. Dumont, R. Watson, and S. Pennock, "Use of the parabolic equation propagation model to predict TV white space availability," in *Antennas and Propagation Conference (LAPC), 2010 Loughborough*, 2010, pp. 353–356.

[80] N. Dumont, R. Watson, and S. Pennock, "Fine resolution simulation of TV white space availability and model validation," in *Vehicular Technology Conference (VTC Fall), 2011 IEEE*, 2011, pp. 1–5.

[81] N. Dumont, R. Watson, and S. Pennock, "Propagation modelling for white space geo-location databases," in *Antennas and Propagation (EUCAP), 2012 6th European Conference on*, 2012, pp. 2175–2179.

[82] T. Shimomura, T. Oyama, and H. Seki, "Analysis of TV white space availability in Japan," in *Vehicular Technology Conference (VTC Fall), 2012 IEEE*, 2012, pp. 1–5.

[83] *Radio-frequency protection ratios for AM vestigial sideband terrestrial television systems interfered with by unwanted analogue vision signals and their associated sound signals*, ITU-R Recommendation BT.655-7.

[84] (2012, Sep) National land cover 2009 (nlc 2009) spatial data. South African National Biodiversity Institute. [Online]. Available: http://bgis.sanbi.org/

[85] (2012, Nov) Census 2011: Spatial metadata for digital spatial boundaries. Statistics South Africa. [Online]. Available: http://www.statssa.gov.za

[86] *The radio refractive index: its formula and refractivity data*, ITU-R Recommendation P.453-10.

[87] (2012, Apr) Radio refractivity data (recommendation p.453) - refractivity-gradient-65m dataset. IRU-R SG3. [Online]. Available: http://www.itu.int/oth/R0A04/

[88] *Guide to the application of the propagation methods of Radiocommunication Study Group 3*, Recommendation, ITU-R P.1144-6.

[89] T. Hengl and I. Evans, "Chapter 2: Mathematical and digital models of the land surface," in *Geomorphometry Concepts, Software, Applications*, T. Hengl and H. I. Reuter, Eds. Elsevier, 2009, vol. Volume 33, pp. 31–63.

[90] C. Thomas and W. Featherstone, "Validation of Vincenty's formulas for the geodesic using a new fourth-order extension of Kivioja's formula," *Journal of Surveying Engineering*, vol. 131, no. 1, pp. 20–26, 2005.

[91] T. Vincenty, "Direct and inverse solutions of geodesics on the ellipsoid with application of nested equations," *Survey Review*, vol. 176, pp. 88–93, 1975.

[92] T. G. Farr, P. A. Rosen, E. Caro, R. Crippen, R. Duren, S. Hensley, M. Kobrick, M. Paller, E. Rodriguez, L. Roth, D. Seal, S. Shaffer, J. Shimada, J. Umland, M. Werner, M. Oskin, D. Burbank, and D. Alsdorf, "The shuttle radar topography mission," *Rev. Geophys.*, vol. 45, no. 2, p. RG2004, May 2007.

[93] (2012, Jun) Aster global digital elevation map. [Online]. Available: http://asterweb.jpl.nasa.gov/gdem.asp

[94] H. Weepener, H. van den Berg, M. Metz, and H. Hamandawana, "The development of a hydrologically improved digital elevation model and derived products for South Africa based on the SRTM DEM," WRC Report, Jan 2012.

[95] A. van Niekerk, "Developing a very high resolution DEM of South Africa," *PositionIT Magazine*, pp. 55–60, Nov/Dec 2012.

[96] E. Rodriguez, C. Morris, J. Belz, E. Chapin, J. Martin, W. Daffer, and S. Hensley, "An assessment of the SRTM topographic products," Jet Propulsion Laboratory, Tech. Rep. JPL D-31639, 2005.

[97] H. I. Reuter, A. Nelson, and A. Jarvis, "An evaluation of void-filling interpolation methods for SRTM data." *International Journal of Geographical Information Science*, vol. 21, no. 9, pp. 983–1008, Oct. 2007.

[98] M. Meybeck, P. Green, and C. Vrsmarty, "A new typology for mountains and other relief classes," *Mountain Research and Development*, vol. 21, no. 1, pp. 34–45, Feb. 2001.

[99] A. Jarvis, H. Reuter, A. Nelson, and E. Guevara. (2008) Hole-filled seamless SRTM data V4, international centre for tropical agriculture (CIAT). [Online]. Available: http://srtm.csi.cgiar.org

[100] (2012, Jan) Datums and coordinate systems. National Geo-spatial Information: South Africa. [Online]. Available: http://www.ngi.gov.za/index.php/Geodesy-GPS/datums-and-coordinate-systems.html

[101] TR8350.2, "Department of defense world geodetic system 1984 - its definition and relationships with local geodetic systems," National Imagery and Mapping Agency, Tech. Rep., 2000. [Online]. Available: http://earth-info.nga.mil/GandG/publications/index.html

[102] (2012, Apr.) Radio refractivity data (recommendation p.453) - delta N and No maps. ITU-R SG3. [Online]. Available: http://www.itu.int/oth/R0A04/

[103] C. Haslett, *Essentials of Radio Wave Propagation*. Cambridge , UK : Cambridge University Press, 2007.

[104] J. P. Kleijnen, "Verification and validation of simulation models," *European Journal of Operational Research*, vol. 82, no. 1, pp. 145–162, Apr. 1995.

[105] R. Sargent, "Verification and validation of simulation models," in *Simulation Conference (WSC), Proceedings of the 2011 Winter*, 2011, pp. 183–198.

[106] (2012, Aug.) Calculation of effective antenna heights (eff_hgt) using the SRTM3 terrain database. ITU-T. Version 1. [Online]. Available: http://www.itu.int/SRTM3/

[107] J. L. Devore and N. R. Farnum, *Applied Statistics for Engineers and Scientists*, 2nd ed. Belmont, CA : Thomson Brooks/Cole, 2005.

[108] (2013, Aug.) Overzicht digitale omroepzenders. Agentschap Telecom, Ministerie van Economische Zaken, Landbouw en Innovatie. [Online]. Available: http://appl.at-ez.nl/dav/index.html

[109] (2013, Aug.) The Netherlands Cadastre, Land Registry and Mapping Agency. Kadaster. [Online]. Available: http://www.kadaster.nl/web/english.htm

[110] R. Makgothlo, Personal correspondence, Radio-Frequency Specialist, ICASA, Aug 2012.

[111] "Erratum to the final terrestrial broadcasting plan," in *Government Gazette*, Rebuplic of South Africa, 24 Jun 2011, no. 34386, notice 414.

[112] "Second erratum to the final terrestrial broadcasting plan of 2008," in *Government Gazette*, Republic of South Africa, 21 Dec. 2012, vol. 36026, notice 1061.

[113] *Characteristics of radiated signals of conventional analogue television systems*, ITU-R Recommendation BT.1701-1.

[114] *Implementation guidelines for a second generation digital terrestrial television broadcasting system (DVB-T2)*, Digital Video Broadcasting (DVB) Bluebook A133, Feb. 2012. [Online]. Available: http://www.dvb.org

[115] D. Wong and J. Lee, *Statistical Analysis of Geographic Information with ArcView GIS and ArcGIS*. John Wiley & Sons, Inc., 2005.

[116] (2012, Nov) Census 2001: Spatial metadata for digital spatial boundaries. Statistics South Africa. [Online]. Available: http://www.statssa.gov.za

[117] J. Stewart, *Early Transcendentals Multivariable Calculus*, 5th ed., K. Townes, Ed. Thomson Wadsworth, 2003.

[118] T. Waywell, "The effect of various map projections on surface area," *PositionIT Magazine*, no. 5, jul. 2009.

[119] U. Deichmann, D. Balk, and G. Yetman, "Transforming population data for interdisciplinary usages: From census to grid," NASA Socioeconomic Data and Applications Center (SEDAC), Tech. Rep., Oct 2001. [Online]. Available: http://sedac.ciesin.columbia.edu/

[120] M. Goodchild and N. Siu-Ngan Lam, "Areal interpolation: a variant of the traditional spatial problem." *Geo-Processing*, vol. 1, no. 3, pp. 297–312, 1980.

[121] M. Goodchild, L. Anselin, and U. Deichmann, "A framework for the areal interpolation of socioeconomic data," *Environment & Planning A*, vol. 25, no. 3, pp. 383–397, 1993.

[122] D. O'Sullivan and D. Unwin, *Geographic Information Analysis*. John Wiley & Sons, Inc., 2002.

[123] (2012, Dec) Reboot initiative. FCC. [Online]. Available: http://reboot.fcc.gov/

[124] (2013, Aug) The Cape Town TV white spaces trial. TENET (Tertiary Education and Research Network of South Africa). [Online]. Available: http://www.tenet.ac.za/about-us/the-cape-town-tv-white-spaces-trial

[125] "Broadband policy for South Africa," in *Government Gazette*, Jul. 2010, no. 33377, notice 617, pp. 4–21.

[126] *National Development Plan 2030: Our Future - make it work*, National Planning Commission, Department: The Presidency, Republic of South Africa, 2012. [Online]. Available: http://www.npconline.co.za/

[127] *Obstacles of significance to air navigation*, South African Civil Aviation Authority AIC 21.14, Mar. 2006. [Online]. Available: http://www.caa.co.za/

Appendix A

DTT entries

Remarks on DTT entries

The DTT entries added to the PU data structure are shown in table A.2 - A.6. However, entries marked with an asterisk are omitted from inclusion due to duplicate entries based on the site coordinates and channel number. The entries with the higher ERP are considered in each case. The entries omitted and the corresponding entries kept are indicated in table A.1. Other than aforementioned duplicate entries, the DTT list is consistent with annexure F of the Final Terrestrial Broadcasting Plan and the two erratums to the plan [5], [111], [112].

Table A.1: Duplicate DTT entries omitted from PU data structure

Entry no.		Entry no.	
Keep	Ommit	Keep	Ommit
17	19	18	20
333	335	334	336
341	343	342	344
425	427	426	428

Table A.2: DTT entries considered (1 of 6)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (kW)	Polarisation	Multiplex	Antenna height (m)
1	ALEXANDER BAY	16E2949	28S3632	27	522	0.1	V	DTT1	32
2	ALEXANDER BAY	16E2949	28S3632	29	538	0.1	V	DTT2	32
3	ALIWAL NORTH	26E3400	30S4705	21	474	10	H	DTT1	134
4	ALIWAL NORTH	26E3400	30S4705	25	506	10	H	DTT2	134
5	AMANDA GLEN	18E4033	33S5118	38	610	0.02	V	DTT1	9
6	AMANDA GLEN	18E4033	33S5118	50	706	0.02	V	DTT2	9
7	ANDRIESKRAAL	24E4233	33S4637	40	626	0.01	V	DTT2	11
8	ANDRIESKRAAL	24E4233	33S4637	36	594	0.01	V	DTT1	11
9	AURORA	18E3829	33S4939	38	610	0.001	V	DTT1	24
10	AURORA	18E3829	33S4939	50	706	0.001	V	DTT2	24
11	BARKLY EAST	27E2600	30S5130	27	522	0.35	V	DTT1	207
12	BARKLY EAST	27E2600	30S5130	31	554	0.35	V	DTT2	207
13	BEAUFORT WEST	22E3025	32S1529	41	634	56.1	H	DTT1	210
14	BEAUFORT WEST	22E3025	32S1529	45	666	60	H	DTT2	210
15	BEDFORD	26E0257	32S3757	21	474	10	H	DTT1	134
16	BEDFORD	26E0257	32S3757	25	506	10	H	DTT2	134
17	BETHLEHEM	28E2958	28S1410	35	586	10	H	DTT1	160
18	BETHLEHEM	28E2958	28S1410	31	554	10	H	DTT2	160
19	BETHLEHEM (TOWN)	28E2958	28S1410	35	586	0.15	V	DTT1	160
20	BETHLEHEM (TOWN)	28E2958	28S1410	31	554	0.155	V	DTT2	160
21	BEZVALLEY	28E 0 0	26S1141	54	738	0.07	V	DTT1	19
22	BEZVALLEY	28E 0 0	26S1141	58	770	0.07	V	DTT2	19
23	BLOEMFONTEIN	26E1350	29S0613	52	722	100	H	DTT1	214
24	BLOEMFONTEIN	26E1350	29S0613	55	746	100	H	DTT2	214
25	BLOUBERG	28E5912	23S0419	37	602	2	V	DTT1	22
26	BLOUBERG	28E5912	23S0419	41	634	2	V	DTT2	22
27	BOESMANSKOP	27E1255	30S0028	35	586	10	H	DTT1	220
28	BOESMANSKOP	27E1255	30S0028	29	538	10	H	DTT2	220
29	BRONKHORSPRUIT	28E4338	25S4613	32	562	0.2	V	DTT1	20
30	BRONKHORSPRUIT	28E4338	25S4613	34	578	0.2	V	DTT2	20
31	BURGERSDORP	26E2021	31S0002	47	682	0.1	V	DTT1	22
32	BURGERSDORP	26E2021	31S0002	51	714	0.1	V	DTT2	22
33	BURGERSFORT	30E1948	24S4005	33	570	50	H	DTT1	10
34	BURGERSFORT	30E1948	24S4005	29	538	50	H	DTT2	10
35	BUTTERWORTH	28E1225	32S1635	23	490	10	H	DTT1	253
36	BUTTERWORTH	28E1225	32S1635	27	522	10	H	DTT2	253
37	CALA	27E4502	31S3315	46	674	10	V	DTT1	148
38	CALA	27E4502	31S3315	48	690	10	V	DTT2	148
39	CALVINIA	19E4657	31S2303	24	498	10	H	DTT1	221
40	CALVINIA	19E4657	31S2303	26	514	10	H	DTT2	221
41	CAPE TOWN	18E2315	34S0315	38	610	20	H	DTT1	151
42	CAPE TOWN	18E2315	34S0315	50	706	20	H	DTT2	151
43	CAROLINA	30E3757	26S1037	64	818	10	H	DTT1	222
44	CAROLINA	30E3757	26S1037	66	834	10	H	DTT2	222
45	CERES	19E2732	33S1510	25	506	11	V	DTT1	72
46	CERES	19E2732	33S1510	33	570	11	V	DTT2	72
47	CHRISTIANA	24E5550	27S5303	56	754	1	H	DTT1	221
48	CHRISTIANA	24E5550	27S5303	60	786	1	H	DTT2	221
49	CLIFTON	18E2237	33S5630	27	522	0.02	H	DTT1	11
50	CLIFTON	18E2237	33S5630	29	538	0.02	H	DTT2	11
51	COLESBERG	25E0328	30S4230	27	522	0.5	V	DTT1	12
52	COLESBERG	25E0328	30S4230	31	554	0.5	V	DTT2	12
53	CRADOCK	25E3227	32S1801	44	658	10	H	DTT1	176
54	CRADOCK	25E3227	32S1801	35	586	10	H	DTT2	176
55	DAVEL	29E3726	26S2730	40	626	50	H	DTT1	259
56	DAVEL	29E3726	26S2730	44	658	50	H	DTT2	259
57	DE AAR	23E5916	30S2749	56	754	50	H	DTT1	214
58	DE AAR	23E5916	30S2749	60	786	50	H	DTT2	214
59	DEBEERSRUS	22E1200	26S3600	54	738	50	H	DTT1	251
60	DEBEERSRUS	22E1200	26S3600	58	770	50	H	DTT2	251
61	DESPATCH	25E2529	33S4553	45	666	0.2	V	DTT1	13
62	DESPATCH	25E2529	33S4553	49	698	0.2	V	DTT2	13
63	DEWETSDORP	26E3937	29S3444	62	812	0.01	V	DTT1	187
64	DEWETSDORP	26E3937	29S3444	66	844	0.01	V	DTT2	187
65	DONNYBROOK	29E5119	29S5456	64	818	10	H	DTT1	153
66	DONNYBROOK	29E5119	29S5456	68	850	10	H	DTT2	153
67	DORINGKRUIN	26E4100	26S4905	24	498	1	V	DTT1	24
68	DORINGKRUIN	26E4100	26S4905	28	530	1	V	DTT2	24
69	DOUGLAS	23E3149	29S0414	55	746	10	H	DTT1	259
70	DOUGLAS	23E3149	29S0414	59	778	10	H	DTT2	259
71	DULLSTROOM	30E1117	25S3421	57	762	5	H	DTT1	191
72	DULLSTROOM	30E1117	25S3421	51	714	5	H	DTT2	191
73	DURBAN	30E4300	29S4611	46	674	100	H	DTT1	241
74	DURBAN	30E4300	29S4611	50	706	100	H	DTT2	241
75	DURBAN NORTH	31E0224	29S4552	46	674	1	V	DTT1	149
76	DURBAN NORTH	31E0224	29S4552	50	706	1	V	DTT2	149
77	DZAMBA	30E1841	22S4905	36	594	1	V	DTT1	45
78	DZAMBA	30E1841	22S4905	32	562	1	V	DTT2	45
79	EAST LONDON	27E4858	32S5620	58	770	50	H	DTT1	210
80	EAST LONDON	27E4858	32S5620	62	802	50	H	DTT2	210
81	ELANDS HEIGHT	28E0710	30S4744	47	682	10	V	DTT1	60
82	ELANDS HEIGHT	28E0710	30S4744	26	514	10	V	DTT2	60

Table A.3: DTT entries considered (2 of 6)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (kW)	Polarisation	Multiplex	Antenna height (m)
83	ELLIOT	27E5157	31S1036	62	802	0.4	V	DTT1	73
84	ELLIOT	27E5157	31S1036	66	834	0.4	V	DTT2	73
85	ELLISRAS	27E3946	23S4222	25	506	0.24	V	DTT1	20
86	ELLISRAS	27E3946	23S4222	29	538	0.24	V	DTT2	20
87	EMPANGENI	31E5330	28S4440	60	786	0.05	V	DTT1	60
88	EMPANGENI	31E5330	28S4440	56	754	0.05	V	DTT2	60
89	ENGCOBO	28E0034	31S3920	44	658	10	V	DTT1	35
90	ENGCOBO	28E0034	31S3920	48	690	10	V	DTT2	35
91	ENTSHATSHONGO	28E4010	32S0839	23	490	50	V	DTT1	40
92	ENTSHATSHONGO	28E4010	32S0839	27	522	50	V	DTT2	40
93	ENZELSBURG	26E1316	25S2507	54	738	2	H	DTT1	53
94	ENZELSBURG	26E1316	25S2507	58	770	2	H	DTT2	53
95	ERMELO	29E5957	26S3035	57	762	0.05	V	DTT1	132
96	ERMELO	29E5957	26S3035	61	794	0.05	V	DTT2	132
97	ESHOWE	31E1737	28S5129	56	754	10	H	DTT2	134
98	ESHOWE	31E1737	28S5129	60	786	10	H	DTT1	134
99	ESTCOURT	29E5156	29S0055	22	482	0.05	V	DTT1	30
100	ESTCOURT	29E5156	29S0055	47	682	0.05	V	DTT2	30
101	FAANS GROVE	22E2418	27S0559	40	626	50	H	DTT1	148
102	FAANS GROVE	22E2418	27S0559	44	658	50	H	DTT2	148
103	FICKSBURG TOWN	27E5127	28S5236	41	634	0.05	V	DTT1	37
104	FICKSBURG TOWN	27E5127	28S5236	49	698	0.05	V	DTT2	37
105	FISHOEK	18E2612	34S0859	38	610	0.1	V	DTT1	25
106	FISHOEK	18E2612	34S0859	50	706	0.1	V	DTT2	25
107	FRANSCHHOEK	19E0426	33S5426	38	610	1	V	DTT1	23
108	FRANSCHHOEK	19E0426	33S5426	50	706	1	V	DTT2	23
109	GABA	30E4225	22S4702	36	594	4	V	DTT1	33
110	GABA	30E4225	22S4702	32	562	4	V	DTT2	33
111	GANYESA	24E1600	26S3612	30	546	30	H	DTT1	155
112	GANYESA	24E1600	26S3612	34	578	30	H	DTT2	155
113	GA-RANKUWA	28E0125	25S3612	54	738	12.5	V	DTT1	95
114	GA-RANKUWA	28E0125	25S3612	58	770	12.5	V	DTT2	95
115	GARIES	18E0443	30S1852	54	738	50	H	DTT1	226
116	GARIES	18E0443	30S1852	58	770	50	H	DTT2	226
117	GEORGE	22E2704	33S5538	64	818	112	H	DTT1	147
118	GEORGE	22E2704	33S5538	68	850	112	H	DTT2	147
119	GLENCOE	29E5651	28S0904	48	690	10	H	DTT1	135
120	GLENCOE	29E5651	28S0904	52	722	10	H	DTT2	135
121	GRAAFF-REINET	24E2704	32S0444	32	562	20	H	DTT1	138
122	GRAAFF-REINET	24E2704	32S0444	36	594	20	H	DTT2	138
123	GRABOUW	18E5803	34S0605	38	610	0.5	V	DTT1	27
124	GRABOUW	18E5803	34S0605	50	706	0.5	V	DTT2	27
125	GRAHAMSTOWN	26E4231	33S1715	50	706	20	H	DTT1	210
126	GRAHAMSTOWN	26E4231	33S1715	46	674	20	H	DTT2	210
127	GREYTOWN	30E3210	29S0046	58	770	10	H	DTT1	160
128	GREYTOWN	30E3210	29S0046	62	802	10	H	DTT2	160
129	GREYTOWN DORP	30E3648	29S0205	58	770	1	V	DTT1	13
130	GREYTOWN DORP	30E3648	29S0205	62	802	1	V	DTT2	13
131	GROOT BRAKRIVIER	22E1300	34S0231	31	554	0.025	V	DTT1	14
132	GROOT BRAKRIVIER	22E1300	34S0231	39	618	0.025	V	DTT2	14
133	GROOT MARICO	26E2608	25S3711	47	682	0.2	V	DTT1	24
134	GROOT MARICO	26E2608	25S3711	51	714	0.2	V	DTT2	24
135	GROOTDERM	17E0500	28S2600	27	522	1	H	DTT1	183
136	GROOTDERM	17E0500	28S2600	29	538	1	H	DTT2	183
137	HAENERTSBURG	29E5648	23S5954	23	490	20	H	DTT1	70
138	HAENERTSBURG	29E5648	23S5954	27	522	20	H	DTT2	70
139	HAMAKUYA	30E4821	22S4149	36	594	0.2	V	DTT1	10
140	HAMAKUYA	30E4821	22S4149	32	562	0.2	V	DTT2	10
141	HANKEY	24E5213	33S4952	42	642	0.04	V	DTT1	50
142	HANKEY	24E5213	33S4952	46	674	0.04	V	DTT2	50
143	HARRISMITH	29E0625	28S1518	40	626	50	V	DTT1	20
144	HARRISMITH	29E0625	28S1518	44	658	50	V	DTT2	20
145	HECTORSPRUIT	31E3620	25S2847	30	546	0.631	V	DTT1	25
146	HECTORSPRUIT	31E3620	25S2847	34	578	0.631	V	DTT2	25
147	HEIDELBERG	28E2053	26S2919	42	642	0.1	V	DTT1	98
148	HEIDELBERG	28E2053	26S2919	50	706	0.1	V	DTT2	98
149	HELDERKRUIN	27E5132	26S0605	54	738	1	V	DTT1	98
150	HELDERKRUIN	27E5132	26S0605	58	770	1	V	DTT2	98
151	HERMANUS	19E1318	34S2447	26	514	0.6	V	DTT2	32
152	HERMANUS	19E1318	34S2447	30	546	0.6	V	DTT1	32
153	HEXRIVIER	19E3923	33S3054	37	562	0.1	V	DTT2	37
154	HEXRIVIER	19E3923	33S3054	41	634	0.1	V	DTT1	37
155	HOEDSPRUIT	30E5208	24S3230	21	474	5	H	DTT1	160
156	HOEDSPRUIT	30E5208	24S3230	25	506	5	H	DTT2	160
157	HOLY CROSS	29E3825	31S0756	62	802	30	V	DTT1	100
158	HOLY CROSS	29E3825	31S0756	64	818	30	V	DTT2	100
159	HOUMOED	19E5300	29S1200	35	586	50	H	DTT2	251
160	HOUT BAY	18E2056	34S0044	38	610	4	V	DTT1	22
161	HOWICK	30E1352	29S3013	46	674	0.008	V	DTT1	29
162	HOWICK	30E1352	29S3013	50	706	0.008	V	DTT2	29
163	ITSOSENG	25E5518	26S0430	59	778	33	V	DTT1	65
164	ITSOSENG	25E5518	26S0430	63	810	33	V	DTT2	65

Table A.4: DTT entries considered (3 of 6)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (kW)	Polarisation	Multiplex	Antenna height (m)
165	JOHANNESBURG	28E0026	26S1131	54	738	120	H	DTT1	237
166	JOHANNESBURG	28E0026	26S1131	58	770	120	H	DTT2	237
167	KALAHARI	21E4000	27S2100	28	530	20	H	DTT1	251
168	KALAHARI	21E4000	27S2100	36	594	20	H	DTT2	251
169	KAREEDOUW	24E2548	34S0129	40	626	5	H	DTT1	94
170	KAREEDOUW	24E2548	34S0129	48	690	5	H	DTT2	94
171	KIESEL	27E0800	23S5200	53	730	10	H	DTT1	251
172	KIESEL	27E0800	23S5200	57	762	10	H	DTT2	251
173	KIMBERLEY	24E5419	28S5114	28	530	10	H	DTT1	245
174	KIMBERLEY	24E5419	28S5114	36	594	10	H	DTT2	245
175	KING WILLIAMS TOWN	27E1536	32S4044	49	698	18	H	DTT1	160
176	KING WILLIAMS TOWN	27E1536	32S4044	45	666	18	H	DTT2	160
177	KIRKWOOD	25E2653	33S2322	26	514	0.02	V	DTT1	13
178	KIRKWOOD	25E2653	33S2322	34	578	0.02	V	DTT2	13
179	KLEINMOND	19E0828	34S2315	30	546	0.8	V	DTT1	15
180	KLEINMOND	19E0828	34S2315	26	514	0.6	V	DTT2	15
181	KLERKSDORP	26E2429	26S4514	56	754	10	H	DTT1	253
182	KLERKSDORP	26E2429	26S4514	60	786	10	H	DTT2	253
183	KLIPVOORDAM	27E4542	25S0918	36	594	0.01	V	DTT1	75
184	KLIPVOORDAM	27E4542	25S0918	32	562	0.01	V	DTT2	75
185	KNYSNA	23E0235	34S0418	24	498	0.5	V	DTT1	24
186	KNYSNA	23E0235	34S0418	28	530	0.5	V	DTT2	24
187	KOKSTAD	29E2924	30S3642	26	514	0.4	V	DTT1	12
188	KOKSTAD	29E2924	30S3642	30	546	0.4	V	DTT2	12
189	KROONSTAD	27E1110	27S2516	25	506	20	H	DTT1	222
190	KROONSTAD	27E1110	27S2516	29	538	20	H	DTT2	222
191	KURUMAN	23E1849	27S2105	23	490	5	H	DTT1	155
192	KURUMAN	23E1849	27S2105	27	522	5	H	DTT2	155
193	KURUMAN HILLS	23E3338	27S5313	23	490	20	H	DTT1	226
194	KURUMAN HILLS	23E3338	27S5313	27	522	20	H	DTT2	226
195	KUTAMA	29E3731	23S0219	26	514	0.1	V	DTT1	35
196	KUTAMA	29E3731	23S0219	30	546	0.1	V	DTT2	35
197	LADISMITH (CAPE)	21E2520	33S3754	30	546	10	H	DTT1	73
198	LADISMITH (CAPE)	21E2520	33S3754	34	578	10	H	DTT2	73
199	LADYBRAND	27E2242	29S1018	32	562	1	H	DTT1	160
200	LADYBRAND	27E2242	29S1018	36	594	1	H	DTT2	160
201	LADYSMITH	29E4719	28S3523	38	610	1	V	DTT1	64
202	LADYSMITH	29E4719	28S3523	46	674	1	V	DTT2	64
203	LINMEYER	28E0416	26S1608	54	738	0.1	H	DTT1	25
204	LINMEYER	28E0416	26S1608	58	770	0.1	H	DTT2	25
205	LOMBAARDSVLAKTE	22E1500	28S2015	55	746	10	H	DTT1	251
206	LOMBAARDSVLAKTE	22E1500	28S2015	59	778	10	H	DTT2	251
207	LOSKOP	29E1242	28S3941	47	682	1.413	V	DTT1	25
208	LOSKOP	29E1242	28S3941	36	594	1	V	DTT2	25
209	LOUIS TRICHARDT	29E4526	23S0002	26	514	100	V	DTT1	153
210	LOUIS TRICHARDT	29E4526	23S0002	30	546	100	V	DTT2	153
211	LOUWSBURG	31E1632	27S3344	46	674	14.12	V	DTT1	68
212	LOUWSBURG	31E1632	27S3344	50	706	14.12	V	DTT2	68
213	LYDENBURG	30E2604	25S0619	26	514	0.04	V	DTT1	24
214	LYDENBURG	30E2604	25S0619	30	546	0.04	V	DTT2	24
215	MABOPANE	28E0348	25S3057	54	738	1	V	DTT1	10
216	MABOPANE	28E0348	25S3057	58	770	1	V	DTT2	10
217	MADIBOGO	25E1514	26S2728	59	778	4	H	DTT1	167
218	MADIBOGO	25E1514	26S2728	63	810	4	H	DTT2	167
219	MAKADIMA	25E4923	25S2647	54	738	12	H	DTT1	70
220	MAKADIMA	25E4923	25S2647	58	770	12	H	DTT2	70
221	MALAMBA	30E1509	22S5356	36	594	0.08	V	DTT1	48
222	MALAMBA	30E1509	22S5356	32	562	0.08	V	DTT2	48
223	MATATIELE	28E4919	30S2345	46	674	10	H	DTT1	220
224	MATATIELE	28E4919	30S2345	50	706	10	H	DTT2	220
225	MATJIESFONTEIN	20E3020	33S1652	47	682	10	H	DTT1	134
226	MATJIESFONTEIN	20E3020	33S1652	51	714	10	H	DTT2	134
227	MBUZINI	31E5453	25S5226	62	802	2	V	DTT1	50
228	MBUZINI	31E5453	25S5226	66	834	2	V	DTT2	50
229	MENLO PARK	28E1609	25S4615	54	738	0.04	V	DTT1	23
230	MENLO PARK	28E1609	25S4615	58	770	0.04	V	DTT2	23
231	MIDDELBURG	29E2324	25S4904	60	786	50	H	DTT1	253
232	MIDDELBURG	29E2324	25S4904	56	754	50	H	DTT2	253
233	MIER	20E1815	26S4130	53	730	50	H	DTT1	251
234	MIER	20E1815	26S4130	57	762	50	H	DTT2	251
235	MMABATHO	25E3646	25S5022	24	498	20	V	DTT1	90
236	MMABATHO	25E3646	25S5022	36	594	20	V	DTT2	90
237	MOGWASE	27E1600	25S1026	62	802	33	V	DTT1	75
238	MOGWASE	27E1600	25S1026	66	834	33	V	DTT2	75
239	MOLEMA	30E0240	23S1838	58	770	0.2	V	DTT1	10
240	MOLEMA	30E0240	23S1838	62	802	0.2	V	DTT2	10
241	MONDEOR	27E5952	26S1652	54	738	0.02	V	DTT1	19
242	MONDEOR	27E5952	26S1652	58	770	0.02	V	DTT2	19
243	MONTAGU	20E0837	33S4716	26	514	0.05	V	DTT1	12
244	MONTAGU	20E0837	33S4716	30	546	0.05	V	DTT2	12
245	MOOI RIVER	29E5204	29S1107	47	682	10	H	DTT1	160
246	MOOI RIVER	29E5204	29S1107	67	842	10	H	DTT2	160

Table A.5: DTT entries considered (4 of 6)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (kW)	Polarisation	Multiplex	Antenna height (m)
247	MORETELETSI	26E4212	25S1748	26	514	35	V	DTT1	65
248	MORETELETSI	26E4212	25S1748	34	578	35	V	DTT2	65
249	MOTSWEDI	25E5218	25S1655	54	738	7	V	DTT1	75
250	MOTSWEDI	25E5218	25S1655	58	770	7	V	DTT2	75
251	MOUNT AYLIFF	29E2341	30S5011	62	802	10	H	DTT1	136
252	MOUNT AYLIFF	29E2341	30S5011	64	818	10	H	DTT2	136
253	MOUNT FLETCHER	28E3041	30S5011	47	682	1	H	DTT1	55
254	MOUNT FLETCHER	28E3041	30S5011	26	514	1	H	DTT2	55
255	MULBARTON	28E0356	26S1736	54	738	0.03	V	DTT1	14
256	MULBARTON	28E0356	26S1736	58	770	0.03	V	DTT2	14
257	NAPIER	19E5333	34S3145	42	642	1	H	DTT1	214
258	NAPIER	19E5333	34S3145	46	674	1	H	DTT2	214
259	NELSPRUIT	30E4635	25S3055	54	738	10	H	DTT1	136
260	NELSPRUIT	30E4635	25S3055	58	770	10	H	DTT2	136
261	NEWCASTLE	29E5712	27S4307	37	602	1	V	DTT1	61
262	NEWCASTLE	29E5712	27S4307	41	634	1	V	DTT2	61
263	NGANGELIZWE	28E4831	31S3715	41	634	0.2	H	DTT1	16
264	NGANGELIZWE	28E4831	31S3715	34	578	0.2	H	DTT2	16
265	NOENIEPUT	20E1830	27S3500	30	546	10	H	DTT1	251
266	NOENIEPUT	20E1830	27S3500	34	578	10	H	DTT2	251
267	NONGOMA	31E3927	27S5418	33	570	10	H	DTT1	194
268	NONGOMA	31E3927	27S5418	31	554	10	H	DTT2	194
269	NOUPOORT	24E5601	31S1814	33	570	1	H	DTT1	160
270	NOUPOORT	24E5601	31S1814	37	602	1	H	DTT2	160
271	NQELENI	29E0734	31S457	41	634	10	V	DTT1	100
272	NQELENI	29E0734	31S457	34	578	10	V	DTT2	100
273	NQUTU	30E4042	28S1543	63	810	15.1	V	DTT1	102
274	NQUTU	30E4042	28S1543	40	626	15.1	V	DTT2	102
275	NYLSTROOM	28E2559	24S4758	22	482	1	V	DTT1	41
276	NYLSTROOM	28E2559	24S4758	26	514	1	V	DTT2	41
277	OUDTSHOORN	22E1602	33S4016	40	626	100	H	DTT1	153
278	OUDTSHOORN	22E1602	33S4016	48	690	100	H	DTT2	153
279	OVERPORT	30E5954	29S5002	46	674	1.3	V	DTT1	75
280	OVERPORT	30E5954	29S5002	50	706	1.3	V	DTT2	75
281	PAARL	18E5624	33S4253	38	610	2.5	V	DTT1	137
282	PAARL	18E5624	33S4253	50	706	2.5	V	DTT2	137
283	PANKOP	28E2416	25S0944	64	818	20	H	DTT1	72
284	PANKOP	28E2416	25S0944	68	850	20	H	DTT2	72
285	PATENSIE	24E4943	33S4537	48	690	0.01	V	DTT1	12
286	PATENSIE	24E4943	33S4537	52	722	0.01	V	DTT2	12
287	PAUL SAUER DAM	24E3343	33S4513	35	586	0.02	V	DTT1	12
288	PAUL SAUER DAM	24E3343	33S4513	39	618	0.02	V	DTT2	12
289	PETRUS STEYN	28E1906	27S3100	36	594	10	H	DTT1	238
290	PETRUS STEYN	28E1906	27S3100	34	578	10	H	DTT2	238
291	PHALABORWA	31E0824	23S5702	26	514	0.2	V	DTT1	30
292	PHALABORWA	31E0824	23S5702	30	546	0.2	V	DTT2	30
293	PIET PLESSIS	24E4955	26S1456	46	674	10	H	DTT1	253
294	PIET PLESSIS	24E4955	26S1456	23	490	10	H	DTT2	253
295	PIET RETIEF	30E4103	27S0111	56	754	10	H	DTT1	257
296	PIET RETIEF	30E4103	27S0111	60	786	10	H	DTT2	257
297	PIETERMARITZBURG	30E1949	29S3447	46	674	1	V	DTT1	93
298	PIETERMARITZBURG	30E1949	29S3447	50	706	1	V	DTT2	93
299	PIKETBERG	18E4419	32S4909	29	538	120	H	DTT1	183
300	PIKETBERG	18E4419	32S4909	31	554	120	H	DTT2	183
301	PILANESBERG	27E0535	25S2107	57	762	16	V	DTT1	76
302	PILANESBERG	27E0535	25S2107	65	826	16	V	DTT2	76
303	PLETTENBERG BAY	23E2230	34S0332	47	682	0.125	V	DTT1	20
304	PLETTENBERG BAY	23E2230	34S0332	51	714	0.125	V	DTT2	20
305	POFADDER	18E5625	29S1430	55	746	10	H	DTT1	143
306	POFADDER	18E5625	29S1430	59	778	10	H	DTT2	143
307	POMFRET	23E3444	25S4952	40	626	1	V	DTT1	143
308	POMFRET	23E3444	25S4952	44	658	1	V	DTT2	143
309	PONGOLA	31E3900	27S3134	39	618	0.2	V	DTT1	13
310	PONGOLA	31E3900	27S3134	43	650	0.2	V	DTT2	13
311	PORT ELIZABETH	25E2629	33S5610	45	666	112	H	DTT1	210
312	PORT ELIZABETH	25E2629	33S5610	49	698	112	H	DTT2	210
313	PORT ELIZABETH CIT	25E3531	33S5528	45	666	2	V	DTT1	63
314	PORT ELIZABETH CIT	25E3531	33S5528	49	698	2	V	DTT2	63
315	PORT SHEPSTONE	30E1717	30S4407	40	626	10	H	DTT1	214
316	PORT SHEPSTONE	30E1717	30S4407	44	658	10	H	DTT2	214
317	PORTSTJOHNS	29E3139	31S3639	41	634	10	H	DTT1	55
318	PORTST JOHNS	29E3139	31S3639	34	578	10	H	DTT2	55
319	POTCHEFSTROOM	27E0432	26S4146	56	754	0.1	V	DTT1	28
320	POTCHEFSTROOM	27E0432	26S4146	60	786	0.1	V	DTT2	28
321	POTGIETERSRUS	29E1410	24S0924	48	690	10	H	DTT1	153
322	POTGIETERSRUS	29E1410	24S0924	52	722	10	H	DTT2	153
323	PRETORIA	27E5903	25S410	54	738	100	H	DTT1	132
324	PRETORIA	27E5903	25S410	58	770	100	H	DTT2	132
325	PRETORIA NORTH	28E1007	25S4125	54	738	0.02	V	DTT1	23
326	PRETORIA NORTH	28E1007	25S4125	58	770	0.02	V	DTT2	23
327	PRIESKA	22E3657	29S4052	22	482	50	H	DTT1	257
328	PRIESKA	22E3657	29S4052	30	546	50	H	DTT2	257

Table A.6: DTT entries considered (5 of 6)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (kW)	Polarisation	Multiplex	Antenna height (m)
329	PUNDA MARIA	30E5919	22S4328	32	562	10	H	DTT1	90
330	PUNDA MARIA	30E5919	22S4328	36	594	10	H	DTT2	90
331	QUDENI	30E5159	28S3803	60	786	15.1	V	DTT1	102
332	QUDENI	30E5159	28S3803	56	754	15.1	V	DTT2	102
333	QUEENSTOWN	26E4705	31S4356	26	514	50	H	DTT1	153
334	QUEENSTOWN	26E4705	31S4356	30	546	50	H	DTT2	153
335	QUEENSTOWN (DORF	26E4705	31S4356	26	514	0.1	H	DTT1	153
336	QUEENSTOWN (DORF	26E4705	31S4356	30	546	0.1	H	DTT2	153
337	RICHARDS BAY	32E0624	28S4710	60	786	0.19	V	DTT1	12
338	RICHARDS BAY	32E0624	28S4710	56	754	0.19	V	DTT2	12
339	RIVERSDALE	21E0741	34S0107	32	562	20	H	DTT1	153
340	RIVERSDALE	21E0741	34S0107	36	594	20	H	DTT2	153
341	RUSTENBURG	27E0706	25S3656	45	666	5	H	DTT1	98
342	RUSTENBURG	27E0706	25S3656	53	730	5	H	DTT2	98
343	RUSTENBURG (CASH	27E0706	25S3656	45	666	0.1	H	DTT1	98
344	RUSTENBURG (CASH	27E0706	25S3656	53	730	0.1	H	DTT2	98
345	SABIE	30E4534	25S0744	23	490	0.1	V	DTT1	12
346	SABIE	30E4534	25S0744	27	522	0.1	V	DTT2	12
347	SASOLBURG	27E4935	26S4745	37	602	0.05	V	DTT1	50
348	SASOLBURG	27E4935	26S4745	45	666	0.05	V	DTT2	50
349	SCHWEIZER RENEKE	25E1307	27S0813	44	658	100	H	DTT1	263
350	SCHWEIZER RENEKE	25E1307	27S0813	40	626	10	H	DTT2	263
351	SEA POINT	18E2351	33S5433	38	610	0.4	V	DTT1	76
352	SEA POINT	18E2351	33S5433	50	706	0.4	V	DTT2	76
353	SECUNDA	29E1210	26S2940	44	658	0.1	V	DTT1	222
354	SECUNDA	29E1210	26S2940	40	626	0.1	V	DTT2	222
355	SENEKAL	27E3026	28S1519	50	706	10	H	DTT1	222
356	SENEKAL	27E3026	28S1519	64	738	1	H	DTT2	222
357	SEVERN	23E0400	26S2400	48	690	10	H	DTT1	251
358	SEVERN	23E0400	26S2400	52	722	10	H	DTT2	251
359	SHANZHA	30E1400	22S5736	36	594	2	V	DTT1	8
360	SHANZHA	30E1400	22S5736	32	562	2	V	DTT2	8
361	SIBASA	30E2654	22S5657	36	594	8	V	DTT1	52
362	SIBASA	30E2654	22S5657	32	562	8	V	DTT2	52
363	SIMONSTOWN	18E2537	34S1154	38	610	0.25	V	DTT1	21
364	SIMONSTOWN	18E2537	34S1154	50	706	0.25	V	DTT2	21
365	SMITHFIELD	26E2156	29S5543	29	538	50	H	DTT1	220
366	SMITHFIELD	26E2156	29S5543	59	778	50	H	DTT2	220
367	SOMERSET EAST	25E3441	32S4245	61	794	0.05	V	DTT1	12
368	SOMERSET EAST	25E3441	32S4245	65	826	0.05	V	DTT2	12
369	SPRINGBOK	17E4829	29S3504	21	474	10	H	DTT1	226
370	SPRINGBOK	17E4829	29S3504	25	506	10	H	DTT2	226
371	SPRINGFONTEIN	25E4608	30S1614	42	642	10	H	DTT1	134
372	SPRINGFONTEIN	25E4608	30S1614	46	674	10	H	DTT2	134
373	STANDERTON	29E1251	26S5737	42	642	0.1	V	DTT1	189
374	STANDERTON	29E1251	26S5737	46	674	0.1	V	DTT2	189
375	STEINKOPF	17E3500	29S0500	38	610	10	H	DTT1	189
376	STEINKOPF	17E3500	29S0500	42	642	10	H	DTT2	189
377	STELLENBOSCH	18E5211	33S5456	38	610	0.5	V	DTT1	31
378	STELLENBOSCH	18E5211	33S5456	50	706	0.5	V	DTT2	31
379	STERKSPRUIT	27E1614	30S4144	45	666	20	V	DTT1	60
380	STERKSPRUIT	27E1614	30S4144	49	698	20	V	DTT2	60
381	STRAALHOEK	29E5053	30S2049	51	714	10	V	DTT1	65
382	STRAALHOEK	29E5053	30S2049	54	738	10	V	DTT2	65
383	SUIDRAND (KROONST	27E1416	27S4118	25	506	0.25	V	DTT1	19
384	SUIDRAND (KROONST	27E1416	27S4118	29	538	0.25	V	DTT2	19
385	SUNNYSIDE	28E1224	25S4553	54	738	1	V	DTT1	168
386	SUNNYSIDE	28E1224	25S4553	58	770	1	V	DTT2	168
387	SUPINGSTAD	26E0136	24S4720	64	818	2	V	DTT1	28
388	SUPINGSTAD	26E0136	24S4720	68	850	2	V	DTT2	28
389	SUURBERG	25E3429	33S1455	38	610	5	H	DTT1	192
390	SUURBERG	25E3429	33S1455	42	642	5	H	DTT2	192
391	SWARTRUGGENS	26E4809	25S4059	47	682	0.5	V	DTT1	51
392	SWARTRUGGENS	26E4809	25S4059	51	714	0.5	V	DTT2	51
393	TABLE MOUNTAIN	18E2413	33S5725	38	610	0.2	V	DTT1	13
394	TABLE MOUNTAIN	18E2413	33S5725	50	706	0.5	V	DTT2	13
395	TAUNG	24E3700	27S3130	39	618	18	H	DTT1	155
396	TAUNG	24E3700	27S3130	51	714	174	H	DTT2	155
397	THABA NCHU	26E4545	29S1524	63	810	20	H	DTT1	65
398	THABA NCHU	26E4545	29S1524	67	842	20	H	DTT2	65
399	THABAZIMBI	27E3651	24S2759	46	674	10	H	DTT1	214
400	THABAZIMBI	27E3651	24S2759	50	706	10	H	DTT2	214
401	THE BLUFF	31E0045	29S5440	46	674	2.5	V	DTT1	32
402	THE BLUFF	31E0045	29S5440	50	706	2.5	V	DTT2	32
403	THEUNISSEN	26E3450	28S1155	30	546	10	H	DTT1	268
404	THEUNISSEN	26E3450	28S1155	34	578	10	H	DTT2	268
405	THLABANE	27E1139	25S3716	45	666	0.2	V	DTT1	29
406	THLABANE	27E1139	25S3716	53	730	1.3	V	DTT2	29
407	TOLWE	28E2729	23S0459	47	682	16	V	DTT1	43
408	TOLWE	28E2729	23S0459	51	714	16	V	DTT2	43
409	TOUWSRIVIER	20E0112	33S2059	34	578	0.05	V	DTT1	13
410	TOUWSRIVIER	20E0112	33S2059	36	594	0.02	V	DTT2	13

Table A.7: DTT entries considered (6 of 6)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (kW)	Polarisation	Multiplex	Antenna height (m)
411	TSHAMAVUDZI	30E3142	22S3915	36	594	0.25	V	DTT1	44
412	TSHAMAVUDZI	30E3142	22S3915	32	562	0.25	V	DTT2	44
413	TYGERBERG	18E3546	33S5229	38	610	2	V	DTT1	75
414	TYGERBERG	18E3546	33S5229	50	706	2	V	DTT2	75
415	TZANEEN	30E0017	23S4706	58	770	20	H	DTT1	98
416	TZANEEN	30E0017	23S4706	62	802	20	H	DTT2	98
417	UBOMBO	32E0452	27S3342	53	730	10	H	DTT1	98
418	UBOMBO	32E0452	27S3342	57	762	10	H	DTT2	98
419	UGIE	27E5826	31S1128	39	618	0.5	V	DTT1	53
420	UGIE	27E5826	31S1128	43	650	0.5	V	DTT2	53
421	ULUNDI	31E2338	28S2700	60	786	10	V	DTT1	124
422	ULUNDI	31E2338	28S2700	56	754	10	V	DTT2	124
423	UMTATA	28E4436	31S3548	41	634	10	H	DTT1	221
424	UMTATA	28E4436	31S3548	34	578	10	H	DTT2	221
425	UNIONDALE	23E0306	33S4323	55	746	2.5	V	DTT2	48
426	UNIONDALE	23E0306	33S4323	36	594	1	V	DTT2	48
427	UNIONDALE (TOWN)	23E0306	33S4323	36	594	1	V	DTT1	48
428	UNIONDALE (TOWN)	23E0306	33S4323	55	746	1	V	DTT2	48
429	UPINGTON	21E4412	28S5256	33	570	50	H	DTT1	257
430	UPINGTON	21E4412	28S5256	29	538	50	H	DTT2	257
431	UPINGTON TOWN	21E1200	28S3025	29	538	0.4	V	DTT2	33
432	UPINGTON TOWN	21E1200	28S3025	33	570	0.38	V	DTT1	33
433	VAN RHYNSDORP	18E4124	31S4516	48	690	50	H	DTT1	195
434	VAN RHYNSDORP	18E4124	31S4516	52	722	50	H	DTT2	195
435	VERULAM	31E0219	29S3825	31	554	0.01	V	DTT1	13
436	VERULAM	31E0219	29S3825	35	586	0.01	V	DTT2	13
437	VICTORIA WEST	23E1350	31S4115	43	650	10	H	DTT1	103
438	VICTORIA WEST	23E1350	31S4115	47	682	10	H	DTT2	103
439	VILLA NORA	28E2100	23S4200	24	498	10	H	DTT1	189
440	VILLA NORA	28E2100	23S4200	28	530	10	H	DTT2	189
441	VILLIERSDORP	19E3025	33S5809	53	730	10	H	DTT1	152
442	VILLIERSDORP	19E3025	33S5809	65	826	10	H	DTT2	152
443	VOLKSRUST	29E5315	27S1833	58	770	10	H	DTT1	178
444	VOLKSRUST	29E5315	27S1833	62	802	10	H	DTT2	178
445	VRYHEID	30E4738	27S4427	26	514	10	H	DTT1	138
446	VRYHEID	30E4738	27S4427	30	546	10	H	DTT2	138
447	VRYHEID TOWN	30E4623	27S4644	26	514	0.04	H	DTT1	10
448	VRYHEID TOWN	30E4623	27S4644	30	546	0.04	H	DTT2	10
449	WELVERDIEND	27E1455	26S2647	23	490	10	H	DTT1	153
450	WELVERDIEND	27E1455	26S2647	31	554	10	H	DTT2	153
451	WILLISTON	20E5508	31S1931	38	610	10	H	DTT1	12
452	WILLISTON	20E5508	31S1931	46	674	10	H	DTT2	12
453	WILLOWMORE	23E2736	33S1405	39	618	1	H	DTT1	73
454	WILLOWMORE	23E2736	33S1405	51	714	1	H	DTT2	73
455	WINDYBRIDGE	27E1405	32S4510	45	666	20	H	DTT1	125
456	WINDYBRIDGE	27E1405	32S4510	49	698	20	H	DTT2	125
457	WITSIESHOEK	28E5052	28S3102	34	578	0.25	V	DTT1	31
458	WITSIESHOEK	28E5052	28S3102	36	594	0.25	V	DTT2	31
459	ZEERUST	26E0251	25S5137	39	618	20	H	DTT1	252
460	ZEERUST	26E0251	25S5137	36	594	20	H	DTT2	252

Appendix B

Mobile DTT entries

Remarks on Mobile DTT entries

The mobile DTT entries as added to the PU data structure are shown in table B.1. The height for entry 49 and 50 was kept at 0 m, as found in the ICASA TV transmitter database. An alternative height for this location could not be found in the Civil Aviation Authority (CAA) obstacle database [127]. The Mobile DTT list is consistent with annexure G of the Final Terrestrial Broadcasting Plan [5].

Table B.1: Mobile DTT entries considered

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (kW)	Polarisation	Multiplex	Antenna height (m)
1	AMANDA GLEN	18E4033	33S5118	28	530	0.2512	V	MDTT1	9
2	AMANDA GLEN	18E4033	33S5118	32	562	0.2512	V	MDTT2	9
3	AURORA	18E3829	33S4939	28	530	0.2512	V	MDTT1	24
4	AURORA	18E3829	33S4939	32	562	0.2512	V	MDTT2	24
5	BEZ VALLEY	28E0504	26S1141	35	586	0.2512	V	MDTT1	19
6	BEZ VALLEY	28E0504	26S1141	33	570	0.2512	V	MDTT2	19
7	BLOEMFONTEIN	26E1350	29S0613	33	570	50	H	MDTT1	214
8	BLOEMFONTEIN	26E1350	29S0613	47	682	50	H	MDTT2	214
9	CAPE TOWN	18E2315	34S0315	32	562	6.7999	H	MDTT2	151
10	CAPE TOWN	18E2315	34S0315	28	530	6.7999	H	MDTT1	151
11	DURBAN	30E4300	29S4611	33	570	199.526	H	MDTT1	241
12	DURBAN	30E4300	29S4611	25	506	12.2999	H	MDTT2	241
13	DURBAN NORTH	31E0224	29S4552	33	570	1	V	MDTT1	62
14	DURBAN NORTH	31E0224	29S4552	25	506	1	V	MDTT2	62
15	EAST LONDON	27E4858	32S5620	32	562	10	H	MDTT2	210
16	EAST LONDON	27E4858	32S5620	36	594	10	H	MDTT1	210
17	FISHHOEK	18E2612	34S0859	28	530	0.2512	V	MDTT1	25
18	FISHHOEK	18E2612	34S0859	32	562	0.2512	V	MDTT2	25
19	GEORGE	22E2704	33S5538	37	602	112	H	MDTT1	147
20	GEORGE	22E2704	33S5538	41	634	112	H	MDTT2	147
21	GRABOUW	18E5803	34S0605	28	530	0.5	V	MDTT1	27
22	GRABOUW	18E5803	34S0605	32	562	0.5	V	MDTT2	27
23	HELDERKRUIN	27E5132	26S0605	35	586	0.8	V	MDTT1	98
24	HELDERKRUIN	27E5132	26S0605	33	570	0.8	V	MDTT2	98
25	HOUT BAY	18E2056	34S0044	28	530	4.0004	V	MDTT1	22
26	HOUT BAY	18E2056	34S0044	32	562	4.0004	V	MDTT2	22
27	JOHANNESBURG	28E0026	26S1131	35	586	120.005	H	MDTT1	241
28	JOHANNESBURG	28E0026	26S1131	33	570	120.005	H	MDTT2	241
29	KIMBERLEY	24E5419	28S5114	38	610	50	H	MDTT1	245
30	KIMBERLEY	24E5419	28S5114	45	666	50	H	MDTT2	245
31	KLERKSDORP	26E2429	26S4514	24	498	5	H	MDTT1	253
32	KLERKSDORP	26E2429	26S4514	28	530	5	H	MDTT2	253
33	MENLO PARK	28E1609	25S4615	35	586	0.2512	V	MDTT1	23
34	MENLO PARK	28E1609	25S4615	33	570	0.2512	V	MDTT2	23
35	MIDDELBURG	29E2324	25S4904	27	522	10	H	MDTT2	253
36	MIDDELBURG	29E2324	25S4904	31	554	10	H	MDTT1	253
37	MONDEOR	27E5934	26S1652	35	586	0.2512	V	MDTT1	19
38	MONDEOR	27E5934	26S1652	33	570	0.2512	V	MDTT2	19
39	MULBARTON	28E0356	26S1736	35	586	0.2512	V	MDTT1	14
40	MULBARTON	28E0356	26S1736	33	570	0.2512	V	MDTT2	14
41	NELSPRUIT	30E4635	25S3055	45	666	50	H	MDTT1	136
42	NELSPRUIT	30E4635	25S3055	48	690	50	H	MDTT2	136
43	OVERPORT	30E5954	29S5002	33	570	1.2999	V	MDTT1	75
44	OVERPORT	30E5954	29S5002	25	506	1.2999	V	MDTT2	75
45	PAARL	18E5624	33S4253	28	530	2.4998	V	MDTT1	137
46	PAARL	18E5624	33S4253	32	562	2.4998	V	MDTT2	137
47	PIETERMARITZBURG	30E1949	29S3447	33	570	1	V	MDTT1	93
48	PIETERMARITZBURG	30E1949	29S3447	25	506	1	V	MDTT2	93
49	Pietersburg	29E2754	23S5310	34	578	5	H	MDTT1	0
50	Pietersburg	29E2754	23S5310	39	618	5	H	MDTT2	0
51	PORT ELIZABETH	25E2629	33S5610	28	530	10	H	MDTT1	210
52	PORT ELIZABETH	25E2629	33S5610	32	562	10	H	MDTT2	210
53	PRETORIA	27E5903	25S4120	35	586	100	H	MDTT1	132
54	PRETORIA	27E5903	25S4120	33	570	100	H	MDTT2	132
55	PRETORIA NORTH	28E1007	25S4125	35	586	0.2512	V	MDTT1	23
56	PRETORIA NORTH	28E1007	25S4125	33	570	0.2512	V	MDTT2	23
57	RUSTENBURG	27E0706	25S3656	49	698	5	H	MDTT1	98
58	SEA POINT	18E2919	33S5609	28	530	0.4	V	MDTT1	76
59	SEA POINT	18E2919	33S5609	32	562	0.4	V	MDTT2	76
60	SIMONSTOWN	18E2537	34S1154	28	530	0.2512	V	MDTT1	21
61	SIMONSTOWN	18E2537	34S1154	32	562	0.2512	V	MDTT2	21
62	STELLENBOSCH	18E5211	33S5456	28	530	0.2512	V	MDTT1	31
63	STELLENBOSCH	18E5211	33S5456	32	562	0.2512	V	MDTT2	31
64	SUNNYSIDE	28E1224	25S4553	35	586	1	V	MDTT1	168
65	SUNNYSIDE	28E1224	25S4553	33	570	1	V	MDTT2	168
66	TABLE MOUNTAIN	18E2413	33S5725	28	530	0.2512	V	MDTT1	13
67	TABLE MOUNTAIN	18E2413	33S5725	32	562	0.5	V	MDTT2	13
68	THE BLUFF	31E0045	29S5440	33	570	2.4998	V	MDTT1	32
69	THE BLUFF	31E0045	29S5440	25	506	2.4998	V	MDTT2	32
70	THEUNISSEN	26E3450	28S1155	39	618	50	H	MDTT1	268
71	THEUNISSEN	26E3450	28S1155	43	650	50	H	MDTT2	268
72	TYGERBERG	18E3546	33S5229	28	530	1.9999	V	MDTT1	75
73	TYGERBERG	18E3546	33S5229	32	562	1.9999	V	MDTT2	75

Appendix C

Analogue entries

Remarks on analogue entries

The analogue entries added to the PU data structure are shown in table C.3 - C.23. The analogue entries includes the analogue and analogue self-help entries as imported from the ICASA TV transmitter database. The tables details all the entries with status operational (OPE/OP) or licensed (LIC/LI) as found in the ICASA TV transmitter database.

Certain analogue entries are omitted from inclusion due to the occurrence of duplicate entries based on coordinates and channel number. In each instance of duplication, the entry with the higher ERP and/or antenna height are considered. The entries omitted and the corresponding entries kept are indicated in table C.2. Entries omitted or modified for other reasons are described and motivated in table C.1.

Table C.1: Analogue entries modified

Entry number	Reason
725	Omitted, coordinates are in Zimbabwe
856	Omitted, coordinates are in Mozambique
918	Omitted, coordinates are in Indian Ocean
1414	Omitted, coordinates are in Atlantic ocean
1415	Omitted, coordinates are in Atlantic ocean
1416	Omitted, coordinates are in Atlantic ocean
168	Omitted, invalid channel number and frequency
69	Set antenna height = 10 m
125	Set antenna height = 10 m
225	Set antenna height = 76 m
607	Set antenna height = 10 m
1019	Set antenna height = 10 m
1365	Set antenna height = 10 m
1363	Set antenna height = 10 m
1567	Set channel = 48
1374	Set channel = 65
1372	Set channel = 67

Table C.2: Duplicate analogue entries omitted from PU data structure

Entry no.		Entry no.		Entry no.		Entry no.		Entry no.		Entry no.	
Keep	Ommit	Keep	Ommit	Keep	Ommit	Keep	Ommit	Keep	Ommit	Keep	Ommit
1649	1652	1428	1430	1261	1231	1262	1232	921	920	1434	1436
1754	1755	931	938	1813	1814	934	927	928	935	930	937
1543	1577	126	127	1254	1247	1103	1104	1166	1101	1167	1102
1363	1366	1365	1364	191	193	1489	1490	1210	1212	1046	1047
31	32	1038	1037	1040	1039	560	561	440	436	441	437
442	438	443	439	1204	1205	716	717	1405	1409	1410	1406
764	763	1569	1407	1570	1408	1544	1543	1744	1743	575	574
480	353	923	922	1779	1778	674	673	1786	1785	622	623
929	936	908	909	798	797	565	566	805	804	389	388
713	714	1629	1628	595	591	596	592	597	593		

Table C.3: Analogue entries considered (1 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1	ABERDEEN	24E0302	32S2840	21	471.25	7	V	LI	SBC1	18
2	ABERDEEN	24E0302	32S2840	25	503.25	7	V	LI	SBC2	18
3	ABERDEEN	24E0302	32S2840	29	535.25	7	V	LI	SBC3	18
4	ADELAIDE	26E2036	32S4152	42	639.25	3	V	OPE	MNET	12
5	AGGENEYS BLACK MNTN	18E5004	29S1452	43	647.25	6	V	OPE	SBC1	10
6	AGGENEYS BLACK MNTN	18E5004	29S1452	47	679.25	6	V	OPE	SBC3	10
7	AGGENEYS BLACK MNTN	18E5715	29S1403	4	175.25	9	V	OPE	MNET	17
8	AGGENEYS BLACK MNTN	18E5715	29S1403	22	479.25	10	V	OPE	MNET	17
9	AGULHAS	20E0110	34S4906	56	751.25	9	V	OPE	SBC3	9
10	AGULHAS	20E0110	34S4906	60	783.25	3	V	OPE	SBC2	9
11	AGULHAS	20E0110	34S4906	64	815.25	3	V	OPE	SBC1	9
12	AGULHAS II	20E0138	34S4923	42	639.25	3	V	OPE	SBC2	20
13	AGULHAS II	20E0138	34S4923	48	687.25	3	V	OPE	SBC1	20
14	AL MUGHNI RPO	28E0042	26S1111	66	834	20	V	OPE	RAMG	151
15	ALEXANDER BAY	16E2949	28S3632	53	727.25	20	V	OPE	SBC2	32
16	ALEXANDER BAY	16E2949	28S3632	57	759.25	20	V	OPE	MNET	32
17	ALEXANDER BAY	16E2949	28S3632	61	791.25	20	V	OPE	SBC1	32
18	ALEXANDER BAY	16E2949	28S3632	65	823.25	20	V	OPE	SBC3	32
19	ALIWAL NOORD C37	26E4113	30S4309	67	839.25	9	H	OPE	MNET	10
20	ALIWAL NOORD GOEDEM	26E2218	30S3330	46	671.25	-3	H	OPE	SBC1	10
21	ALIWAL NORTH	26E3400	30S4705	53	727.25	40	H	OPE	SBC1	134
22	ALIWAL NORTH	26E3400	30S4705	57	759.25	50	H	OPE	etv	134
23	ALIWAL NORTH	26E3400	30S4705	61	791.25	50	H	OPE	SBC2	134
24	AMANDA GLEN	18E4033	33S5118	21	471.25	13	V	OPE	SBC2	9
25	AMANDA GLEN	18E4033	33S5118	25	503.25	13	V	OPE	SBC3	9
26	AMANDA GLEN	18E4033	33S5118	29	535.25	13	V	OPE	MNET	9
27	AMANDA GLEN	18E4033	33S5118	33	567.25	13	V	OPE	SBC1	9
28	AMANDA GLEN	18E4033	33S5118	61	791.25	13	V	OPE	etv	9
29	ANDRIESKRAAL	24E4233	33S4637	24	495.25	10	V	OPE	SBC2	11
30	ANDRIESKRAAL	24E4233	33S4637	28	527.25	10	V	OPE	SBC1	11
31	ANDRIESKRAAL	24E4233	33S4637	32	559.25	10	V	OPE	SBC3	11
32	ANDRIESKRAAL	24E4233	33S4637	32	562	10	V	OPE	SABC	11
33	ANDRIESKRAAL	24E4233	33S4637	36	594	10	V	OPE	SABC	11
34	ARNOT ESKOM T104	29E4843	25S5633	63	807.25	0	V	OPE	MNET	10
35	ASKHAM	20E4736	27S0003	22	479.25	17	V	LIC	SBC1	45
36	ASKHAM	20E4736	27S0003	26	511.25	17	V	LIC	SBC2	45
37	ASKHAM	20E4736	27S0003	30	543.25	17	V	LIC	SBC3	45
38	ASKHAM	20E4736	27S0003	34	575.25	17	V	LIC	ETV	45
39	ASKHAM BLOUKRANS	20E2227	26S5729	22	479.25	14	H	OPE	SBC2	30
40	ASKHAM TWEE RIVIEREN	20E3434	26S3414	23	487.25	6	V	OPE	SBC2	20
41	ASKHAM TWEE WELKOM	20E3434	26S3414	27	519.25	6	V	LIC	SBC3	18
42	ATOK PLATINUM MINE	29E5045	24S1616	26	511.25	-3	V	OPE	MNET	10
43	ATOK PLATINUM MINE	29E5045	24S1616	30	543.25	-3	V	OPE	SBC1	10
44	ATOK PLATINUM MINE	29E5045	24S1616	34	575.25	-3	V	OPE	SBC2	10
45	AUGRABIES	20E2732	28S3927	56	751.25	0	V	OPE	MNET	20
46	AURORA	18E3829	33S4939	23	487.25	4.1	V	OPE	SBC2	22
47	AURORA	18E3829	33S4939	31	551.25	4.1	V	OPE	SBC3	22
48	AURORA	18E3829	33S4939	35	583.25	4.1	V	OPE	MNET	22
49	AURORA	18E3829	33S4939	53	727.25	4.1	V	OPE	SBC1	22
50	AURORA	18E3829	33S4939	57	759.25	4.1	V	OPE	etv	22
51	BADPLAAS STERKSPRUIT	30E4235	25S5442	48	687.25	-10	V	OPE	SBC2	10
52	BARBERTON AGNES	30E5909	25S4947	39	615.25	4.8	V	OPE	SBC2	10
53	BARBERTON AGNES	30E5909	25S4947	43	647.25	4.8	V	OPE	SBC1	10
54	BARBERTON AGNES	30E5909	25S4947	47	679.25	4.8	V	OPE	MNET	10
55	BARBERTON AGNES	30E5909	25S4947	51	711.25	4.8	V	OPE	SBC3	10
56	BARBERTON FAIRVIEW	31E0536	25S4417	26	511.25	-1	V	LI	MNET	10
57	BARBERTON FAIRVIEW	31E0536	25S4417	30	543.25	-1	V	OPE	SBC1	10
58	BARBERTON FAIRVIEW	31E0536	25S4417	34	575.25	-1	V	OPE	SBC2	10
59	BARBERTON SHEBA	31E0832	25S4246	40	623.25	4.8	V	OPE	MNET	10
60	BARBERTON SHEBA	31E0832	25S4246	44	655.25	4.8	V	OPE	SBC3	10
61	BARBERTON SHEBA	31E0832	25S4246	48	687.25	4.8	V	OPE	SBC1	10
62	BARBERTON SHEBA	31E0832	25S4246	52	719.25	4.8	V	OPE	SBC2	10
63	BARBERTON SHEBA LINK	31E0727	25S4206	56	751.25	3	V	OPE	SBC2	10
64	BARBERTON SHEBA LINK	31E0727	25S4206	60	783.25	3	V	OPE	MNET	10
65	BARBERTON SHEBA LINK	31E0727	25S4206	64	815.25	3	V	OPE	SBC1	10
66	BARBERTON SHEBA LINK	31E0727	25S4206	68	847.25	3	V	OPE	SBC3	10
67	BARBERTON TONETTI	31E2225	25S3726	34	575.25	-3	V	OPE	SBC1	10
68	BARKLY E ASHTON	27E3841	30S4642	44	655.25	-10	V	OPE	SBC2	10
69	BARKLY E GROOTVLEI	27E3734	30S5850	10	223.25	7	V	OPE	SBC2	0
70	BARKLY E HALSTONE	27E4746	30S4405	48	687.25	-1	V	OPE	SBC2	10
71	BARKLY E NAAUPOORT	27E2845	31S1142	23	487.25	-10	V	OPE	SBC2	10
72	BARKLY EAST	27E3549	30S5731	27	519.25	6	V	LIC	SBC3	16
73	BARKLY EAST	27E3549	30S5731	31	551.25	6	V	LIC	ETV	16
74	BARKLY EAST	27E3549	30S5731	35	583.25	6	V	LIC	SBC1	16
75	BARKLY EAST	27E2600	30S5130	23	487.25	25.5	V	OPE	SBC2	51
76	BARKLY EAST C37.1	27E3745	30S5850	35	583.25	-3	V	OPE	SBC1	10
77	BARRYDALE	20E4433	33S5407	56	751.25	12	V	OPE	SBC2	10
78	BARRYDALE	20E4433	33S5407	58	767.25	12	V	LI	ETV	10
79	BARRYDALE	20E4433	33S5407	60	783.25	12	V	OPE	SBC1	10
80	BARRYDALE	20E4433	33S5407	64	815.25	12	V	OPE	SBC3	10
81	BARRYDALE	20E4433	33S5407	68	847.25	12	V	LI	MNET	10
82	BEAUFORT WEST	22E3431	32S2049	37	599.25	6	V	LIC	etv	20
83	BEAUFORT WEST	22E3025	32S1529	4	175.25	32	H	OPE	MNET	50
84	BEAUFORT WEST	22E3025	32S1529	7	199.25	36	H	OPE	SBC1	50
85	BEAUFORT WEST	22E3025	32S1529	10	223.25	41	H	OPE	SBC2	195
86	BEDFORD	26E0258	32S3757	23	487.25	40	H	OPE	SBC2	134
87	BEDFORD	26E0258	32S3757	27	519.25	40	H	LIC	etv	134
88	BEDFORD	26E0258	32S3757	31	551.25	40	H	OPE	SBC3	134
89	BEDFORD CAMERONS GLN	26E0242	32S2645	42	639.25	0	V	OPE	SBC2	10

Table C.4: Analogue entries considered (2 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
90	BEDFORD EILDON	26E0329	32S2440	41	631.25	0	V	OPE	SBC2	10
91	BEDFORD EILDON	26E0329	32S2440	45	663.25	-3	V	OPE	SBC1	10
92	BEESHOEK POSTMASBURG	23E0120	28S1827	39	615.25	7	V	OPE	MNET	10
93	BERGVILLE BERWIN	29E2540	28S4515	47	679.25	6	V	OPE	SBC2	6
94	BERGVILLE JAGERS	29E0857	28S3520	38	607.25	3	V	OPE	SBC3	10
95	BERGVILLE JAGERS	29E0857	28S3520	34	575.25	7	V	LIC	ETV	18
96	BERGVILLE JAGERS	29E0553	28S3543	38	607.25	7	V	LIC	SBC3	18
97	BERGVILLE JAGERS	29E0553	28S3543	42	639.25	7	V	OPE	SBC2	18
98	BERGVILLE JAGERS	29E0553	28S3543	46	671.25	7	V	OPE	SBC1	18
99	BERGVILLE JAGERS	29E0553	28S3543	50	703.25	7	V	OPE	MNET	18
100	BETHAL	29E2920	26S2742	55	743.25	7	V	LI	MNET	18
101	BETHANIE	27E3514	25S3338	44	655.25	16	V	OPE	BOP	31
102	BETHLEHEM	28E2958	28S1410	55	743.25	50	H	OPE	SBC2	160
103	BETHLEHEM	28E2958	28S1410	63	807.25	50	H	OPE	SBC1	160
104	BETHLEHEM	28E2958	28S1410	59	775.25	50	H	OPE	etv	164
105	BETHLEHEM PANORAMA	28E1956	28S1317	53	727.25	7	V	OPE	SBC2	10
106	BETHLEHEM PANORAMA	28E1953	28S1314	43	647.25	11	V	LIC	ETV	20
107	BETHLEHEM PANORAMA	28E1953	28S1314	47	679.25	11	V	LIC	SBC3	20
108	BETHLEHEM PANORAMA	28E1956	28S1317	51	711.25	7	V	OPE	SBC1	20
109	BETHLEHEM TOWN	28E1954	28S1317	61	791.25	21.8	V	OPE	MNET	10
110	BETHULIE	25E5815	30S2931	56	751.25	0	V	OPE	MNET	10
111	BETHULIE	25E5815	30S2931	60	783.25	0	V	OPE	SBC2	10
112	BETHULIE	25E5815	30S2931	64	815.25	0	V	OPE	SBC1	10
113	BETHULIE	25E5815	30S2931	68	847.25	0	V	OPE	SBC3	10
114	BETTYSBAAI C2.3	18E5342	34S2225	35	583.25	12	V	LIC	ETV	25
115	BETTYSBAAI C2.3	18E5342	34S2225	39	615.25	12	V	OPE	SBC3	25
116	BETTYSBAAI C2.3	18E5342	34S2225	47	679.25	12	V	OPE	SBC2	25
117	BETTYSBAAI C2.3	18E5342	34S2225	51	711.25	12	V	OPE	SBC1	25
118	BEZ VALLEY	28E0504	26S1141	24	495.25	18.4	V	OPE	CSN	19
119	BEZ VALLEY	28E0504	26S1141	28	527.25	18.4	V	OP	etv	19
120	BEZ VALLEY	28E0504	26S1141	56	751.25	18.4	V	OPE	SBC3	19
121	BEZ VALLEY	28E0504	26S1141	60	783.25	18.4	V	OPE	SBC1	19
122	BEZ VALLEY	28E0504	26S1141	64	815.25	18.4	V	OPE	MNET	19
123	BEZ VALLEY	28E0504	26S1141	68	847.25	18.4	V	OPE	SBC2	19
124	BLIKANA	27E3745	30S3448	39	615.25	3	V	OPE	SBC2	10
125	BLOEMENDALHF	28E1013	26S3501	62	802.55	16	V	OPE	RPLP	0
126	BLOEMENDALHF	28E1013	26S3501	66	834.75	16	V	OPE	METR	10
127	BLOEMENDALHF	28E1013	26S3501	66	834.75	16	V	OPE	METR	10
128	BLOEMFONTEIN	26E1350	29S0613	6	191.25	40	H	OPE	MNET	195
129	BLOEMFONTEIN	26E1350	29S0613	9	215.25	50	H	OPE	SBC2	195
130	BLOEMFONTEIN	26E1350	29S0613	13	247.43	50	H	OPE	SBC1	195
131	BLOEMFONTEIN	26E1350	29S0613	40	623.25	41.5	H	OPE	CSN	214
132	BLOEMFONTEIN	26E1350	29S0613	44	655.25	51.5	H	OPE	SBC3	214
133	BLOEMFONTEIN	26E1350	29S0613	48	687.25	51.5	H	OPE	etv	214
134	BLOEMHOF	25E3604	27S3836	29	535.25	6	V	LI	SBC3	45
135	BLOEMHOF	25E3604	27S3836	39	615.25	13.8	V	OPE	MNET	45
136	BLOUBERG	28E5912	23S0419	45	663.25	33	V	OPE		22
137	BLOUBERG	28E5912	23S0419	49	695.25	33	V	LIC	etv	22
138	BO-TREINTJIESPLAAS	20E2937	31S5320	21	471.25	5.4	V	OPE	SBC2	10
139	BO-VISRIVIER	20E2522	32S1854	52	719.25	8.4	V	OPE	SBC2	10
140	BO-VISRIVIER DRIEFNT	20E2928	32S2639	66	831.25	5.1	V	OPE	SBC2	10
141	BOESMANSKOP	27E1255	30S0028	23	487.25	40	H	OPE	SBC2	220
142	BOESMANSKOP	27E1255	30S0028	27	519.25	30	H	OPE	SBC1	220
143	BOESMANSKOP	27E1255	30S0028	31	551.25	40	H	OPE	etv	220
144	BONNIEVALE	20E0709	33S5632	21	471.25	17	V	OPE	SBC2	10
145	BONNIEVALE	20E0709	33S5632	25	503.25	17	V	OPE	SBC3	10
146	BONNIEVALE	20E0709	33S5632	29	535.25	17	V	OPE	SBC1	10
147	BONNIEVALE	20E0709	33S5632	33	567.25	17	V	OPE	MNET	10
148	BONNIEVALE	20E0709	33S5632	37	599.25	17	V	LI	ETV	10
149	BONNIEVALE HAPPY VAL	20E0413	33S5610	33	567.25	6	V	LIC	SBC1	10
150	BONNIEVALE HAPPY VAL	20E0413	33S5610	51	711.25	6	V	LIC	ETV	10
151	BONNIEVALE HAPPY VAL	20E0413	33S5610	59	775.25	6	V	LIC	SBC2	10
152	BONNIEVALE HAPPY VAL	20E0413	33S5610	63	807.25	6	V	LIC	SBC3	10
153	BOTHAVILLE	26E3716	27S2150	43	647.25	5.1	V	OPE	MNET	10
154	BRANDVLEI	20E2902	30S2715	61	791.25	8	V	LIC	SBC3	20
155	BRANDVLEI	20E2600	30S0600	53	730	50	H	OPE	DTT	220
156	BRANDVLEI	20E2902	30S2715	57	759.25	8	V	LIC	SBC1	220
157	BRANDVLEI RODE S PUT	20E4817	30S1026	37	599.25	12	H	OPE	SBC2	10
158	BREDASDORP	20E0310	34S3136	53	727.25	4	V	OPE	SBC1	20
159	BREDASDORP	20E0310	34S3136	57	759.25	4	V	OPE	MNET	20
160	BREDASDORP	20E0310	34S3136	61	791.25	7	V	OPE	SBC3	20
161	BREERIVIER HUGOSKRAL	19E1414	33S3430	56	751.25	-0.5	V	OPE	SBC2	10
162	BREERIVIER WITELSRIV	19E1126	33S3621	67	839.25	-3	V	OPE	SBC2	10
163	BREERIVIER WOLWEKLOF	19E1600	33S2520	53	727.25	-3	V	OPE	SBC2	10
164	BREERIVIER WOLWEKLOF	19E1600	33S2520	57	759.25	-3	V	OPE	SBC1	10
165	BREERIVIER WOLWEKLOF	19E1600	33S2520	61	791.25	-3	V	OPE	MNET	10
166	BRITSTOWN	23E3007	30S3516	54	735.25	6	V	LIC	SBC3	15
167	BRITSTOWN	23E3007	30S3516	58	767.25	6	V	LIC	ETV	15
168	BRIXTON	28E0027	26S1131	0	427	20	V	OPE	R 702	10
169	BRONKHORSTSPRUIT	28E4338	25S4613	36	591.25	23	V	OPE	MNET	19
170	BUFFELSRIVIER	17E3556	29S4158	55	743.25	6	V	LIC	ETV	18
171	BUFFELSRIVIER	17E3556	29S4158	59	775.25	6	V	LIC	ETV	18
172	BUFFELSRIVIER	17E3556	29S4158	63	807.25	6	V	LIC	ETV	18
173	BUFFELSRIVIER	17E3556	29S4158	67	839.25	6	V	LIC	ETV	18
174	BURGERDORP	20E0715	31S0003	47	679.25	10	V	OPE	MNET	0
175	BURGERSDORP	26E2021	31S0002	51	711.25	10	V	LI	SBC3	10
176	BURGERSDORP	26E2021	31S0002	39	615.25	20	V	OPE	SBC2	12
177	BURGERSDORP	26E2021	31S0002	43	647.25	20	V	OPE	SBC1	12
178	BURGERSDORP	26E2020	31S0003	47	679.25	10	V	OPE	M-NET	12

Table C.5: Analogue entries considered (3 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
179	BURGERSFRT TEIKEN BV	30E1730	24S5454	31	551.25	6.8	V	OPE	SBC2	10
180	BURGERSFRT WELGEVOND	30E1919	24S4515	21	471.25	6	V	OPE	SBC2	10
181	BUTTERWORTH	28E0927	32S1917	4	175.25	20	V	OPE	SBC2	0
182	BUTTERWORTH	28E0927	32S1917	7	199.25	20	V	OPE	SBC1	0
183	BUTTERWORTH	28E1225	32S1635	29	535.25	40	H	OPE	SBC2	221
184	BUTTERWORTH	28E1225	32S1635	31	551.25	40	H	OPE	etv	221
185	BUTTERWORTH	28E1225	32S1635	33	567.25	40	H	OPE	SBC1	221
186	BUTTERWORTH	28E1225	32S1635	35	583.25	40	H	OP	SBC3	221
187	BUTTERWORTH	28E1225	32S1635	21	471.25	37	H	OPE	MNET	253
188	BUTTERWORTH	28E1225	32S1635	25	503.25	40	H	OPE	TBNC	253
189	CALA	27E4132	31S3044	52	719.25	0	V	OPE	SBC2	10
190	CALA	27E4502	31S3315	38	607.25	47	V	OPE	SBC1	148
191	CALA	27E4502	31S3315	50	703.25	37	V	OPE	TBNC	148
192	CALA LINK	27E4502	31S3315	42	639.25	0	H	OPE	SBC1	10
193	CALA LINK	27E4502	31S3315	50	703.25	0	H	OPE	SBC1	10
194	CALA LUFUTHA	27E3849	31S3825	22	479.25	16	V	LIC	SBC1	10
195	CALA LUFUTHA	27E3849	31S3825	26	511.25	16	V	LIC	SBC2	10
196	CALA LUFUTHA	27E3849	31S3825	30	543.25	16	V	LIC	SBC3	10
197	CALEDON	19E2532	34S1303	21	471.25	5.1	V	LIC	SBC2	10
198	CALEDON	19E2532	34S1303	23	487.25	5.1	V	LIC	ETV	10
199	CALEDON	19E2532	34S1303	25	503.25	5.1	V	LIC	SBC1	10
200	CALEDON	19E2532	34S1303	29	535.25	5.1	V	LIC	SBC3	10
201	CALEDON	19E2532	34S1303	33	567.25	5.1	V	LIC	MNET	10
202	CALEDON HELDERSTROOM	19E2154	34S0429	35	583.25	6	V	OPE	M-NET	10
203	CALEDON HELDERSTROOM	19E2154	34S0429	40	623.25	6	V	LIC	ETV	10
204	CALEDON HELDERSTROOM	19E2154	34S0429	55	743.25	6	V	OPE	SBC2	10
205	CALEDON HELDERSTROOM	19E2154	34S0429	63	807.25	6	V	OPE	SBC1	10
206	CALEDON HELDERSTROOM	19E2154	34S0429	67	839.25	6	V	OPE	SBC3	10
207	CALEDON MEERLUSKLOOF	19E2537	34S0245	59	775.25	3	V	OPE	SBC2	10
208	CALITZDORP	21E4037	33S3150	21	471.25	12.5	V	LIC	SBC3	10
209	CALITZDORP	21E4037	33S3150	25	503.25	12.5	V	OPE	SBC2	10
210	CALITZDORP	21E4037	33S3150	29	535.25	12.5	V	OPE	SBC1	10
211	CALITZDORP	21E4037	33S3150	33	567.25	13	V	OPE	MNET	10
212	CALVINIA	19E4634	31S2700	30	543.25	15	H	LIC	SBC1	10
213	CALVINIA	19E4634	31S2700	34	575.25	15	V	OPE	sbc3	10
214	CALVINIA	19E4657	31S2303	22	479.25	40	H	OPE	SBC2	221
215	CALVINIA C21	19E4634	31S2700	26	511.25	19	V	OPE	MNET	10
216	CALVINIA C21	19E4657	31S2303	30	543.25	40	H	LIC	ETV	221
217	CALVINIA NARESIE	19E2618	31S1803	24	495.25	5.1	V	OPE	SBC2	10
218	CAMPUS BAY	25E4100	33S5905	66	837	7.8	V	OPE		30
219	CAPE TOWN	18E2315	34S0315	5	183.25	42	V	OPE	SBC1	138
220	CAPE TOWN	18E2315	34S0315	8	207.25	42	V	OPE	SBC2	138
221	CAPE TOWN	18E2315	34S0315	11	231.25	42	V	OPE	MNET	138
222	CAPE TOWN	18E2315	34S0315	58	767.25	38.3	H	OPE	etv	148
223	CAPE TOWN	18E2315	34S0315	62	799.25	38.3	H	OPE	SBC3	148
224	CAPE TOWN	18E2315	34S0315	54	735.25	24	H	OPE	CSN	151
225	CAPETOWN	18E2339	33S5432	66	833.25	20	V	OPE	RBSH	0
226	CARLTONVILLE DEELKRL	27E1836	26S2807	55	743.25	15	V	OPE	MNET	68
227	CARLTONVILLE W/D/LVL	27E2405	26S2507	28	527.25	9	V	LIC	BOP	73
228	CARLTONVILLE W/D/LVL	27E2405	26S2507	32	559.25	9	V	LIC	ETV	73
229	CARLTONVILLE W/D/LVL	27E2405	26S2507	54	735.25	9	V	OPE	MNET	73
230	CARLTONVILLE W/D/LVL	27E2405	26S2507	58	767.25	9	V	OPE	SBC3	73
231	CARLTONVILLE W/D/LVL	27E2405	26S2507	62	799.25	9	V	OPE	SBC1	73
232	CARLTONVILLE W/D/LVL	27E2405	26S2507	66	831.25	9	V	OPE	SBC2	73
233	CARNARVON	22E0747	30S5831	37	599.25	-3	V	LIC	SBC1	10
234	CARNARVON	22E0747	30S5831	41	631.25	-3	V	LIC	SBC3	10
235	CARNARVON	22E0747	30S5831	45	663.25	4.8	V	LIC	SBC2	10
236	CARNARVON	22E2229	30S5414	40	623.25	40	H	OPE	SBC2	252
237	CARNARVON	22E2229	30S5414	44	655.25	40	H	LIC	etv	252
238	CAROLINA	30E3757	26S1037	42	639.25	40	H	OPE	SABC1	222
239	CAROLINA	30E3757	26S1037	46	671.25	40	H	OPE	etv	222
240	CAROLINA	30E3757	26S1037	50	703.25	40	H	OPE	SABC2	222
241	CAROLINA ROOIHOOGTE	30E2122	25S5932	55	743.25	14	V	OPE	SBC2	20
242	CAROLINA ROOIHOOGTE	30E2122	25S5932	59	775.25	14	V	OPE	SBC1	20
243	CATHCART C18.1	27E0811	32S1736	37	599.25	3	V	OPE	SBC2	10
244	CERES	19E1700	33S2100	33	570	40.4	V	LIC	DTT	70
245	CERES	19E2732	33S1510	21	471.25	40.4	V	OPE	SBC2	72
246	CERES	19E2732	33S1510	29	535.25	40.4	V	LIC	etv	72
247	CERES C12.1	19E2732	33S1513	25	503.25	21	V	OPE	SBC1	10
248	CERES C12.1	19E2732	33S1513	33	567.25	21	V	OPE	SBC3	10
249	CERES C12.1	19E2732	33S1513	29	535.25	21	V	OPE	MNET	18
250	CEZA	31E2444	27S5812	22	479.25	16	V	LIC	SBC1	10
251	CEZA	31E2444	27S5812	26	511.25	16	V	LIC	SBC2	10
252	CEZA	31E2444	27S5812	30	543.25	16	V	LIC	SBC3	10
253	CEZA	31E2444	27S5812	34	575.25	16	V	LIC	ETV	10
254	CHRISTIANA	25E1024	27S5348	37	599.25	6	V	OPE	MNET	33
255	CHRISTIANA	25E1024	27S5348	41	631.25	6	V	LIC	SBC3	33
256	CHRISTIANA	24E5550	27S5303	54	735.25	40	H	OPE	etv	221
257	CHRISTIANA	24E5550	27S5303	58	767.25	40	H	OPE	SBC1	221
258	CHRISTIANA	24E5550	27S5303	62	799.25	40	H	OPE	SBC2	221
259	CHRISTIANA	24E5550	27S5303	66	831.25	40	H	OPE	SBC3	221
260	CITRUSDAL	19E0107	32S3450	55	743.25	12	V	OPE	SBC2	10
261	CITRUSDAL	19E0107	32S3450	59	775.25	12	V	OPE	SBC3	10
262	CITRUSDAL	19E0107	32S3450	63	807.25	12	V	OPE	SBC1	10
263	CITRUSDAL	19E0107	32S3450	67	839.25	12	V	OPE	MNET	10
264	CITRUSDAL PALMIETFNT	18E5336	32S2649	64	815.25	-10	V	OPE	SBC2	10
265	CLANWILLIAM	18E5242	32S1047	24	495.25	4.5	V	OPE	SBC2	10
266	CLANWILLIAM	18E5242	32S1047	28	527.25	4.5	V	OPE	SBC1	10
267	CLANWILLIAM	18E5242	32S1047	32	559.25	4.5	V	OPE	SBC3	10
268	CLANWILLIAM	18E5242	32S1047	36	591.25	4.5	V	LIC	ETV	10

Table C.6: Analogue entries considered (4 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
269	CLANWILLIAM ELANDSFN	18E5235	32S2149	23	487.25	10	V	OPE	SBC2	10
270	CLARENS	28E2457	28S3125	53	727.25	3	V	OPE	SBC3	10
271	CLARENS	28E2457	28S3125	57	759.25	10	V	OPE	SBC1	10
272	CLARENS	28E2457	28S3125	65	823.25	10	V	OPE	SBC2	10
273	CLIFTON	18E2237	33S5630	21	471.25	10	H	OPE	etv	11
274	CLIFTON	18E2237	33S5630	23	487.25	10	H	OPE	SBC1	11
275	CLIFTON	18E2237	33S5630	25	503.25	10	H	OPE	MNET	11
276	CLIFTON	18E2237	33S5630	31	551.25	10	H	OPE	SBC2	11
277	CLIFTON	18E2237	33S5630	35	583.25	10	H	OPE	SBC3	11
278	CLIFTON	18E2237	33S5630	38	610	10	H	OPE	SABC	11
279	CLIFTON	18E2237	33S5630	50	706	10	H	OPE	SABC	11
280	CLOCOLAN O62	27E3500	28S5448	48	687.25	16	V	OPE	SBC1	10
281	CLOCOLAN O62	27E3500	28S5448	52	719.25	16	V	OPE	MNET	10
282	CLUB PORTUGUESE STL	28E0325	26S1415	66	831	20	V	OPE	RCPT	10
283	COLESBERG	25E0517	30S4401	31	551.25	6	V	LIC	ETV	10
284	COLESBERG	25E0517	30S4401	35	583.25	13	V	LIC	SBC1	10
285	COLESBERG	25E0517	30S4401	42	639.25	6	V	OPE	MNET	10
286	COLESBERG	25E0328	30S4230	23	487.25	27	V	OPE	SBC2	12
287	COLESBERG	25E0328	30S4230	27	522	27	V	OPE		12
288	CONCORDIA	17E5611	29S3247	21	471.25	6	V	LIC	SBC1	13
289	CONCORDIA	17E5611	29S3247	25	503.25	6	V	LIC	SBC1	13
290	CONCORDIA	17E5611	29S3247	29	535.25	6	V	LIC	SBC3	13
291	CONCORDIA	17E5611	29S3247	33	567.25	6	V	LIC	ETV	13
292	COOKHOUSE	25E4740	32S4418	53	727.25	9	V	OPE	SBC2	11
293	COOKHOUSE	25E4740	32S4418	57	759.25	9	V	OPE	SBC1	11
294	COOKHOUSE	25E4740	32S4418	61	791.25	9	V	OPE	SBC3	11
295	COOKHOUSE	25E4740	32S4418	65	823.25	9	V	LI	ETV	11
296	CRADOCK	25E3749	32S0951	56	751.25	15	V	OPE	MNET	30
297	CRADOCK	25E3749	32S0951	60	783.25	15	V	LIC	ETV	30
298	CRADOCK	25E3227	32S1801	40	623.25	40	H	OPE	SBC2	160
299	CRADOCK	25E3227	32S1801	44	655.25	40	H	LIC	etv	160
300	CRADOCK	25E3227	32S1801	48	687.25	30	H	OPE	SBC1	160
301	CRADOCK	25E3227	32S1801	52	719.25	40	H	OPE	SBC3	160
302	CRADOCK BERGKWAGGA	25E2748	32S1332	28	527.25	11	V	OPE	SBC2	0
303	CRADOCK BERGKWAGGA	25E2748	32S1332	32	559.25	11	V	OPE	SBC1	0
304	CRADOCK GEVANGENIS	25E3629	32S0938	38	607.25	-10	V	OPE	SBC2	10
305	CRADOCK GEVANGENIS	25E3629	32S0938	42	639.25	-10	V	OPE	SBC1	10
306	CRADOCK GEVANGENIS	25E3629	32S0938	50	703.25	-10	V	LIC	SBC3	10
307	DANIELSKUIL	23E3254	28S1039	21	471.25	6	V	OPE	SBC2	10
308	DANIELSKUIL	23E3254	28S1039	25	503.25	6	V	OPE	MNET	10
309	DAVEL	29E3726	26S2730	22	479.25	47	H	OPE	SBC2	253
310	DAVEL	29E3726	26S2730	26	511.25	47	H	OPE	SBC3	253
311	DAVEL	29E3726	26S2730	30	543.25	47	H	OPE	SBC1	253
312	DAVEL	29E3726	26S2730	34	575.25	47	H	OPE	etv	253
313	DE AAR	23E5916	30S2749	5	183.25	50	H	OPE	SBC2	214
314	DE AAR	23E5916	30S2749	8	207.25	50	H	LIC	etv	214
315	DE AAR	23E5916	30S2749	11	231.25	40	H	OPE	SBC1	214
316	DE AAR II C47	24E0124	30S3840	24	495.25	12	V	OPE	MNET	26
317	DE AAR II C47	24E0124	30S3840	28	527.25	12	V	LIC	SBC3	26
318	DE AAR II C47	24E0124	30S3840	32	559.25	7	V	OPE	SBC3	26
319	DE AAR II C47	24E0124	30S3840	36	591.25	12	V	LIC	etv	26
320	DE RUST	22E3219	33S2937	27	519.25	-5.2	V	OPE	SBC1	10
321	DE RUST	22E3219	33S2937	35	583.25	-5.2	V	OPE	SBC2	10
322	DELAREYVILLE	25E2734	26S4218	39	615.25	14	V	OPE	MNET	25
323	DELAREYVILLE	25E2734	26S4218	43	647.25	14	V	OPE	SBC3	25
324	DESPATCH	25E2529	33S4553	22	479.25	23	V	OPE	SBC2	13
325	DESPATCH	25E2529	33S4553	26	511.25	23	V	OPE	SBC1	13
326	DESPATCH	25E2529	33S4553	30	543.25	23	V	OPE	SBC3	13
327	DESPATCH	25E2529	33S4553	34	575.25	23	V	OPE	etv	13
328	DEWETSDORP	26E3937	29S3444	54	735.25	10	V	OPE	SBC2	13
329	DEWETSDORP O61.1	26E3937	29S3444	58	767.25	4.8	V	OPE	SBC3	13
330	DEWETSDORP O61.1	26E3937	29S3444	62	799.25	4.8	V	OPE	SBC1	13
331	DEWETSDORP O61.1	26E3937	29S3444	65	823.25	7.8	V	OPE	MNET	13
332	DIBENG	22E5301	27S3517	54	735.25	9	V	LIC	SBC3	24
333	DONNYBROOK	29E5119	29S5456	6	191.25	40	H	OPE	SBC2	138
334	DONNYBROOK	29E5119	29S5456	9	215.25	40	H	OPE	SBC1	138
335	DONNYBROOK	29E5119	29S5456	56	751.25	53.8	H	OPE	etv	153
336	DONNYBROOK	29E5119	29S5456	60	783.25	53.8	H	OP	SBC3	153
337	DORDRECHT	27E0211	31S2307	24	495.25	9	V	LIC	ETV	15
338	DORDRECHT	27E0211	31S2307	28	527.25	9	V	LIC	ETV	15
339	DORDRECHT	27E0211	31S2307	32	559.25	9	V	LIC	ETV	15
340	DORDRECHT	27E0211	31S2307	36	591.25	9	V	LIC	ETV	15
341	DORDRECHT DRIEFNTEIN	27E0235	31S2508	40	623.25	-10	H	OPE	SBC1	10
342	DORDRECHT DRIEFNTEIN	27E0235	31S2508	44	655.25	-10	H	OPE	SBC2	10
343	DORINGKRUIN	26E4100	26S4905	68	847.25	13	V	OPE	MNET	24
344	DOUGLAS	23E3149	29S0414	53	727.25	40	H	LIC	etv	253
345	DOUGLAS	23E3149	29S0414	57	759.25	40	H	OPE	SBC2	253
346	DUIVELSKLOOF	30E0859	23S4136	37	599.25	14	V	OPE	SBC3	10
347	DUIVELSKLOOF	30E0859	23S4136	41	631.25	17	V	OPE	SBC2	10
348	DUIVELSKLOOF	30E0859	23S4136	45	663.25	17	V	OPE	SBC1	10
349	DUIVELSKLOOF	30E0859	23S4136	49	695.25	14	V	OPE	MNET	10
350	DULLSTROOM	30E1117	25S3421	53	727.25	40	H	OPE	SBC2	191
351	DULLSTROOM	30E1117	25S3421	57	759.25	40	H	LIC	etv	191
352	DULLSTROOM	30E1117	25S3421	61	791.25	33	H	OPE	SBC1	191
353	DUNDEE GLENCOE	30E0906	28S0949	37	599.25	17	V	OPE	MNET	0
354	DURBAN	30E4300	29S4611	4	175.25	50	H	OPE	SBC2	226
355	DURBAN	30E4300	29S4611	7	199.25	50	H	OPE	SBC1	226
356	DURBAN	30E4300	29S4611	10	223.25	50	H	OPE	MNET	226
357	DURBAN	30E4300	29S4611	13	247.43	50	H	OPE	SBC3	226

Table C.7: Analogue entries considered (5 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
358	DURBAN	30E4300	29S4611	38	607.25	53.9	H	OPE	etv	241
359	DURBAN	30E4300	29S4611	42	639.25	40.9	H	OPE	CSN	241
360	DZAMBA	30E1841	22S4905	53	727.25	24	V	OP	SBC2	32
361	DZAMBA	30E1841	22S4905	67	839.25	24	V	OPE	SBC1	32
362	EAST LONDON	27E4858	32S5620	4	175.25	50	H	OP	SBC3	195
363	EAST LONDON	27E4858	32S5620	6	191.25	40	H	OPE	MNET	195
364	EAST LONDON	27E4858	32S5620	9	215.25	50	H	OPE	SBC2	195
365	EAST LONDON	27E4858	32S5620	13	247.43	50	H	OPE	SBC1	195
366	EAST LONDON	27E4858	32S5620	54	735.25	54	H	OPE	etv	210
367	EKSTEENFONTEIN	17E1515	28S4927	53	727.25	6	V	LIC	SBC1	13
368	EKSTEENFONTEIN	17E1515	28S4927	57	759.25	6	V	LIC	SBC2	13
369	EKSTEENFONTEIN	17E1515	28S4927	61	791.25	6	V	LIC	SBC3	13
370	EKSTEENFONTEIN	17E1515	28S4927	65	823.25	6	V	LIC	ETV	13
371	EKULINDENI	31E0047	26S0321	53	727.25	6	V	OPE	SBC2	10
372	EKULINDENI	31E0047	26S0321	57	759.25	6	V	OPE	SBC1	10
373	EKULINDENI	31E0047	26S0321	61	791.25	6	V	OPE	SBC3	10
374	ELANDS HEIGHT	28E0710	30S4744	4	175.25	50	V	LIC	SBC1	60
375	ELANDS HEIGHT	28E0710	30S4744	6	191.25	50	V	LIC	SBC1	60
376	ELLIOT	27E5157	31S1036	58	767.25	26	V	OPE	SBC2	72
377	ELLISRAS	27E3946	23S4222	21	471.25	23.8	V	OPE	MNET	19
378	ELLISRAS T109	27E5734	23S3741	53	727.25	20	V	OPE	SBC3	10
379	EMPANGENI	31E5330	28S4440	32	562	17	V	OPE	SABC	60
380	EMPANGENI	31E5330	28S4440	34	578	17	V	OPE	SABC	60
381	EMPANGENI	31E5330	28S4440	40	623.25	17	V	OPE	MNET	60
382	EMPANGENI	31E5330	28S4440	44	655.25	17	V	OPE	SBC2	60
383	EMPANGENI	31E5330	28S4440	48	687.25	17	V	OPE	SBC1	60
384	EMPANGENI	31E5330	28S4440	52	719.25	17	V	OPE	SBC3	60
385	ENGCOBO	28E0024	31S4019	40	623.25	4.8	V	OPE	SBC1	10
386	ENGCOBO	28E0024	31S4019	52	719.25	4.8	V	OPE	SBC2	10
387	ENGCOBO	28E0035	31S3920	40	623.25	40	V	OPE	SBC1	35
388	ENGCOBO	28E0035	31S3920	49	695.25	32	V	LIC	TBNC	35
389	ENGCOBO	28E0035	31S3920	49	695.25	32	V	OPE	TBNC	35
390	ENGCOBO	28E0035	31S3920	52	719.25	40	V	OPE	SBC2	35
391	ENGCOBOLINK	27E5710	31S3711	62	799.25	0	V	OPE	SBC1	10
392	ENGCOBOLINK	27E5710	31S3711	66	831.25	3	V	OPE	SBC2	10
393	ENTSHATSHONGO	28E4010	32S0839	26	511.25	47	V	OPE	SBC1	40
394	ENTSHATSHONGO	28E4010	32S0839	30	543.25	47	V	OPE	SABC2	40
395	ENZELSBERG	26E1316	25S2507	22	479.25	33	H	OPE	SBC2	53
396	ENZELSBERG	26E1316	25S2507	30	543.25	33	H	OPE	SBC1	53
397	ENZELSBERG	26E1316	25S2507	55	743.25	33	H	LI	etv	53
398	ENZELSBERG	26E1316	25S2507	67	839.25	33	H	OPE	SABC3	53
399	ERMELO	29E5957	26S3035	67	839.25	17.7	V	OPE	MNET	14
400	ESHOWE	31E1737	28S5129	24	495.25	50	H	OPE	SBC3	134
401	ESHOWE	31E1737	28S5129	28	527.25	50	H	OPE	SBC1	134
402	ESHOWE	31E1737	28S5129	32	559.25	50	H	OPE	etv	134
403	ESHOWE	31E1737	28S5129	36	591.25	50	H	OPE	SBC2	134
404	ESTCOURT	29E5156	29S0055	31	554	17	V	OPE	SABC	30
405	ESTCOURT	29E5156	29S0055	39	615.25	17	V	OPE	SBC2	30
406	ESTCOURT	29E5156	29S0055	43	647.25	17	V	OPE	SBC1	30
407	ESTCOURT	29E5156	29S0055	51	711.25	17	V	OPE	SBC3	30
408	FELIXTON	31E5348	28S5015	22	479.25	13	V	OPE	SBC2	47
409	FELIXTON	31E5348	28S5015	26	511.25	13	V	OPE	SBC1	47
410	FELIXTON	31E5348	28S5015	30	543.25	13	V	OPE	SBC3	47
411	FICKSBURG	27E5130	28S5230	31	551.25	4	V	OPE	SBC3	10
412	FICKSBURG O62.1	27E5130	28S5230	23	487.25	13	V	OPE	MNET	10
413	FICKSBURG O62.1	27E5130	28S5230	27	519.25	4	V	OPE	SBC1	10
414	FICKSBURG TOWN	27E5127	28S5236	37	599.25	17	V	OPE	SBC2	37
415	FISHHOEK	18E2612	34S0859	55	743.25	20	V	OPE	SBC2	25
416	FISHHOEK	18E2612	34S0859	57	759.25	20	V	OP	etv	25
417	FISHHOEK	18E2612	34S0859	59	775.25	20	V	OPE	SBC1	25
418	FISHHOEK	18E2612	34S0859	63	807.25	20	V	OPE	SBC3	25
419	FISHHOEK	18E2612	34S0859	67	839.25	20	V	OPE	MNET	25
420	FOCHVILLE ELANDSRAND	27E2135	26S2715	35	583.25	22	V	OPE	MNET	55
421	FORT BEAUFORT LORR	26E3933	32S3833	45	663.25	2	V	OPE	SBC2	0
422	FOURIESBURG	28E1253	28S3737	40	623.25	2	V	OPE	SBC2	10
423	FOURIESBURG	28E1253	28S3737	48	687.25	5.1	V	OPE	MNET	10
424	FOURIESBURG	28E1253	28S3737	52	719.25	2	V	OPE	SBC1	10
425	FRANKFORT	28E3027	27S1647	56	751.25	0	V	OPE	SBC3	55
426	FRANKFORT	28E3027	27S1647	60	783.25	0	V	OPE	MNET	55
427	FRANKFORT	28E3027	27S1647	64	815.25	0	V	OPE	SBC2	55
428	FRANKFORT	28E3027	27S1647	68	847.25	0	V	OPE	SBC1	55
429	FRANSCHHOEK	19E0426	33S5426	53	727.25	36	V	OPE	SBC2	23
430	FRANSCHHOEK	19E0426	33S5426	55	743.25	30	V	OPE	CSN	23
431	FRANSCHHOEK	19E0426	33S5426	57	759.25	36	V	OPE	SBC1	23
432	FRANSCHHOEK	19E0426	33S5426	59	775.25	36	V	OPE	etv	23
433	FRANSCHHOEK	19E0426	33S5426	61	791.25	30	V	OPE	MNET	23
434	FRANSCHHOEK	19E0426	33S5426	65	823.25	30	V	OPE	SBC3	23
435	FRANSCHHOEK DRAKNSTN	19E0808	33S5515	33	567.25	6	V	OPE	SBC2	5
436	FRANSCHHOEK LA MOTTE	19E0429	33S5423	32	559.25	-1	H	OPE	SBC2	10
437	FRANSCHHOEK LA MOTTE	19E0429	33S5423	41	631.25	-1	H	OPE	M-NET	10
438	FRANSCHHOEK LA MOTTE	19E0429	33S5423	45	663.25	-1	H	OPE	SBC1	10
439	FRANSCHHOEK LA MOTTE	19E0429	33S5423	49	695.25	-1	H	OPE	SBC3	10
440	FRANSCHKLA MOTTE	19E0429	33S5423	32	559.25	0	H	OPE	SBC2	10
441	FRANSCHKLA MOTTE	19E0429	33S5423	41	631.25	0	H	OPE	MNET	10
442	FRANSCHKLA MOTTE	19E0429	33S5423	45	663.25	0	H	OPE	SBC1	10
443	FRANSCHKLA MOTTE	19E0429	33S5423	49	695.25	0	H	OPE	SBC3	10
444	FRASERBURG	21E3027	31S5458	53	727.25	7	V	OPE	MNET	18
445	FRASERBURG	21E3027	31S5458	55	743.25	7	V	LIC	ETV	18
446	FRASERBURG	21E3027	31S5458	57	759.25	7	V	OPE	SBC2	18
447	FRASERBURG	21E3027	31S5458	61	791.25	7	V	LIC	SBC1	18

Table C.8: Analogue entries considered (6 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
448	FRASERBURG	21E3027	31S5458	65	823.25	7	V	LIC	SBC3	18
449	FRASERBURG BURGERPOS	21E0205	31S4847	33	567.25	0	V	OPE	SBC2	10
450	FRASERBURG TAFELKOP	21E1221	32S0949	23	487.25	12	V	OPE	SBC2	0
451	GABA	30E4225	22S4702	44	655.25	36	V	OPE	SBC2	33
452	GABA	30E4225	22S4702	51	711.25	36	V	OPE	SBC1	33
453	GANYESA	24E1600	26S3612	22	479.25	44.8	H	OPE	SBC1	155
454	GANYESA	24E1600	26S3612	26	511.25	44.8	H	OPE	SBC2	155
455	GARIES	18E0443	30S1852	8	207.25	41.1	H	OPE	SBC2	226
456	GARIES	18E0443	30S1852	11	231.25	41.1	H	LIC	etv	226
457	GARIES C30	17E5913	30S3331	36	591.25	2	V	OPE	MNET	10
458	GENADENDAL	19E3258	34S0139	21	471.25	3	V	LIC	ETV	10
459	GENADENDAL	19E3258	34S0139	24	495.25	3	V	LIC	SBC1	10
460	GENADENDAL	19E3258	34S0139	28	527.25	3	V	OPE	SBC2	10
461	GENADENDAL	19E3258	34S0139	32	559.25	3	V	LIC	SBC3	10
462	GENADENDAL	19E3258	34S0139	36	591.25	6	V	OPE	MNET	10
463	GEORGE	22E2704	33S5538	5	183.25	42	V	OPE	SBC2	138
464	GEORGE	22E2704	33S5538	7	199.25	42	V	OPE	MNET	138
465	GEORGE	22E2704	33S5538	11	231.25	42	V	OPE	SBC1	138
466	GEORGE	22E2704	33S5538	56	751.25	42.3	H	OPE	SBC3	147
467	GEORGE	22E2704	33S5538	60	783.25	42.3	H	OPE	etv	147
468	GEORGE BERGPLAAS	22E4346	33S5308	37	599.25	11	V	OPE	SBC2	10
469	GEORGE BERGPLAAS	22E4346	33S5308	41	631.25	11	V	OPE	SBC1	10
470	GIYANI	30E4023	23S1937	21	471.28	14	V	OPE	MNET	10
471	GIYANI	30E4023	23S1937	29	535.25	14	V	OPE	SBC1	10
472	GLEN COWIE	29E4829	24S5033	21	471.25	-2.2	V	LIC	SBC1	9
473	GLEN COWIE	29E4829	24S5033	60	783.25	-2.2	V	LIC	SBC2	9
474	GLEN COWIE	29E4829	24S5033	64	815.25	-2.2	V	LIC	SBC3	9
475	GLEN COWIE	29E4829	24S5033	68	847.25	-2.2	V	LIC	ETV	9
476	GLENCOE	29E5651	28S0904	23	487.25	50	H	OPE	SBC3	135
477	GLENCOE	29E5651	28S0904	27	519.25	50	H	OPE	SBC2	135
478	GLENCOE	29E5651	28S0904	31	551.25	50	H	OPE	SBC1	135
479	GLENCOE	29E5651	28S0904	35	583.25	50	H	OPE	etv	135
480	GLENCOE/DUNDEE	30E0906	28S0949	37	599.25	17	V	LI	MNET	10
481	GLENCOE/DUNDEE N75	30E0906	28S0949	38	607.25	20	V	LIC	MNET	10
482	GLENMILL GLENDALE	31E0754	29S1904	40	623.25	15	V	OPE	MNET	10
483	GLENMILL GLENDALE	31E0754	29S1904	44	655.25	2	V	OPE	SBC3	10
484	GLENMILL GLENDALE	31E0754	29S1904	48	687.25	2	V	OPE	SBC1	10
485	GLENMILL GLENDALE	31E0754	29S1904	52	719.25	2	V	OPE	SBC2	10
486	GOODHOUSE	18E1401	28S5420	56	751.25	6	V	LIC	SBC1	10
487	GOODHOUSE	18E1401	28S5420	60	783.25	6	V	LIC	SBC2	10
488	GOODHOUSE	18E1401	28S5420	64	815.25	6	V	LIC	SBC3	10
489	GOODHOUSE	18E1401	28S5420	68	847.25	6	V	LIC	ETV	10
490	GRAAFF-REIN 2 C2	24E3151	32S1425	9	215.25	8	V	OPE	SBC1	10
491	GRAAFF-REIN 2 C2	24E3151	32S1425	13	247.43	8	V	LIC	ETV	10
492	GRAAFF-REIN 2 C2	24E3151	32S1425	22	479.25	16	V	OPE	MNET	10
493	GRAAFF-REIN 2 C2	24E3151	32S1425	30	543.25	16	V	OPE	SBC3	10
494	GRAAFF-REINET	24E3011	32S1542	26	511.25	-3	V	OPE	SBC1	10
495	GRAAFF-REINET	24E3011	32S1542	34	575.25	-3	V	OPE	SBC2	10
496	GRAAFF-REINET	24E2704	32S0444	6	191.25	41.4	V	OPE	SBC2	138
497	GRAAFF-REINET	24E2704	32S0444	13	247.43	41.4	V	LIC	etv	138
498	GRAAFFWATER	18E3654	32S0830	25	503.25	8	V	LIC	SBC3	9
499	GRAAFFWATER	18E3654	32S0830	29	535.25	8	V	LIC	ETV	9
500	GRABOUW	18E5803	34S0605	39	615.25	27	V	OPE	SBC2	27
501	GRABOUW	18E5803	34S0605	43	647.25	27	V	OPE	SBC1	27
502	GRABOUW	18E5803	34S0605	47	679.25	27	V	OPE	SBC3	27
503	GRABOUW	18E5803	34S0605	51	711.25	27	V	OPE	etv	27
504	GRAHAMSTOWN	26E4231	33S1715	5	183.25	50	H	OPE	SBC1	195
505	GRAHAMSTOWN	26E4231	33S1715	8	207.25	50	H	OPE	SBC2	195
506	GRAHAMSTOWN	26E4231	33S1715	11	231.25	30	H	OPE	MNET	195
507	GRAHAMSTOWN	26E4231	33S1715	39	615.25	54.1	H	OPE	SBC3	210
508	GRAHAMSTOWN	26E4231	33S1715	43	647.25	54.1	H	OPE	etv	210
509	GRAHAMSTOWN C9	26E3004	33S1942	29	535.25	8	V	OPE	SBC3	10
510	GRAHAMSTOWN C9	26E3004	33S1942	33	567.25	8	V	OPE	MNET	10
511	GRANAATBOSKLK LOOP10	20E0847	30S0014	57	759.25	13.5	V	OPE	SBC2	30
512	GRAVELOTTE MURCHISON	30E4252	23S5308	49	695.25	9	V	OPE	SBC1	10
513	GREYLINGSTAD T124	28E4611	26S4417	54	735.25	7	H	OPE	MNET	10
514	GREYLINGSTAD T124	28E4611	26S4417	58	767.25	7	H	OPE	SBC2	10
515	GREYLINGSTAD T124	28E4611	26S4417	62	799.25	7	H	OPE	SBC1	10
516	GREYTOWN	30E3210	29S0046	53	727.25	40	H	OPE	SBC2	160
517	GREYTOWN	30E3210	29S0046	57	759.25	40	H	OPE	etv	160
518	GREYTOWN	30E3210	29S0046	61	791.25	40	H	OPE	SBC1	160
519	GREYTOWN	30E3210	29S0046	65	823.25	40	H	OPE	SBC3	160
520	GREYTOWN N64.1	30E3647	29S0205	63	807.25	15.5	V	OPE	MNET	10
521	GREYTOWN MUDEN	30E2147	28S5658	21	471.25	16	V	OPE	SBC2	10
522	GREYTOWN MUDEN	30E2147	28S5658	25	503.25	13	V	OPE	SBC1	10
523	GREYTOWNDORP	30E3648	29S0205	34	575.25	14.8	V	OPE	SBC2	13
524	GREYTOWNDORP	30E3648	29S0205	55	743.25	14.8	V	OPE	SBC2	13
525	GREYTOWNDORP	30E3648	29S0205	59	775.25	14.8	V	OPE	SBC1	13
526	GREYTOWNDORP N	30E3647	29S0205	67	839.25	14.8	V	OPE	SBC3	13
527	GRIEKWASTAD C59	23E1349	28S4913	65	823.25	3	H	OPE	SBC1	10
528	GROBLERSHOOP	21E4412	28S5257	23	487.25	17	V	LIC	SBC1	80
529	GROBLERSHOOP	21E4412	28S5257	27	519.25	17	V	LIC	SBC3	80
530	GROBLERSHOOP	21E4412	28S5257	31	551.25	17	V	LIC	ETV	80
531	GROBLERSHOOP * C57	21E4412	28S5257	4	175.25	17.8	H	LIC	SBC3	80
532	GROBLERSHOOP * C57	21E4412	28S5257	7	199.25	17.8	H	OPE	SBC1	80
533	GROOT BRAKRIVIER	22E1300	34S0231	23	487.25	14	V	OPE	SBC2	14
534	GROOT BRAKRIVIER	22E1300	34S0231	27	519.25	14	V	OPE	SBC1	14
535	GROOT BRAKRIVIER	22E1300	34S0231	35	583.25	14	V	OPE	SBC3	14
536	GROOT BRAKRIVIER	22E1300	34S0231	39	618	14	V	OPE	SABC	14

Table C.9: Analogue entries considered (7 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
537	GROOT MARICO	26E2608	25S3711	43	647.25	23	V	OPE	SBC2	48
538	GROOTDERM BAKEN	16E4713	28S2511	30	543.25	-3	V	OPE	MNET	10
539	GROOTDERM BAKEN	16E4713	28S2511	34	575.25	-3	V	OPE	SBC2	10
540	GROOTDERM BRANDKAROS	16E3935	28S2928	64	815.25	3	V	OPE	SBC2	10
541	GROOTDERM KODASPIEK	16E5935	28S1339	27	519.25	17	V	OPE	SBC2	10
542	GROOTDERM KUBOES	16E5920	28S2707	39	615.25	6	V	OPE	SBC2	20
543	GROOTDERM KUBOES	16E5920	28S2707	43	647.25	6	V	LIC	SBC1	20
544	GROOTDERM KUBOES	16E5920	28S2707	46	671.25	6	V	LIC	SBC3	20
545	GROOTDERM KUBOES	16E5920	28S2707	51	711.25	6	V	LIC	ETV	20
546	GROOTDERM SENDLNGDRF	16E5352	28S0724	24	495.25	0	V	OPE	MNET	10
547	GROOTDERM SENDLNGDRF	16E5352	28S0724	32	559.25	0	V	OPE	SBC2	10
548	GROOTVLEI ESKOM	28E2840	26S4426	21	471.25	11	V	OPE	MNET	10
549	GROOTVLEI ESKOM	28E2840	26S4426	25	503.25	11	V	OPE	SBC3	10
550	GROOTVLEI ESKOM	28E2840	26S4426	29	535.25	11	V	OPE	SBC1	10
551	GROOTVLEI ESKOM	28E2840	26S4426	33	567.25	11	V	OPE	SBC2	10
552	HANKEY	24E5308	33S5014	39	615.25	10	V	OPE	SBC2	12
553	HANKEY	24E5308	33S5014	43	647.25	10	V	OPE	SBC1	12
554	HANKEY	24E5308	33S5014	47	679.25	10	V	OPE	SBC3	12
555	HANKEY C8.3	24E5309	33S5014	54	735.25	6	V	OPE	MNET	10
556	HANKEY C8.3	24E5213	33S4952	22	479.25	6	V	OPE	SBC1	50
557	HANKEY C8.3	24E5213	33S4952	24	495.25	6	V	OPE	ETV	50
558	HANKEY C8.3	24E5213	33S4952	26	511.25	6	V	OPE	SBC2	50
559	HANKEY C8.3	24E5213	33S4952	30	543.25	6	V	OPE	SBC3	50
560	HANKEY C8.3	24E5213	33S4952	34	575.25	6	V	OPE	MNET	50
561	HANKEY C8.3	24E5213	33S4952	34	575.25	6	V	OPE	MNET	50
562	HARDING	29E5224	30S3503	22	479.25	5.1	V	OPE	SBC2	10
563	HARDING	29E5224	30S3503	25	503.25	5.1	V	OPE	SBC1	10
564	HARDING	29E5224	30S3503	29	535.25	5.1	V	OPE	MNET	10
565	HARDING	29E5224	30S3503	34	575.25	5.1	V	OPE	SBC3	10
566	HARDING	29E5224	30S3503	34	575.25	5.1	V	LIC	ETV	10
567	HARDING WEZA	29E4443	30S3455	28	527.25	8	V	OPE	SBC1	10
568	HARDING WEZA	29E4443	30S3455	36	591.25	1.1	V	OPE	SBC2	10
569	HARRISMITH	29E1240	28S1552	4	175.25	51	V	LIC	SBC1	123
570	HARRISMITH	29E1240	28S1552	7	199.25	51	V	LIC	SABC2	123
571	HARRISMITH O74	29E0625	28S1518	21	471.25	11	V	OPE	MNET	20
572	HARRISMITH STERKFNTN	29E0246	28S2440	37	599.25	7	V	OPE	SBC2	10
573	HARRISMITH STERKFNTN	29E0246	28S2440	41	631.25	7	V	OPE	SBC1	10
574	HARTSWATER	24E4829	27S4456	56	751.25	17	V	OPE	MNET	0
575	HARTSWATER	24E4829	27S4456	56	751.25	17	V	LI	MNET	10
576	HECTORSPRUIT	31E3620	25S2847	22	479.25	28	V	LIC	SBC1	25
577	HECTORSPRUIT	31E3620	25S2847	26	511.25	28	V	OPE	SABC2	25
578	HECTORSPRUIT	31E3620	25S2847	30	546	28	V	LIC	SABC	25
579	HECTORSPRUIT	31E3620	25S2847	34	578	28	V	OPE	SABC	25
580	HECTORSPRUIT IVAURA	31E3916	25S3416	21	471.25	9	V	OPE	SBC1	10
581	HECTORSPRUIT IVAURA	31E3916	25S3416	34	575.25	9	V	OPE	SBC2	10
582	HEIDELBERG	28E2053	26S2919	38	607.25	20	V	OPE	etv	32
583	HEIDELBERG	28E2053	26S2919	46	671.25	20	V	OPE	CSN	32
584	HEIDELBERG	28E2053	26S2919	56	751.25	20	V	OPE	SBC2	32
585	HEIDELBERG	28E2053	26S2919	60	783.25	20	V	OPE	SBC3	32
586	HEIDELBERG	28E2053	26S2919	64	815.25	20	V	OPE	SBC1	32
587	HEIDELBERG	28E2053	26S2919	68	847.25	20	V	OPE	MNET	32
588	HEIDELBERG CP	20E5656	34S0553	24	495.25	6	V	LIC	SBC3	10
589	HEIDELBERG CP	20E5656	34S0553	28	527.25	6	V	LIC	ETV	10
590	HEIDELBERG CP	20E5656	34S0553	32	559.25	6	V	OPE	SBC1	10
591	HEIDELBERG WITSAND	20E5042	34S2343	40	623.25	4	V	LIC	SBC1	25
592	HEIDELBERG WITSAND	20E5042	34S2343	44	655.25	4	V	LIC	SBC2	25
593	HEIDELBERG WITSAND	20E5042	34S2343	48	687.25	4	V	LIC	SBC3	25
594	HEIDELBERG WITSAND	20E5042	34S2343	52	719.25	4	V	LIC	ETV	25
595	HEIDELBRG CP WITSAND	20E5042	34S2343	40	623.25	4	V	OPE	SBC1	25
596	HEIDELBRG CP WITSAND	20E5042	34S2343	44	655.25	4	V	OPE	SBC2	25
597	HEIDELBRG CP WITSAND	20E5042	34S2343	48	687.25	4	V	OPE	SBC3	25
598	HEILBRON	27E5753	27S1729	44	655.25	0	V	OPE	SBC2	12
599	HEILBRON	27E5753	27S1729	48	687.25	0	V	OPE	SBC3	12
600	HEILBRON	27E5753	27S1729	52	719.25	0	V	OPE	SBC1	12
601	HELDERKRUIN	27E5132	26S0605	22	479.25	28.8	V	OPE	MNET	98
602	HELDERKRUIN	27E5132	26S0605	26	511.25	28.8	V	OPE	SBC3	98
603	HELDERKRUIN	27E5132	26S0605	30	543.25	28.8	V	OPE	SBC2	98
604	HELDERKRUIN	27E5132	26S0605	34	575.25	28.8	V	OPE	SBC1	98
605	HELDERKRUIN	27E5132	26S0605	45	663.25	28.8	V	OPE	etv	98
606	HELDERKRUIN	27E5132	26S0605	49	695.25	26.5	V	OPE	CSN	98
607	HELDERSTROOM	19E2347	34S0524	56	751.25	6	V	OPE	MNET	0
608	HELDERSTROOM	19E2347	34S0524	35	583.25	6	V	LI	MNET	10
609	HERMANUS	19E1318	34S2447	21	471.25	27.8	V	OPE	etv	32
610	HERMANUS	19E1318	34S2447	24	495.25	27.8	V	OPE	SBC2	32
611	HERMANUS	19E1318	34S2447	28	527.25	27.8	V	OPE	SBC1	32
612	HERMANUS	19E1318	34S2447	32	559.25	27.8	V	OPE	SBC3	32
613	HERMANUS * C2.1	19E1318	34S2447	36	591.25	14.8	V	OPE	MNET	32
614	HEROLDSBAAI	22E2323	34S0313	38	607.25	7.5	V	OPE	MNET	10
615	HEROLDSBAAI	22E2323	34S0313	42	639.25	4.5	V	OPE	SBC2	10
616	HEROLDSBAAI	22E2323	34S0313	46	671.25	4.5	V	OPE	SBC1	10
617	HEROLDSBAAI	22E2323	34S0313	50	703.25	7.5	V	OPE	SBC3	10
618	HERSCHEL	27E1110	30S3543	22	479.25	6	V	LIC	SBC1	15
619	HERSCHEL	27E1110	30S3543	26	511.25	6	V	LIC	SBC2	15
620	HERSCHEL	27E1110	30S3543	30	543.25	6	V	LIC	SBC3	15
621	HERSCHEL	27E1110	30S3543	34	575.25	6	V	LIC	ETV	15
622	HEX RIVIER VALLEY	19E4054	33S2840	27	519.25	14	V	LIC	ETV	40
623	HEX RIVIER VALLEY	19E4054	33S2840	27	519.25	14	V	LIC	SBC3	40
624	HEX RIVIER VALLEY	19E4054	33S2840	31	551.25	14	V	LIC	SBC1	40
625	HEXR SANDHLS KANETVL	19E3208	33S3100	63	807.25	-10	V	OPE	SBC2	10
626	HEXRIVIER	19E3923	33S3054	23	487.25	20	V	OPE	SBC2	18

Table C.10: Analogue entries considered (8 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
627	HEXRIVIER	19E3923	33S3054	27	519.25	20	V	LIC	etv	18
628	HLOBANE ALPHA AN	31E0736	27S4327	58	767.25	-3	V	OPE	SBC2	15
629	HLOBANE ALPHA AN	31E0736	27S4327	62	799.25	-3	V	OPE	SBC1	15
630	HLOBANE AMCOAL	31E0615	27S4124	40	623.25	16.1	V	OPE	SBC2	5
631	HLOBANE AMCOAL	31E0615	27S4124	52	719.25	17	V	OPE	SBC1	5
632	HLOBANE COLLIERY	30E5935	27S4254	22	479.25	3	V	OPE	SBC2	10
633	HLOBANE COLLIERY	30E5935	27S4254	25	503.25	3	V	OPE	SBC1	10
634	HLOBANE COLLIERY	31E0206	27S4242	28	527.25	8	V	OPE	SBC1	20
635	HLOBANE COLLIERY	31E0206	27S4242	32	559.25	8	V	OPE	SBC2	20
636	HLOBANE COLLIERY	31E0206	27S4242	36	591.25	8	V	OPE	SBC3	20
637	HLOBANE RUSTENBURG	31E1106	27S4729	55	743.25	10	V	OPE	SBC2	10
638	HOEDSPRUIT	30E5208	24S3230	39	615.25	50	H	OPE	SBC2	160
639	HOEDSPRUIT	30E5208	24S3230	43	647.25	43	H	OPE	SBC3	160
640	HOEDSPRUIT	30E5208	24S3230	47	679.25	43	H	OPE	SBC1	160
641	HOEDSPRUIT	30E5208	24S3230	51	711.25	50	H	OPE	etv	160
642	HOEDSPRUIT T112	30E5219	24S3222	45	663.25	23	V	OPE	MNET	30
643	HONDEKLIPBAAI	17E1634	30S1902	23	487.25	7	V	LIC	SBC1	20
644	HONDEKLIPBAAI	17E1634	30S1902	42	639.25	7	V	LIC	SBC3	20
645	HOPETOWN	24E0506	29S3747	38	607.25	10	V	LIC	ETV	30
646	HOPETOWN	24E0506	29S3747	42	639.25	10	V	LIC	SBC1	30
647	HOPETOWN	24E0506	29S3747	46	671.25	10	V	LIC	SBC2	30
648	HOPETOWN	24E0506	29S3747	50	703.25	10	V	LIC	SBC3	30
649	HORIZON	27E5131	26S0644	68	852.5	20	V	OPE	RHIZ	12
650	HOTAZEL	22E5759	27S1220	38	607.25	17	V	OPE	MNET	10
651	HOTAZEL	22E5759	27S1220	42	639.25	17	V	LIC	SBC3	10
652	HOTAZEL BLACK ROCK	22E5002	27S0733	46	671.25	11	V	LIC	SBC3	10
653	HOTAZEL BLACKROCK	22E5002	27S0733	50	703.25	11	V	OPE	MNET	10
654	HOUT BAY	18E2056	34S0044	48	687.25	36	V	OPE	etv	22
655	HOUT BAY	18E2056	34S0044	52	719.25	36	V	OPE	CSN	22
656	HOUT BAY	18E2056	34S0044	56	751.25	36	V	OPE	SBC1	22
657	HOUT BAY	18E2056	34S0044	60	783.25	36	V	OPE	SBC2	22
658	HOUT BAY	18E2056	34S0044	64	815.25	36	V	OPE	MNET	22
659	HOUT BAY	18E2056	34S0044	68	847.25	36	V	OPE	SBC3	22
660	HOWICK	30E1352	29S3013	21	471.25	9	V	OPE	SBC2	29
661	HOWICK	30E1352	29S3013	25	503.25	9	V	OPE	SBC1	29
662	HOWICK	30E1352	29S3013	29	535.25	9	V	OPE	SBC3	29
663	HOWICK	30E1352	29S3013	31	551.25	9	V	OPE	SBC3	29
664	HUMANSDORP EERSTERIV	24E1319	34S0411	39	615.25	7	V	OPE	SBC2	10
665	HUMANSDORP OUBOSSTND	24E1125	34S0326	51	711.25	7	V	OPE	SBC2	10
666	IFAFA MARINA	30E3823	30S2621	32	559.25	3	V	OPE	SBC2	10
667	INDWE PINEGROVE	27E1806	31S2023	40	623.25	13	V	OPE	SBC2	10
668	INDWE PINEGROVE	27E1806	31S2023	48	687.25	13	V	OPE	SBC1	10
669	JAGERSFONTEIN	25E2552	29S4522	38	607.25	7	V	LIC	SBC3	10
670	JAGERSFONTEIN O48.2	25E2552	29S4522	42	639.25	7	V	OPE	SBC2	10
671	JAGERSFONTEIN O48.2	25E2552	29S4522	50	703.25	7	V	OPE	SBC1	10
672	JAMESTOWN	26E4917	31S0653	23	487.25	5.4	V	OPE	SBC2	10
673	JAN KEMPDORP	24E5043	27S5451	38	607.25	13	V	LI	MNET	10
674	JAN KEMPDORP T71	24E5043	27S5451	38	607.25	13	V	LIC	MNET	24
675	JANSENVILLE	24E4005	32S5620	45	663.25	7	H	OPE	SBC1	10
676	JANSENVILLE	24E4005	32S5620	49	695.25	7	H	OPE	MNET	10
677	JANSENVILLE	24E4005	32S5620	53	727.25	1.8	H	OPE	SBC2	10
678	JANSENVILLE	24E4005	32S5620	61	791.25	4	H	OPE	SBC3	10
679	JANSENVILLE IVONIA	24E4436	32S4553	21	471.25	1.1	V	OPE	SBC2	10
680	JANSVILLE SCHIETPORT	24E3854	33S1320	50	703.25	9	V	OPE	MNET	10
681	JANSVILLE SCHIETPORT	24E3854	33S1320	55	743.25	9	V	OPE	SBC3	10
682	JANSVILLE SCHIETPORT	24E3854	33S1320	67	839.25	8.5	V	OPE	MNET	10
683	JOHANNESBURG	28E0027	26S1131	6	191.25	50	H	OPE	SBC1	225
684	JOHANNESBURG	28E0027	26S1131	9	215.25	50	H	OPE	SBC2	225
685	JOHANNESBURG	28E0027	26S1131	13	247.43	50	H	OPE	SABC3	225
686	JOHANNESBURG	28E0027	26S1131	39	615.25	50	H	OPE	MNET	240
687	JOHANNESBURG	28E0027	26S1131	43	647.25	50	H	OPE	CSN	240
688	JOHANNESBURG	28E0027	26S1131	47	679.25	53	H	OPE	ETV	240
689	JOHANNESBURG	28E0027	26S1131	58	767.25	43	H	OPE	DTT	240
690	JOHANNESBURG	28E0027	26S1131	62	799.25	50.8	H	LIC	ODTT	240
691	JOUBERTINA	23E5218	33S4917	22	479.25	6	V	OPE	SBC1	10
692	JOUBERTINA	23E5218	33S4917	26	511.25	6	V	OPE	MNET	10
693	JOUBERTINA	23E5218	33S4917	30	543.25	6	V	OPE	SBC2	10
694	JOUBERTINA	23E5218	33S4917	34	575.25	16	V	LIC	SBC3	10
695	JOUBERTINA	23E5218	33S4917	37	599.25	16	V	LIC	ETV	10
696	JOUBERTINA DIEPKLOOF	23E5100	33S5115	23	487.25	2	V	OPE	SBC2	10
697	KAKAMAS	20E3730	28S4706	37	599.25	9	V	OPE	MNET	32
698	KAKAMAS	20E3730	28S4706	41	631.25	9	V	LIC	SBC1	32
699	KAKAMAS	20E3730	28S4706	45	663.25	9	V	LIC	SBC3	32
700	KAKAMAS SEEKOEISTEEK	20E0250	28S2726	54	735.25	7.5	V	OPE	SBC2	10
701	KANGWANE EKULINDENI	31E0225	26S0334	53	727.25	6	V	OPE	SBC2	10
702	KANGWANE EKULINDENI	31E0225	26S0334	57	759.25	6	V	OPE	SBC1	10
703	KANGWANE KANYAMAZANE	31E1113	25S2719	57	759.25	7	V	OPE	SBC2	10
704	KANGWANE KANYAMAZANE	31E1113	25S2719	61	791.25	7	V	OPE	SBC1	10
705	KANGWANE LOUIEVILLE	31E1635	25S4015	40	623.25	7	V	OPE	SBC2	10
706	KANGWANE LOUIEVILLE	31E1635	25S4015	44	655.25	7	V	OPE	SBC1	10
707	KANGWANE STEYNSDORP	30E5840	26S0720	43	647.25	0	V	LIC	SBC3	10
708	KANGWANE STEYNSDORP	30E5840	26S0720	47	679.25	0	V	LIC	SBC1	10
709	KANGWANE STEYNSDORP	30E5840	26S0720	51	711.25	0	V	LIC	SBC2	10
710	KANGWANE SWALLUWNEST	30E5315	26S1315	53	727.25	10	V	OPE	SBC2	10
711	KANGWANE SWALLUWNEST	30E5315	26S1315	57	759.25	10	V	OPE	SBC1	10
712	KAREEDOUW	24E1715	33S5748	54	735.25	13	V	OPE	SBC2	10
713	KAREEDOUW	24E1715	33S5748	58	767.25	13	V	OPE	MNET	10
714	KAREEDOUW	24E1715	33S5748	58	767.25	7	V	LI	MNET	10
715	KAREEDOUW	24E1715	33S5748	62	799.25	13	V	OPE	SBC1	10
716	KAREEDOUW	24E1715	33S5748	66	831.25	13	V	OPE	SBC3	10
717	KAREEDOUW	24E1715	33S5748	66	831.25	10	V	OPE	SBC3	10

Table C.11: Analogue entries considered (9 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
718	KAREEDOUW	24E2548	34S0129	25	503.25	30	H	OPE	SBC2	93
719	KAREEDOUW	24E2548	34S0129	29	535.25	30	H	LIC	etv	93
720	KAREEDOUW	24E2548	34S0129	33	567.25	30	H	OPE	SBC1	93
721	KEIMOES	20E5950	28S4300	56	751.25	9	V	OPE	SBC1	10
722	KEIMOES	20E5950	28S4300	60	783.25	9	V	OPE	SBC2	10
723	KEIMOES	20E5950	28S4300	64	815.25	9	V	OPE	SBC3	10
724	KEIMOES	20E5950	28S4300	68	847.25	9	V	OPE	MNET	10
725	KEIMOS	28E4300	20S5950	68	847.25	3	V	OPE	MNET	0
726	KENHARDT	21E0950	29S2050	53	727.25	6	V	OPE	SBC1	20
727	KENHARDT	21E0950	29S2050	57	759.25	9	V	OPE	SBC2	20
728	KENHARDT	21E0950	29S2050	61	791.25	9	V	OPE	SBC3	20
729	KENHARDT	21E0950	29S2050	65	823.25	6	V	LI	MNET	20
730	KENHART	29E2050	29S0950	65	823.25	6	V	OPE	MNET	0
731	KESTELL O74.2	28E4251	28S1805	30	543.25	8	V	OPE	SBC2	10
732	KESTELL O74.2	28E4251	28S1805	34	575.25	1.1	V	OPE	SBC1	10
733	KIEPERSOL BOERE-VER.	31E0356	25S0328	53	727.25	16	V	OPE	MNET	10
734	KIEPERSOL BOERE-VER.	31E0356	25S0328	57	759.25	16	V	OPE	SBC2	10
735	KIEPERSOL BOERE-VER.	31E0356	25S0328	61	791.25	16	V	OPE	SBC1	10
736	KIEPERSOL BOERE-VER.	31E0356	25S0328	65	823.25	14.8	V	OPE	SBC3	10
737	KIMBERLEY	24E5419	28S5114	4	175.25	50	H	OPE	SBC2	226
738	KIMBERLEY	24E5419	28S5114	7	199.25	50	H	OPE	SBC1	226
739	KIMBERLEY	24E5419	28S5114	10	223.25	40	H	OPE	MNET	226
740	KIMBERLEY	24E5419	28S5114	24	495.25	51.3	H	OPE	SBC3	242
741	KIMBERLEY	24E5419	28S5114	32	559.25	51.3	H	OPE	etv	245
742	KING WILLIAMS TOWN	27E2450	32S5136	64	815.25	14	H	OPE	MNET	25
743	KING WILLIAMS TOWN	27E2450	32S5136	68	847.25	42.6	H	OPE	SBC3	25
744	KING WILLIAMS TOWN	27E1536	32S4044	38	607.25	42.6	H	OPE	etv	160
745	KING WILLIAMS TOWN	27E1536	32S4044	56	751.25	42.6	H	OPE	SBC2	160
746	KING WILLIAMS TOWN	27E1536	32S4044	60	783.25	42.6	H	OPE	SBC1	160
747	KING WILLIAMS TOWN	27E1536	32S4044	68	847.25	42.6	H	OPE	SBC3	160
748	KIRKWOOD	25E2653	33S2322	22	479.25	13	V	OPE	SBC2	13
749	KIRKWOOD C16.1	25E2653	33S2322	26	511.25	4.8	V	OPE	SBC1	10
750	KIRKWOOD C16.1	25E2653	33S2322	30	543.25	4.8	V	OPE	MNET	10
751	KIRKWOOD C16.1	25E2653	33S2322	34	575.25	4.8	V	OPE	SBC3	10
752	KKL CALITZDORP SPA	21E4608	33S3936	46	671.25	9	V	OPE	SBC2	0
753	KKL KRAKEELRIVIER	23E4223	33S4728	35	583.25	3	V	OPE	SBC2	10
754	KKL LOUTERWATER	23E4116	33S4836	53	727.25	10	V	OPE	SBC1	12
755	KKL LOUTERWATER	23E4116	33S4836	57	759.25	10	V	LIC	SBC3	12
756	KKL LOUTERWATER	23E4116	33S4836	61	791.25	10	V	LIC	SBC2	12
757	KKL MISGUND I	23E3035	33S4738	24	495.25	3	V	OPE	SBC2	10
758	KKL MISGUND II	23E3121	33S4500	55	743.25	10	V	OPE	SBC2	12
759	KKL MISGUND II	23E3121	33S4500	59	775.25	10	V	OPE	SBC1	12
760	KKL MISGUND II	23E3121	33S4500	63	807.25	10	V	OPE	SBC3	12
761	KKL SAPTOU	23E2735	33S4013	41	631.25	15	V	OPE	SBC2	10
762	KKL UITVLUGT	24E0230	33S4834	43	647.25	8	V	OPE	SBC2	10
763	KLEINMOND	19E0051	34S2010	37	599.25	6	V	OPE	SBC1	10
764	KLEINMOND	19E0051	34S2010	37	599.25	9	V	OPE	SBC1	10
765	KLEINMOND	19E0051	34S2010	41	631.25	9	V	OPE	SBC2	10
766	KLEINMOND	19E0051	34S2010	45	663.25	9	V	OPE	SBC3	10
767	KLEINMOND	19E0051	34S2010	49	695.25	9	V	LIC	ETV	10
768	KLEINMOND	19E0828	34S2315	55	743.25	29	V	OPE	SABC2	15
769	KLEINSEE	17E0419	29S4005	52	719.25	7.5	V	LIC	ETV	19
770	KLEINSEE	17E0419	29S4005	56	751.25	7.5	V	OPE	SBC2	19
771	KLEINSEE	17E0419	29S4005	60	783.25	7.5	V	OPE	MNET	19
772	KLEINSEE	17E0419	29S4005	64	815.25	7	V	LIC	SBC1	19
773	KLEINSEE	17E0419	29S4005	68	847.25	7.5	V	OPE	SBC3	19
774	KLERKSDORP	26E2429	26S4514	32	559.25	50	H	OPE	etv	253
775	KLERKSDORP	26E2429	26S4514	37	599.25	40	H	OPE	SBC3	253
776	KLERKSDORP	26E2429	26S4514	41	631.25	50	H	OPE	SBC1	253
777	KLERKSDORP	26E2429	26S4514	45	663.25	50	H	OPE	SBC2	253
778	KLERKSDORP	26E2429	26S4514	49	695.25	40	H	OPE	MNET	253
779	KLIPPLAAT	24E2001	33S0125	22	479.25	9	V	LIC	SBC1	15
780	KLIPPLAAT	24E2001	33S0125	26	511.25	9	V	LIC	SBC2	15
781	KLIPPLAAT	24E2001	33S0125	30	543.25	9	V	LIC	SBC3	15
782	KLIPPLAAT	24E2001	33S0125	34	575.25	9	V	LIC	ETV	15
783	KNYSNA	23E0259	34S0438	54	735.25	16	V	OPE	MNET	20
784	KNYSNA	23E0236	34S0418	22	479.25	27	V	OPE	SBC2	24
785	KNYSNA	23E0236	34S0418	26	511.25	27	V	OPE	SBC1	24
786	KNYSNA	23E0236	34S0418	30	543.25	27	V	OPE	etv	24
787	KNYSNA	23E0236	34S0418	34	575.25	27	V	OPE	SBC3	24
788	KNYSNA BRENTON	23E0231	34S0150	39	615.25	6	V	OPE	SBC2	14
789	KNYSNA BRENTON	23E0231	34S0150	43	647.25	6	V	OPE	SBC1	14
790	KNYSNA BRENTON	23E0231	34S0150	47	679.25	9	V	OPE	MNET	14
791	KNYSNA BRENTON	23E0231	34S0150	51	711.25	6	V	LIC	SBC3	14
792	KNYSNA NATURES VAL.	23E3430	33S5826	54	735.25	4	V	OPE	SBC1	10
793	KNYSNA NATURES VAL.	23E3430	33S5826	58	767.25	4	V	OPE	SBC2	10
794	KOFFIEFONTEIN	24E5929	29S2533	21	471.25	0	V	OPE	SBC1	10
795	KOFFIEFONTEIN	24E5929	29S2533	25	503.25	0	V	OPE	SBC2	10
796	KOFFIEFONTEIN	24E5929	29S2533	29	535.25	-3	V	LIC	SBC3	10
797	KOFFIEFONTEIN	24E5929	29S2533	33	567.25	7	V	LI	MNET	10
798	KOFFIEFONTEIN	24E5929	29S2533	33	567.25	7	V	OPE	MNET	10
799	KOINGNAAS	17E1734	30S1137	35	583.25	5.1	V	LIC	ETV	20
800	KOINGNAAS	17E1734	30S1137	39	615.25	-1	V	OPE	SBC2	20
801	KOINGNAAS	17E1734	30S1137	43	647.25	-1	V	OPE	MNET	20
802	KOINGNAAS	17E1734	30S1137	47	679.25	5.1	V	LIC	SBC1	20
803	KOINGNAAS	17E1734	30S1137	51	711.25	5.1	V	LIC	SBC3	20
804	KOKSTAD	29E2924	30S3642	34	575.25	20	V	LIC	etv	10

Table C.12: Analogue entries considered (10 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
805	KOKSTAD	29E2924	30S3642	34	575.25	26	V	OPE	etv	12
806	KOKSTAD	29E2924	30S3642	42	639.25	26	V	OPE	SBC2	12
807	KOKSTAD * N51.1	29E2924	30S3642	38	607.25	26	V	OPE	SBC3	10
808	KOKSTAD * N51.1	29E2924	30S3642	46	671.25	26	V	OPE	SBC1	10
809	KOKSTAD * N51.1	29E2924	30S3642	50	703.25	20	V	OPE	MNET	10
810	KOKSTAD LUCKNOW	29E1524	30S3430	25	503.25	3.4	V	OPE	MNET	10
811	KOMAGGAS	17E2911	29S4818	23	487.25	6	V	OPE	SBC1	18
812	KOMAGGAS	17E2911	29S4818	27	519.25	6	V	LIC	SBC2	18
813	KOMAGGAS	17E2911	29S4818	31	551.25	6	V	LIC	SBC3	18
814	KOMAGGAS	17E2911	29S4818	35	583.25	6	V	LIC	ETV	18
815	KOMATIPOORT	31E5842	25S2724	54	735.25	8	V	OPE	SBC2	10
816	KOMATIPOORT	31E5842	25S2724	58	767.25	8	V	OPE	SBC1	10
817	KOMATIPOORT	31E5842	25S2724	62	799.25	8	V	OPE	MNET	10
818	KOMATIPOORT	31E5842	25S2724	66	831.25	8	V	OPE	SBC3	10
819	KOPPIES	27E3428	27S1405	40	623.25	7	V	OPE	MNET	25
820	KOUEBOKKEVLD BRONAAR	19E2448	33S0040	28	527.25	-3	V	OPE	SBC1	10
821	KOUEBOKKEVLD BRONAAR	19E2448	33S0040	36	591.25	-3	V	OPE	SBC2	10
822	KROONSTAD	27E1110	27S2516	21	471.25	20	H	OPE	MNET	160
823	KROONSTAD	27E1110	27S2516	53	727.25	50	H	OPE	etv	222
824	KROONSTAD	27E1110	27S2516	57	759.25	50	H	OPE	SBC2	222
825	KROONSTAD	27E1110	27S2516	61	791.25	50	H	OPE	SBC1	222
826	KROONSTAD	27E1110	27S2516	65	823.25	50	H	OPE	SBC3	222
827	KURUMAN	23E1849	27S2105	56	751.25	37	H	LIC	SBC1	155
828	KURUMAN	23E1849	27S2105	60	783.25	37	H	LIC	SBC2	155
829	KURUMAN HILLS	23E3338	27S5313	5	183.25	51	H	OPE	etv	226
830	KURUMAN HILLS	23E3338	27S5313	8	207.25	51	H	OPE	SBC2	226
831	KURUMAN HILLS	23E3338	27S5313	11	231.25	51	H	OPE	SBC1	226
832	KURUMAN MUNIC	23E2542	27S2711	40	623.25	12.2	V	OPE	MNET	31
833	KYALAMI	28E0500	26S0000	62	799.25	30	V	LIC	ODTT	10
834	LADISMITH	21E1612	33S3010	26	511.25	8	H	LIC	ETV	12
835	LADISMITH	21E1612	33S3010	30	543.25	8	H	LIC	SBC1	12
836	LADISMITH	21E1612	33S3010	34	575.25	8	H	LIC	SBC3	12
837	LADISMITH (CAPE)	21E2520	33S3754	22	479.25	40	H	OPE	SBC2	73
838	LADISMITH (CAPE)	21E2520	33S3754	26	511.25	40	H	LIC	etv	73
839	LADISMITH AMALIENSTN	21E2923	33S2928	31	551.25	1.1	V	OPE	SBC2	10
840	LADY GREY	27E1235	30S4251	21	471.25	6	V	LIC	SBC1	12
841	LADY GREY	27E1235	30S4251	25	503.25	6	V	LIC	SBC2	12
842	LADY GREY	27E1235	30S4251	29	535.25	6	V	LIC	SBC3	12
843	LADY GREY	27E1235	30S4251	33	567.25	6	V	LIC	ETV	12
844	LADYBRAND	27E2602	29S1136	53	727.25	12	H	OPE	SBC1	10
845	LADYBRAND	27E2602	29S1136	62	799.25	12	H	OPE	MNET	10
846	LADYBRAND	27E2602	29S1136	66	831.25	19.8	H	OPE	SBC2	10
847	LADYBRAND	27E2242	29S1018	56	751.25	40	H	OPE	SBC2	160
848	LADYBRAND	27E2242	29S1018	60	783.25	33	H	OPE	SBC1	160
849	LADYBRAND	27E2242	29S1018	68	847.25	40	H	OPE	etv	160
850	LADYBRAND ALPHA O62	27E3646	29S0610	64	815.25	6.6	V	OPE	SBC2	10
851	LADYSMITH	29E4719	28S3523	21	471.25	24.8	V	OPE	MNET	64
852	LADYSMITH	29E4719	28S3523	25	503.25	30	V	OPE	SBC3	64
853	LADYSMITH	29E4719	28S3523	29	535.25	30	V	OPE	SBC1	64
854	LADYSMITH	29E4719	28S3523	33	567.25	30	V	OPE	SBC2	64
855	LADYSMITH	29E4719	28S3523	42	639.25	30	V	OPE	etv	64
856	LAINGSBURG	33E1118	20S5106	49	695.25	6	V	OPE	MNET	0
857	LAINGSBURG	20E5106	33S1118	37	599.25	6	V	LIC	SBC1	10
858	LAINGSBURG	20E5106	33S1118	41	631.25	-3	V	LIC	SBC2	10
859	LAINGSBURG	20E5106	33S1118	45	663.25	-3	V	LIC	SBC3	10
860	LAINGSBURG	20E5106	33S1118	49	695.25	6	V	OPE	MNET	10
861	LAINGSBURG DOORNKLF	21E1100	33S2133	54	735.25	-10	V	OPE	SBC2	10
862	LAINGSBURG DRIEFONTN	21E0331	33S2524	27	519.25	6	V	OPE	SBC2	10
863	LAINGSBURG FLORISKRL	20E5959	33S1735	64	815.25	7	V	OPE	SBC2	10
864	LAINGSBURG WILGRBOME	20E5424	32S4549	35	583.25	18	V	OPE	SBC2	10
865	LAMBERTS BAY C20	18E1846	32S0539	56	751.25	4	V	OPE	SBC1	18
866	LAMBERTS BAY C20	18E1846	32S0539	60	783.25	4	V	OPE	SBC3	18
867	LANGEBAAN	18E0211	33S0549	37	599.25	8	V	LIC	ETV	20
868	LANGEBAAN	18E0211	33S0549	40	623.25	8	V	LIC	SBC1	20
869	LANGEBAAN	18E0211	33S0549	44	655.25	8	V	LIC	SBC2	20
870	LANGEBAAN	18E0211	33S0549	48	687.25	8	V	LIC	SBC3	20
871	LANGEBAANWEG	18E0957	32S5818	35	583.25	3	V	OPE	MNET	30
872	LEKKERSING	17E0543	28S5952	37	599.25	6	V	LIC	ETV	20
873	LEKKERSING	17E0543	28S5952	54	735.25	6	V	LIC	SBC1	20
874	LEKKERSING	17E0543	28S5952	58	767.25	6	V	LIC	SBC2	20
875	LEKKERSING	17E0543	28S5952	62	799.25	6	V	LIC	SBC3	20
876	LIME ACRES C69	23E2754	28S2127	43	647.25	7.8	V	OPE	SBC3	22
877	LIME ACRES C69	23E2754	28S2127	47	679.25	6	V	OPE	SBC2	22
878	LIME ACRES C69	23E2754	28S2127	51	711.25	6	V	OPE	SBC1	22
879	LIME ACRES C69	23E2754	28S2127	54	735.25	6	V	OPE	MNET	22
880	LIME ACRES C69	23E2754	28S2127	58	767.25	7.8	V	OPE	ETV	22
881	LINDLEY	27E5509	27S5203	40	623.25	3	V	OPE	SBC2	10
882	LINDLEY	27E5509	27S5203	44	655.25	3	V	OPE	SBC1	10
883	LINDLEY	27E5509	27S5203	48	687.25	3	V	LIC	SBC3	10
884	LINMEYER	28E0416	26S1608	21	471.25	3	H	OPE	CSN	7
885	LINMEYER	28E0416	26S1608	23	487.25	3	H	OPE	SBC3	7
886	LINMEYER	28E0416	26S1608	25	503.25	3	H	OPE	etv	7
887	LINMEYER	28E0416	26S1608	27	519.25	3	H	OPE	SBC1	7
888	LINMEYER	28E0416	26S1608	31	551.25	3	H	OPE	SBC2	7
889	LINMEYER	28E0416	26S1608	35	583.25	3	H	OPE	MNET	7
890	LOERIESFONTEIN C31	19E2657	30S5638	26	511.25	9	V	OPE	SBC2	10
891	LOERIESFONTEIN C31	19E2657	30S5638	30	543.25	9	V	OPE	SBC1	10
892	LOERIESFONTEIN C31	19E2657	30S5638	34	575.25	9	V	OPE	SBC3	10
893	LOHATLHA	22E2119	31S2809	55	743.25	8	V	LIC	SBC1	15
894	LOHATLHA	22E2119	31S2809	59	775.25	8	V	LIC	SBC2	15

Table C.13: Analogue entries considered (11 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
895	LOHATLHA	22E2119	31S2809	63	807.25	8	V	LIC	SBC3	15
896	LOSKOP	29E1242	28S3941	24	495.25	31.5	V	OPE	SBC1	25
897	LOSKOP	29E1242	28S3941	28	527.25	31.5	V	OPE	SABC2	25
898	LOSKOPDAM	29E2253	25S2507	43	647.25	8	V	LIC	SBC3	10
899	LOSKOPDAM	29E2253	25S2507	47	679.25	8	V	LIC	SBC1	10
900	LOSKOPDAM	29E2253	25S2507	51	711.25	8	V	OPE	SBC2	10
901	LOUIS TRIC TIMBADOLA	30E1429	23S0134	58	767.25	7	V	OPE	SBC1	10
902	LOUIS TRIC TIMBADOLA	30E1429	23S0134	62	799.25	7	V	OPE	SBC2	10
903	LOUIS TRICHARDT	29E5407	22S5932	42	639.25	20	V	OPE	MNET	10
904	LOUIS TRICHARDT	29E4526	23S0002	5	183.25	42	V	OPE	SBC3	138
905	LOUIS TRICHARDT	29E4526	23S0002	8	207.25	42	V	OPE	SBC2	138
906	LOUIS TRICHARDT	29E4526	23S0002	11	231.25	42	V	OPE	SBC1	138
907	LOUIS TRICHARDT	29E4526	23S0002	22	479.25	47.5	V	OPE	etv	153
908	LOUWBURG	31E1632	27S3344	38	607.25	41.5	V	OP	SBC1	68
909	LOUWSBURG	31E1632	27S3344	38	607.25	41.5	V	LIC	SABC1	68
910	LOUWSBURG	31E1632	27S3344	42	639.25	41.5	V	LIC	SABC2	68
911	LOUWSBURG ITALA	31E1604	27S3445	33	567.25	3	V	OPE	SBC2	10
912	LOUWSBURG MOOIBANK	31E2242	27S3533	24	495.25	9	V	OPE	SBC1	10
913	LOUWSBURG MOOIBANK	31E2242	27S3533	28	527.25	9	V	OPE	SBC2	10
914	LOUWSBURG SKUTARI	31E0929	27S3952	64	815.25	4	V	OPE	SBC2	10
915	LOUWSCREEK	31E2231	25S3915	4	175.25	10	V	OPE	SBC2	10
916	LOXTON	23E0644	28S0234	43	647.25	22	V	LIC	SBC3	10
917	LUTZVILLE	18E2032	31S3311	38	607.25	3	V	LIC	MNET	10
918	LYDENBURG	33E1118	30S2604	42	639.25	13	V	OPE	MNET	0
919	LYDENBURG	30E2604	25S0619	22	479.25	16	V	OPE	SBC2	24
920	LYDENBURG	30E2604	25S0619	26	511.25	13	V	OPE	SBC1	24
921	LYDENBURG	30E2604	25S0619	26	514	16	V	OPE	SABC	24
922	LYDENBURG	30E2604	25S0619	30	543.25	13	V	LIC	SBC3	24
923	LYDENBURG	30E2604	25S0619	30	546	16	V	LIC	SABC	24
924	LYDENBURG	30E2604	25S0619	38	607.25	13	V	LI	MNET	24
925	LYDENBURG DOORNHOEK	30E2128	25S2123	40	623.25	5.1	V	OPE	SBC2	10
926	LYDENBURG MASHISHING	30E2524	25S0519	59	775.25	5.1	V	OPE	SBC1	10
927	MACHADODORP BOSCHHOE	30E2552	25S5118	22	479.25	5.1	V	OPE	MNET	10
928	MACHADODORP BOSCHHOE	30E2552	25S5118	26	511.25	5.1	V	OPE	SBC1	10
929	MACHADODORP BOSCHHOE	30E2552	25S5118	30	543.25	5.1	V	OPE	SBC3	10
930	MACHADODORP BOSCHHOE	30E2552	25S5118	34	575.25	5.1	V	OPE	SBC2	10
931	MACHADODORP MAMRE	30E3413	25S4202	24	495.25	7.5	H	OPE	SBC2	10
932	MACHADODORP ONVERWAG	30E3848	25S4441	55	743.25	-10	V	OPE	SBC1	10
933	MACHADODORP ONVERWAG	30E3848	25S4441	59	775.25	-10	V	OPE	SBC2	10
934	MACHDODORP BOSCHHOEK	30E2552	25S5118	22	479.25	6	V	OPE	MNET	10
935	MACHDODORP BOSCHHOEK	30E2552	25S5118	26	511.25	4.8	V	OPE	SBC1	10
936	MACHDODORP BOSCHHOEK	30E2552	25S5118	30	543.25	4.8	V	LI	SBC3	10
937	MACHDODORP BOSCHHOEK	30E2552	25S5118	34	575.25	4.8	V	OPE	SBC2	10
938	MACHDRPMAMRE PLANT	30E3413	25S4202	24	495.25	0	H	OPE	SBC2	10
939	MACLEAR	28E1928	31S0402	21	471.25	7	V	OPE	SBC2	10
940	MACLEAR	28E1928	31S0402	33	567.25	7	V	OPE	SBC1	10
941	MADIBOGO	25E1514	26S2728	55	743.25	36	H	LIC	SBC1	167
942	MADIBOGO	25E1514	26S2728	67	839.25	36	H	LIC	SBC2	167
943	MAGALIESBERGNAAUWPT	27E2018	25S5600	6	191.25	0	V	OPE	SBC1	10
944	MAGALIESBERGNAAUWPT	27E2018	25S5600	9	215.25	0	V	OPE	SBC2	10
945	MAGALIESBERGNAAUWPT	27E2018	25S5600	13	247.43	0	V	OPE	SBC3	10
946	MAGALIESBERGNAAUWPT	27E2018	25S5600	26	511.25	0	V	OPE	BOP	10
947	MAGALIESBERGNAAUWPT	27E2018	25S5600	34	575.25	0	V	OPE		10
948	MAGALIESBERGNAAUWPT	27E2018	25S5600	39	615.25	0	V	OPE	MNET	10
949	MALAMBA	30E1509	22S5356	55	743.25	19	V	OPE	SBC2	32
950	MALAMBA	30E1509	22S5356	63	807.25	19	V	OPE	SBC1	32
951	MALELANE I	31E2315	25S3752	30	543.25	19	V	OPE	SBC2	10
952	MALELANE II	31E3620	25S2847	38	607.25	10	V	OPE	MNET	10
953	MALELANE SCHMDL KOFP	31E3351	25S4039	37	599.25	-7	V	OPE	SBC2	0
954	MALMESBURY	18E4508	33S2852	52	719.25	7	V	OPE	ETV	10
955	MALMESBURY	18E4508	33S2852	55	743.25	7	V	OPE	SBC2	10
956	MALMESBURY	18E4508	33S2852	59	775.25	7	V	OPE	MNET	10
957	MALMESBURY	18E4508	33S2852	63	807.25	7	V	OPE	SBC1	10
958	MALMESBURY	18E4508	33S2852	67	839.25	7	V	OPE	SBC3	10
959	MALUTI	28E5036	30S1259	23	487.25	17	V	OPE	SBC1	20
960	MANDINI	31E2539	29S0922	55	743.25	8	V	OPE	MNET	10
961	MANDINI	31E2539	29S0922	59	775.25	8	V	OPE	SBC2	10
962	MANDINI	31E2539	29S0922	63	807.25	8	V	OPE	SBC1	10
963	MANDINI	31E2539	29S0922	67	839.25	8	V	OPE	SBC3	10
964	MARYDALE	22E0539	29S2452	37	599.25	3	V	LIC	ETV	18
965	MARYDALE	22E0539	29S2452	41	631.25	3	V	LIC	SBC1	18
966	MARYDALE	22E0539	29S2452	45	663.25	3	V	LIC	SBC3	18
967	MATATIELE	28E4908	30S2011	54	735.25	6	V	OPE	SBC2	10
968	MATATIELE	28E4908	30S2011	60	783.25	6	V	OPE	SBC1	10
969	MATATIELE	28E4908	30S2011	64	815.25	6	V	OPE	MNET	10
970	MATATIELE	28E4908	30S2011	68	847.25	6	H	LIC	SBC3	10
971	MATATIELE	28E4919	30S2345	40	623.25	40	H	OPE	SBC2	220
972	MATATIELE	28E4919	30S2345	44	655.25	40	H	OPE	SBC3	220
973	MATATIELE	28E4919	30S2345	48	687.25	40	H	OPE	SBC1	220
974	MATATIELE	28E4919	30S2345	52	719.25	40	H	OPE	etv	220
975	MATATIELE LINK N51	28E4835	30S2100	44	655.25	6	H	OPE	SBC1	10
976	MATJIESFONTEIN	20E3020	33S1652	39	615.25	40	H	OPE	SBC2	134
977	MATJIESFONTEIN	20E3020	33S1652	43	647.25	40	H	LIC	etv	134
978	MBUZINI	31E5453	25S5226	5	183.25	32.9	V	LIC	SBC1	50
979	MBUZINI	31E5453	25S5226	8	207.25	32.9	V	OPE	sabc2	50
980	MELMOTH	31E2322	28S3553	22	479.25	6	V	OPE	SBC1	29
981	MELMOTH	31E2322	28S3553	26	511.25	6	V	OPE	SBC2	29
982	MELMOTH	31E2322	28S3553	52	719.25	6	V	OPE	SBC3	29
983	MENLO PARK	28E1609	25S4615	44	655.25	16	V	OPE	CSN	23
984	MENLO PARK	28E1609	25S4615	48	687.25	16	V	OPE	etv	23
985	MENLO PARK	28E1609	25S4615	53	727.25	16	V	OPE	SBC2	23

Table C.14: Analogue entries considered (12 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
986	MENLO PARK	28E1609	25S4615	57	759.25	16	V	OPE	SBC1	23
987	MENLO PARK	28E1609	25S4615	61	791.25	16	V	OPE	MNET	23
988	MENLO PARK	28E1609	25S4615	65	823.25	16	V	OPE	SBC3	23
989	MERWEVILLE	21E3029	32S3936	21	471.25	6	V	LIC	SBC1	15
990	MERWEVILLE	21E3029	32S3936	25	503.25	6	V	LIC	SBC2	15
991	MERWEVILLE	21E3029	32S3936	29	535.25	6	V	LIC	SBC3	15
992	MERWEVILLE	21E3029	32S3936	33	567.25	6	V	LIC	ETV	15
993	MESSINA T122	30E0120	22S2041	39	615.25	17	V	OPE	MNET	20
994	MESSINA T122	30E0120	22S2041	43	647.25	17	V	OPE	SBC3	20
995	MESSINA LINK	29E5743	22S2111	54	735.25	21.5	V	OPE	MNET	20
996	MIDDELBURG	29E2324	25S4904	49	695.25	40	H	OPE	MNET	252
997	MIDDELBURG	29E2324	25S4904	23	487.25	50	H	OP	etv	253
998	MIDDELBURG	29E2324	25S4904	37	599.25	50	H	OPE	SBC3	253
999	MIDDELBURG	29E2324	25S4904	41	631.25	50	H	OPE	SBC2	253
1000	MIDDELBURG	29E2324	25S4904	45	663.25	50	H	OPE	SBC1	253
1001	MIDDELBURG K C35	24E5938	31S2845	38	607.25	17	H	LIC	SBC3	15
1002	MIDDELBURG K C35	24E5938	31S2845	42	639.25	17	H	LIC	ETV	15
1003	MIDDELBURG K C35	24E5938	31S2845	46	671.25	10	H	OPE	SBC2	15
1004	MIDDELBURG K C35	24E5938	31S2845	50	703.25	10	H	OPE	MNET	15
1005	MIDDELBURG K C35	24E5938	31S2845	66	831.25	10	H	OPE	SBC1	15
1006	MIDDELPOS	20E1331	31S5521	53	727.25	8	V	OPE	SBC2	10
1007	MIDMAR ESSELDENE	30E0327	29S3226	59	775.25	1.1	V	OPE	SBC1	10
1008	MIDMAR ESSELDENE	30E0327	29S3226	67	839.25	1.1	V	OPE	SBC2	10
1009	MIDMAR MPOPHOMENI	30E1000	29S3225	39	615.25	9	V	OPE	SBC2	10
1010	MIDMAR MPOPHOMENI	30E1000	29S3225	43	647.25	9	V	OPE	SBC1	10
1011	MIER	20E2025	26S4547	24	495.25	17	V	LIC	SBC1	28
1012	MIER	20E2025	26S4547	28	527.25	17	V	LIC	SBC2	28
1013	MIER	20E2025	26S4547	32	559.25	17	V	LIC	SBC3	28
1014	MIER	20E2025	26S4547	36	591.25	17	V	LIC	ETV	28
1015	MIER KLEIN MIER	20E1632	26S4422	56	751.25	6	V	LIC	SBC1	10
1016	MIER KLEIN MIER	20E1632	26S4422	60	783.25	6	V	LIC	SBC2	10
1017	MIER KLEIN MIER	20E1632	26S4422	64	815.25	6	V	LIC	SBC3	10
1018	MIER KLEIN MIER	20E1632	26S4422	68	847.25	6	V	LIC	ETV	10
1019	MIER LEEUBOS	20E0644	26S4248	34	575.25	6	V	LIC	SBC3	0
1020	MIER LEEUBOS	20E0644	26S4248	22	479.25	6	V	LIC	SBC1	10
1021	MIER LEEUBOS	20E0644	26S4248	26	511.25	6	V	LIC	ETV	10
1022	MIER LEEUBOS	20E0644	26S4248	30	543.25	6	V	LIC	SBC2	10
1023	MIER PHILANDERSBRON	20E0540	26S4838	40	623.25	6	V	LIC	SBC1	10
1024	MIER PHILANDERSBRON	20E0540	26S4838	44	655.25	6	V	LIC	SBC2	10
1025	MIER PHILANDERSBRON	20E0540	26S4838	48	687.25	6	V	LIC	SBC3	10
1026	MIER PHILANDERSBRON	20E0540	26S4838	52	719.25	6	V	LIC	ETV	10
1027	MOGOBOYA	30E1259	23S5936	37	599.25	17	V	LIC	SBC1	17
1028	MOGOBOYA	30E1259	23S5936	41	631.25	17	V	LIC	SBC2	17
1029	MOGOBOYA	30E1259	23S5936	49	695.25	17	V	LIC	SBC3	17
1030	MONDEOR	27E5934	26S1652	22	479.25	19.5	V	OPE	CSN	19
1031	MONDEOR	27E5934	26S1652	24	495.25	19.5	V	OPE	SBC3	19
1032	MONDEOR	27E5934	26S1652	26	511.25	19.5	V	OPE	etv	19
1033	MONDEOR	27E5934	26S1652	28	527.25	19.5	V	OPE	SBC1	19
1034	MONDEOR	27E5934	26S1652	32	559.25	19.5	V	OPE	SBC2	19
1035	MONDEOR	27E5934	26S1652	36	591.25	19.5	V	OPE	MNET	19
1036	MONTAGU	20E0837	33S4716	22	479.25	17	V	OPE	SBC2	12
1037	MONTAGU	20E0837	33S4714	26	511.25	9	V	OPE	SBC1	12
1038	MONTAGU	20E0837	33S4714	26	514	17	V	OPE	SABC	12
1039	MONTAGU	20E0837	33S4714	30	543.25	12	V	OPE	MNET	12
1040	MONTAGU	20E0837	33S4714	30	546	17	V	OPE	MNET	12
1041	MONTAGU	20E0837	33S4716	34	575.25	9	V	OPE	SBC3	12
1042	MONTAGU * C2.2	20E0837	33S4714	37	599.25	9	V	LIC	ETV	12
1043	MONTAGU HOTBATHS	20E0752	33S4552	21	471.25	6	V	LIC	ETV	10
1044	MONTAGU HOTBATHS	20E0752	33S4552	24	495.25	16	V	OPE	MNET	10
1045	MONTAGU HOTBATHS	20E0752	33S4552	28	527.25	6	V	OPE	SBC3	10
1046	MONTAGU HOTBATHS	20E0752	33S4552	32	559.25	4.8	V	OPE	SBC2	10
1047	MONTAGU HOTBATHS	20E0752	33S4552	32	559.25	6	V	OPE	MNET	10
1048	MONTAGU HOTBATHS	20E0752	33S4552	36	591.25	6	V	OPE	SBC1	10
1049	MONTAGU KOO BV	19E4629	33S3916	55	743.25	4	V	OPE	SBC2	10
1050	MOOI RIVIER	30E0027	29S1128	43	647	4.8	H	OPE	SBC3	10
1051	MOOI RIVIER	30E0027	29S1128	47	679.25	8	H	OPE	SBC2	10
1052	MOOI RIVIER	30E0027	29S1128	51	711.25	8	H	OPE	SBC1	10
1053	MOOI RIVIER	29E5204	29S1107	37	599.25	40	H	OPE	SBC2	160
1054	MOOI RIVIER	29E5204	29S1107	41	631.25	40	H	OPE	SBC3	160
1055	MOOI RIVIER	29E5204	29S1107	45	663.25	40	H	OPE	SBC1	160
1056	MOOI RIVIER	29E5204	29S1107	49	695.25	40	H	OPE	etv	160
1057	MOOI RIVIER BRUNTVIL	29E5422	29S1237	41	631.25	11	H	OPE	SBC1	10
1058	MOORREESBURG C11	18E4127	33S0756	31	551.25	7	V	OPE	MNET	10
1059	MOSSELBAAI DANABAAI	22E0239	34S1135	39	615.25	14	V	OPE	SBC2	20
1060	MOSSELBAAI DANABAAI	22E0239	34S1135	43	647.25	13	V	OPE	SBC1	20
1061	MOSSELBAAI DANABAAI	22E0239	34S1135	45	663.25	14	V	OPE	SBC3	20
1062	MOSSELBAAI DANABAAI	22E0239	34S1135	49	695.25	14	V	OPE	MNET	20
1063	MOTSWEDI	25E5218	25S1655	45	663.25	38.5	V	LIC	SBC1	75
1064	MOTSWEDI	25E5218	25S1655	49	695.25	38.5	V	LIC	SBC2	75
1065	MOUNT AYLIFF	29E2341	30S5011	23	487.25	30	H	OPE	MNET	136
1066	MOUNT AYLIFF	29E2341	30S5011	27	519.25	40	H	OPE	TBNC	136
1067	MOUNT AYLIFF	29E2341	30S5011	31	551.25	40	H	OPE	SBC1	136
1068	MOUNT AYLIFF	29E2341	30S5011	35	583.25	33.4	H	OPE	SBC2	136
1069	MOUNT AYLIFF	29E2341	30S5011	39	615.25	40	H	OPE	etv	136
1070	MOUNT AYLIFF	29E2341	30S5011	43	647.25	40	H	OP	SBC3	136
1071	MOUNT FLETCHER	28E3041	30S5011	47	682	30	H	LIC		13
1072	MOUNT FLETCHER	28E3041	30S5011	51	711.25	30	H	LIC	TBNC	13
1073	MSAULI MINE	31E0456	26S0015	24	495.25	8.4	V	OPE	SBC3	10

Table C.15: Analogue entries considered (13 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1074	MSAULI MINE	31E0456	26S0015	37	599.25	6	V	OPE	MNET	10
1075	MSAULI MINE	31E0456	26S0015	39	615.25	8.4	V	OPE	SBC1	10
1076	MSAULI MINE	31E0456	26S0015	46	671.25	8.4	V	OPE	SBC2	10
1077	MSAULI MINE	31E0456	26S0015	51	711.25	8.4	V	OPE	MNET	10
1078	MSAULI MINE LINK	31E0731	25S5513	37	599.25	6	V	OPE	MNET	10
1079	MSAULI MINE LINK	31E0731	25S5513	42	639.25	4.8	V	OPE	SBC2	10
1080	MSAULI MINE LINK	31E0731	25S5513	49	695.25	4.8	V	OPE	SBC1	10
1081	MT-A-SOUR KAROS HTL	28E5927	28S3915	57	759.25	0	V	OPE	SBC1	10
1082	MT-A-SOUR/R.NAT.PARK	28E5729	28S4136	44	655.25	0	V	OPE	SBC1	10
1083	MT-A-SOUR/R.NAT.PARK	28E5729	28S4136	52	719.25	0	V	OPE	SBC2	10
1084	MTFLETCHER	28E3303	30S4324	26	511.25	4.8	V	OPE	SBC1	10
1085	MTFLETCHER	28E3303	30S4324	34	575.25	4.8	V	OPE	SBC1	10
1086	MTSHANYANA	27E4015	31S5124	53	727.25	3	V	OPE	SBC2	10
1087	MTUBATUBA	32E1037	28S2643	22	479.25	-2.2	V	OPE	MNET	10
1088	MULBARTON	28E0356	26S1736	53	727.25	14.8	V	OPE	SBC3	13
1089	MULBARTON	28E0356	26S1736	55	743.25	14.8	V	OPE	CSN	13
1090	MULBARTON	28E0356	26S1736	57	759.25	14.8	V	OPE	SBC1	13
1091	MULBARTON	28E0356	26S1736	59	775.25	14.8	V	OPE	etv	13
1092	MULBARTON	28E0356	26S1736	61	791.25	14.8	V	OPE	SBC2	13
1093	MULBARTON	28E0356	26S1736	65	823.25	14.8	V	OPE	MNET	13
1094	MURRAYSBURG	23E4601	31S5819	21	471.25	1.5	V	OPE	SBC2	10
1095	NABABEEP C41	17E4828	29S3505	40	623.25	14	V	OPE	SBC3	40
1096	NABABEEP C41	17E4828	29S3505	44	655.25	17	V	OPE	MNET	40
1097	NABABEEP C41	17E4828	29S3505	48	687.25	14	V	LIC	ETV	40
1098	NAPIER	19E5333	34S3145	6	191.25	30	V	OPE	SBC1	195
1099	NAPIER	19E5333	34S3145	9	215.25	30	V	OPE	SBC2	195
1100	NAPIER	19E5333	34S3145	38	607.25	42	H	LIC	etv	214
1101	NATAL ANTHRACITE BOS	31E0244	27S4935	45	663.25	-5.2	V	OPE	SBC2	10
1102	NATAL ANTHRACITE BOS	31E0244	27S4935	49	695.25	-5.2	V	OPE	SBC1	10
1103	NATAL ANTHRACITE LAN	31E0244	27S4708	49	695.25	-5.2	V	OPE	SBC1	10
1104	NATAL ANTHRACITE LAN	31E0244	27S4708	49	695.25	-5.2	V	OPE	SBC2	10
1105	NELSPOORT	23E0206	32S0636	53	727.25	9	V	LIC	SBC1	15
1106	NELSPOORT	23E0206	32S0636	57	759.25	9	V	LIC	SBC3	15
1107	NELSPOORT	23E0206	32S0636	61	791.25	9	V	OPE	SBC2	15
1108	NELSPOORT	23E0206	32S0636	65	823.25	9	V	LIC	ETV	15
1109	NELSPOORT COURLNDKLF	22E5656	32S0448	63	807.25	1.1	V	OPE	SBC2	10
1110	NELSPOORT SANATORIUM	23E0205	32S0641	53	727.25	3	V	OPE	SBC1	10
1111	NELSPOORT SANATORIUM	23E0205	32S0641	57	759.25	3	V	OPE	SBC3	10
1112	NELSPOORT SANATORIUM	23E0205	32S0641	61	791.25	3	V	OPE	SBC2	10
1113	NELSPRUIT	30E4635	25S3055	24	495.25	51.8	H	OPE	SBC2	136
1114	NELSPRUIT	30E4635	25S3055	28	527.25	41.8	H	OPE	MNET	136
1115	NELSPRUIT	30E4635	25S3055	32	559.25	51.8	H	OPE	SBC1	136
1116	NELSPRUIT	30E4635	25S3055	36	591.25	41.8	H	OPE	SBC3	136
1117	NELSPRUIT	30E4635	25S3055	38	607.25	51.8	H	OPE	etv	136
1118	NELSPRUIT DENSA	30E5049	25S1611	21	471.25	7	V	OPE	SBC2	10
1119	NELSPRUIT DENSA	30E5049	25S1611	26	511.25	7	V	OPE	SBC1	10
1120	NELSPRUIT DENSA	30E5049	25S1611	34	575.25	7	V	OPE	MNET	10
1121	NELSPRUIT STERKSPRUT	30E3023	25S2329	67	839.25	3	V	OPE	SBC2	10
1122	NEW AMALFI VIELSALM	29E0913	30S0634	47	679.25	-10	V	OPE	SBC1	10
1123	NEW PAN HELLENIC	28E0753	26S0900	66	832.5	20	H	OPE	RPHV	10
1124	NEWCAST KILBARCH	29E5724	27S5018	46	671.25	2	V	OPE	SBC1	10
1125	NEWCAST KILBARCH	29E5724	27S5018	50	703.25	2	V	OPE	SBC2	10
1126	NEWCASTLE	29E5712	27S4307	45	663.25	30	V	OPE	etv	61
1127	NEWCASTLE	29E5712	27S4307	56	751.25	30	V	OP	SBC2	61
1128	NEWCASTLE	29E5712	27S4307	60	783.25	30	V	OP	SBC1	61
1129	NEWCASTLE	29E5712	27S4307	64	815.25	27	V	OP	MNET	61
1130	NEWCASTLE	29E5712	27S4307	68	847.25	30	V	OP	SBC3	61
1131	NGANGELIZWE	28E4831	31S3715	23	487.25	13	H	OPE	etv	16
1132	NGANGELIZWE	28E4831	31S3715	27	519.25	13	H	OPE	SBC3	16
1133	NGANGELIZWE	28E4831	31S3715	39	615.25	13	H	OPE	MNET	16
1134	NGANGELIZWE	28E4831	31S3715	43	647.25	13	H	OPE	SBC2	16
1135	NGANGELIZWE	28E4831	31S3715	47	679.25	13	H	OPE	SBC1	16
1136	NGANGELIZWE	28E4831	31S3715	51	711.25	13	H	OPE	TBNC	16
1137	NGODWANA	30E3909	25S3341	22	479.25	5.4	V	OPE	MNET	10
1138	NGODWANA	30E3909	25S3341	26	511.25	5.4	V	OPE	SBC3	10
1139	NGODWANA	30E3909	25S3341	30	543.25	5.4	V	OPE	SBC1	10
1140	NGODWANA	30E3909	25S3341	34	575.25	5.4	V	OPE	SBC2	10
1141	NGQELENI	29E0042	31S4117	35	583.25	3	H	OPE	SBC1	10
1142	NIEU-BETHESDA	24E3352	31S5206	22	479.25	3	V	LIC	SBC1	10
1143	NIEU-BETHESDA	24E3352	31S5206	26	511.25	3	V	LIC	SBC2	10
1144	NIEU-BETHESDA	24E3352	31S5206	30	543.25	3	V	LIC	SBC3	10
1145	NIEUWOUDTVILLE	19E0425	31S2245	55	743.25	13	V	LIC	SBC1	24
1146	NIEUWOUDTVILLE	19E0425	31S2245	59	775.25	13	V	LIC	SBC2	24
1147	NIEUWOUDTVILLE	19E0425	31S2245	63	807.25	13	V	LIC	SBC3	24
1148	NIEUWOUDTVILLE	19E0425	31S2245	67	839.25	13	V	LIC	ETV	24
1149	NONGOMA	31E3927	27S5418	32	562	40	H	OPE	SABC	194
1150	NONGOMA	31E3927	27S5418	34	578	40	H	OPE	SABC	194
1151	NONGOMA	31E3927	27S5418	54	735.25	40	H	OPE	etv	194
1152	NONGOMA	31E3927	27S5418	58	767.25	40	H	OPE	SBC1	194
1153	NONGOMA	31E3927	27S5418	62	799.25	40	H	OPE	SBC2	194
1154	NONGOMA	31E3927	27S5418	66	831.25	40	H	OPE	SBC3	194
1155	NONGOMA SWARTMFOLOZI	31E1955	27S5816	24	495.25	9	V	OPE	SBC2	10
1156	NORTHAM ZONDEREINDE	27E2053	24S4845	22	479.25	16.8	V	OPE	MNET	75
1157	NORTHAM ZONDEREINDE	27E2053	24S4845	30	543.25	16.8	V	LIC	ETV	75
1158	NORTHAM ZONDEREINDE	27E2053	24S4845	34	575.25	16.8	V	LIC	SBC3	75
1159	NOUPOORT	24E5733	31S1032	56	751.25	4.8	V	LIC	SBC3	10
1160	NOUPOORT	24E5733	31S1032	60	783.25	4.8	V	LIC	SBC1	10
1161	NOUPOORT	24E5733	31S1032	64	815.25	4.8	V	LIC	SBC2	10
1162	NOUPOORT	24E5601	31S1814	54	735.25	40	H	OPE	SBC2	160
1163	NOUPOORT	24E5601	31S1814	58	767.25	40	H	LIC	etv	160

Table C.16: Analogue entries considered (14 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1164	NQUTU	30E4042	28S1543	55	743.25	41.8	V	OPE	SBC1	102
1165	NQUTU	30E4042	28S1543	59	775.25	41.8	V	OPE	SBC2	102
1166	NTL ANTH BOSHOEK	31E0244	27S4935	45	663.25	7	V	OPE	SBC2	10
1167	NTL ANTH BOSHOEK	31E0244	27S4935	49	695.25	7	V	OPE	SBC1	10
1168	NTL ANTH LANGKRANS	31E0244	27S4708	29	535.25	4.8	V	OPE	SBC2	10
1169	NTL ANTH LANGKRANS	31E0244	27S4708	33	567.25	6	V	OPE	SBC1	10
1170	NYLSTROOM	28E2311	24S4229	53	727.25	11.2	V	OPE	MNET	10
1171	NYLSTROOM	28E2559	24S4758	55	743.25	30	V	OPE	SBC2	41
1172	NYLSTROOM	28E2559	24S4758	59	775.25	30	V	OPE	SBC1	41
1173	NYLSTROOM	28E2559	24S4758	63	807.25	30	V	OPE	SBC3	41
1174	NYLSTROOM	28E2559	24S4758	67	839.25	30	V	LIC	etv	41
1175	OHRIGSTAD	30E3051	24S4603	30	543.25	7	V	OPE	SBC2	10
1176	OHRIGSTAD BRANDDRAAI	30E3821	24S3145	37	599.25	8	V	OPE	SBC2	0
1177	OUDTSHOORN	22E1335	33S3449	44	655.25	12	H	LIC	etv	25
1178	OUDTSHOORN	22E1602	33S4016	4	175.25	35	H	OP	SBC3	50
1179	OUDTSHOORN	22E1602	33S4016	13	247.43	35	H	OP	MNET	50
1180	OUDTSHOORN	22E1602	33S4016	6	191.25	42	H	OPE	SBC1	138
1181	OUDTSHOORN	22E1602	33S4016	9	215.25	42	H	OPE	SBC2	138
1182	OUDTSHOORN	22E1602	33S4016	44	655.25	40.7	H	LIC	etv	153
1183	OUDTSHOORN KANGO	22E1633	33S2444	21	471.25	3	V	LIC	SBC1	10
1184	OUDTSHOORN KANGO	22E1633	33S2444	25	503.25	3	V	LIC	SBC2	10
1185	OUDTSHOORN KANGO	22E1633	33S2444	29	535.25	3	V	LIC	SBC3	10
1186	OUTENIQUA GLENTANA	22E1538	34S0309	21	471.25	11	V	OPE	SBC2	10
1187	OUTENIQUA GLENTANA	22E1538	34S0309	25	503.25	11	V	OPE	SBC1	10
1188	OVERPORT	30E5954	29S5002	22	479.25	31	V	OPE	SBC2	74
1189	OVERPORT	30E5954	29S5002	24	495.25	31.1	V	OPE	CSN	74
1190	OVERPORT	30E5954	29S5002	26	511.25	31	V	OPE	SBC1	74
1191	OVERPORT	30E5954	29S5002	28	527.25	31.1	V	OPE	etv	74
1192	OVERPORT	30E5954	29S5002	30	543.25	31	V	OPE	MNET	74
1193	OVERPORT	30E5954	29S5002	34	575.25	31	V	OPE	SBC3	74
1194	OVERSEAS CHINESE RAD	28E0745	25S5735	66	835.5	-60	V	OPE		6
1195	PAARL	18E5624	33S4253	37	599.25	33	V	OPE	SBC2	137
1196	PAARL	18E5624	33S4253	38	610	34	V	OPE	M-NET	137
1197	PAARL	18E5624	33S4253	39	615.25	33	V	OPE	etv	137
1198	PAARL	18E5624	33S4253	41	631.25	33	V	OPE	MNET	137
1199	PAARL	18E5624	33S4253	45	663.25	33	V	OPE	SBC1	137
1200	PAARL	18E5624	33S4253	47	679.25	33	V	OPE	CSN	137
1201	PAARL	18E5624	33S4253	49	695.25	33	V	OPE	SBC3	137
1202	PAARL	18E5624	33S4253	50	706	34	V	OPE	SABC	137
1203	PAFURI	31E0914	22S2334	40	623.25	7	H	OPE	SBC2	10
1204	PARSONS HILL	25E0629	33S5610	68	850.55	20	V	OPE	RAD5	15
1205	PARSONS HILL	25E0629	33S5610	68	850.8	20	V	OPE	RAD5	15
1206	PATENSIE	24E4943	33S4537	56	751.25	10	V	OPE	SBC2	12
1207	PATENSIE	24E4943	33S4537	60	783.25	10	V	OPE	SBC1	12
1208	PATENSIE	24E4943	33S4537	62	802	10	V	OPE	SABC	12
1209	PATENSIE	24E4943	33S4537	64	818	10	V	OPE	SABC	12
1210	PATENSIE	24E4943	33S4537	68	847.25	10	V	OPE	SBC3	12
1211	PATENSIE BOERE C8.5	24E4937	33S4539	64	815.25	9	V	OPE	MNET	10
1212	PATENSIE BOERE C8.5	24E4943	33S4537	68	847.25	10	V	OPE	SBC3	12
1213	PAUL SAUER DAM	24E3343	33S4513	23	487.25	13	V	OPE	SBC2	12
1214	PAUL SAUER DAM	24E3343	33S4513	27	519.25	13	V	OPE	SBC1	12
1215	PAUL SAUER DAM	24E3343	33S4513	29	538	13	V	OPE	SABC	12
1216	PAUL SAUER DAM	24E3343	33S4513	31	551.25	13	V	OPE	SBC3	12
1217	PAUL SAUER DAM	24E3343	33S4513	35	586	13	V	OPE	SABC	12
1218	PAULPIETERSBURG	30E5028	27S2647	53	727.25	17	V	OPE	SBC2	25
1219	PAULPIETERSBURG	30E5028	27S2650	57	759.25	17	V	OPE	SBC1	25
1220	PAULPIETERSBURG	30E5028	27S2647	61	791.25	17	V	LIC	SBC3	25
1221	PAULPIETERSBURG	30E5028	27S2647	65	823.25	17	V	LIC	ETV	25
1222	PEARSTON	25E0808	32S3533	57	759.25	5.1	V	LIC	SBC2	10
1223	PEARSTON C16	25E0808	32S3533	53	727.25	5.1	V	OPE	SBC1	10
1224	PEARSTON C16	25E0808	32S3533	65	823.25	5.1	V	LIC	SBC3	10
1225	PEARSTON BUFFELSHOEK	25E1021	32S2752	46	671.25	-10	V	OPE	SBC2	10
1226	PEARSTON SPIOENKOP	25E0820	32S4848	22	479.25	-2.2	V	OPE	SBC2	10
1227	PEARSTON WILGERFONTN	25E1330	32S3444	46	671.25	1.1	V	OPE	SBC2	10
1228	PELA MISSION	19E0921	29S0151	38	607.25	-3	V	LIC	SBC1	18
1229	PELA MISSION	19E0921	29S0151	42	639.25	-3	V	LIC	SBC2	18
1230	PELA MISSION	19E0921	29S0151	46	671.25	-3	V	LIC	SBC3	18
1231	PELGRIMSRUS GROOTFON	30E4400	24S5642	63	807.25	2.8	V	OPE	SBC2	10
1232	PELGRIMSRUS GROOTFON	30E4400	24S5642	67	839.25	2.8	V	OPE	SBC1	10
1233	PETRUS STEYN	28E1906	27S3100	24	495.25	40	H	OPE	SBC2	221
1234	PETRUS STEYN	28E1906	27S3100	28	527.25	40	H	OPE	etv	221
1235	PETRUS STEYN	28E1906	27S3100	32	559.25	40	H	OPE	SBC1	221
1236	PHALABORWA	31E0824	23S5702	22	479.25	23.8	V	OPE	MNET	29
1237	PHILIPPOLIS 048.1	25E1619	30S1511	21	471.25	6	V	OPE	SBC2	8
1238	PHILIPPOLIS 048.1	25E1619	30S1511	26	511.25	6	V	OPE	SBC1	8
1239	PIET PLESSIS	24E4955	26S1456	38	607.25	40	H	OPE	SBC1	253
1240	PIET PLESSIS	24E4955	26S1456	42	639.25	40	H	OPE	ETV	253
1241	PIET PLESSIS	24E4955	26S1456	46	671.25	40	H	OPE	ETV	253
1242	PIET PLESSIS	24E4955	26S1456	50	703.25	40	H	OPE	SBC2	253
1243	PIET RETIEF	30E4103	27S0111	5	183.25	42	H	OPE	SBC1	257
1244	PIET RETIEF	30E4103	27S0111	8	207.25	42	H	OPE	etv	257
1245	PIET RETIEF	30E4103	27S0111	11	231.25	42	H	OPE	SBC2	257
1246	PIET RETIEF KLIPWAL	31E1601	27S2534	41	631.25	-2.2	V	OPE	SBC1	10
1247	PIET RETIEF POTGIETR	30E5720	26S5450	54	735.25	-5.2	V	OPE	SBC2	10
1248	PIETERMARITZBURG	30E1949	29S3447	22	479.25	30	V	OPE	SBC1	93
1249	PIETERMARITZBURG	30E1949	29S3447	26	511.25	30	V	OPE	SBC2	93
1250	PIETERMARITZBURG	30E1949	29S3447	30	543.25	30	V	OPE	MNET	93
1251	PIETERMARITZBURG	30E1949	29S3447	34	575.25	30	V	OPE	SBC3	93
1252	PIETERMARITZBURG	30E1949	29S3447	40	623.25	30	V	OPE	CSN	93

Table C.17: Analogue entries considered (15 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1253	PIETERMARITZBURG	30E1949	29S3447	44	655.25	30	V	OPE	etv	93
1254	PIETR POTGIETHK	30E5720	26S5450	54	735.25	0	V	OPE	SBC2	10
1255	PIKETBERG	18E4419	32S5457	65	823.25	21	V	OPE	MNET	10
1256	PIKETBERG	18E4419	32S4909	6	191.25	40	H	OPE	SBC1	164
1257	PIKETBERG	18E4419	32S4909	9	215.25	40	H	OPE	SBC2	164
1258	PIKETBERG	18E4419	32S4909	13	247.43	40	H	OPE	SABC3	164
1259	PIKETBERG	18E4419	32S4909	27	519.25	50.5	H	OPE	ETV	183
1260	PILGRIMSRUS BUFFELHK	30E4339	24S4116	55	743.25	7.8	V	OPE	MNET	10
1261	PILGRIMSRUS GROOTFNT	30E4400	24S5642	63	807.25	3	V	OPE	SBC2	10
1262	PILGRIMSRUS GROOTFNT	30E4400	24S5642	67	839.25	3	V	OPE	SBC1	10
1263	PILGRIMSRUS VAALHOEK	30E4557	24S4437	37	599.25	6	V	OPE	MNET	10
1264	PILGRIMSRUS VAK.OORD	30E4305	24S5111	38	607.25	6	V	OPE	MNET	10
1265	PILGRIMSRUS VAK.OORD	30E4305	24S5111	43	647.25	6	V	OPE	SBC2	10
1266	PILGRIMSRUS VAK.OORD	30E4305	24S5111	49	695.25	6	V	OPE	SBC1	10
1267	PLETTENBERG BAY	23E2230	34S0332	23	487.25	21	V	OPE	SBC2	20
1268	PLETTENBERG BAY	23E2230	34S0332	27	519.25	21	V	OPE	SBC3	20
1269	PLETTENBERG BAY	23E2230	34S0332	31	551.25	21	V	OPE	SBC1	20
1270	PLETTENBERG BAY	23E2230	34S0332	35	583.25	21	V	OPE	etv	20
1271	PLETTENBERG BAY WITT	23E1941	34S0023	38	607.25	6	V	OPE	SBC1	10
1272	PLETTENBERG BAY WITT	23E1941	34S0023	42	639.25	6	V	OPE	SBC2	10
1273	PLETTENBERG BAY WITT	23E1941	34S0023	46	671.25	6	V	OPE	SBC3	10
1274	POFADDER	18E5625	29S1430	4	175.25	34	V	LIC	etv	143
1275	POFADDER	18E5625	29S1430	10	223.25	34	V	OPE	SBC2	143
1276	POFADDER DORP	19E2304	29S0524	7	199.25	20	V	OPE	MNET	44
1277	POFADDER KLEINPELLA	18E5811	29S0019	39	615.25	5.1	V	OPE	SBC2	10
1278	POFADDER TOWN C55	19E2304	29S0524	37	599.25	19	V	LIC	SBC1	43
1279	POFADDER TOWN C55	19E2304	29S0524	41	631.25	19	V	LIC	SBC3	43
1280	POFADDER TOWN C55	19E2304	29S0524	45	663.25	19	V	LIC	ETV	43
1281	POFADDER TOWN C55	19E2304	29S0524	49	695.25	19	V	LIC	SBC2	43
1282	POFADDER TOWN C55	19E2304	29S0524	4	175.25	20	V	OPE	SBC2	45
1283	POFADDER WILLEM OPD	19E4905	29S2151	21	471.25	3	V	OPE	SBC2	20
1284	POMFRET	23E3444	25S4952	6	191.25	40	H	OPE	SBC2	143
1285	POMFRET	23E3444	25S4952	9	215.25	40	H	OPE	SBC1	143
1286	POMFRET	23E3444	25S4952	13	247.43	40	H	LIC	etv	143
1287	POMFRET	23E3444	25S4952	40	626	30	V	LIC		143
1288	POMFRET C100	23E3137	25S4924	39	615.25	5.6	V	OPE	MNET	25
1289	PONGOLA	31E3900	27S3134	22	479.25	21.5	V	OPE	SBC2	12
1290	PONGOLA	31E3900	27S3134	26	511.25	21.5	V	OPE	SBC1	12
1291	PONGOLA	31E3900	27S3134	30	543.25	21.5	V	OPE	SBC3	12
1292	PONGOLA	31E3900	27S3134	34	575.25	21.5	V	OPE	etv	12
1293	PORT ALFRED	26E5314	33S3600	53	727.25	7	V	LIC	SBC3	28
1294	PORT ALFRED	26E5314	33S3600	57	759.25	14	V	LIC		28
1295	PORT EDWARD EDEN	30E1123	31S0355	48	687.25	-7	V	OPE	SBC2	10
1296	PORT EDWARD EDEN	30E1123	31S0355	52	719.25	-7	V	OPE	SBC1	10
1297	PORT ELIZABETH	25E2629	33S5610	4	175.25	50	H	OPE	SBC1	195
1298	PORT ELIZABETH	25E2629	33S5610	7	199.25	50	H	OPE	SBC2	195
1299	PORT ELIZABETH	25E2629	33S5610	10	223.25	40	H	OPE	MNET	195
1300	PORT ELIZABETH	25E2629	33S5610	13	247.43	50	H	OP	SABC3	195
1301	PORT ELIZABETH	25E2629	33S5610	37	599.25	41.6	H	OPE		210
1302	PORT ELIZABETH	25E2629	33S5610	41	631.25	51.6	H	OPE	ETV	210
1303	PORT ELIZABETH CITY	25E3531	33S5528	47	679.25	33	V	OPE	etv	63
1304	PORT ELIZABETH CITY	25E3531	33S5528	51	711.25	26	V	OPE	CSN	63
1305	PORT ELIZABETH CITY	25E3531	33S5528	53	727.25	33	V	OPE	SBC2	63
1306	PORT ELIZABETH CITY	25E3531	33S5528	57	759.25	33	V	OPE	SBC1	63
1307	PORT ELIZABETH CITY	25E3531	33S5528	61	791.25	33	V	OPE	SBC3	63
1308	PORT ELIZABETH CITY	25E3531	33S5528	65	823.25	26	V	OPE	MNET	63
1309	PORT NOLLOTH	16E5214	29S1556	21	471.25	9	V	LIC	ETV	10
1310	PORT NOLLOTH	16E5214	29S1556	23	487.25	9	V	OPE	SBC2	10
1311	PORT NOLLOTH	16E5214	29S1556	27	519.25	9	V	OPE	SBC1	10
1312	PORT NOLLOTH	16E5214	29S1556	31	551.25	9	V	OPE	SBC3	10
1313	PORT NOLLOTH	16E5214	29S1556	35	583.25	9	V	OPE	MNET	10
1314	PORT SHEPSTONE	30E1717	30S4407	5	183.25	50	V	OPE	SBC1	195
1315	PORT SHEPSTONE	30E1717	30S4407	8	207.25	50	V	OPE	SBC2	195
1316	PORT SHEPSTONE	30E1717	30S4407	11	231.25	40	V	OPE	MNET	195
1317	PORT SHEPSTONE	30E1717	30S4407	21	471.25	54.7	H	OP	SBC3	214
1318	PORT SHEPSTONE	30E1717	30S4407	29	535.25	54.7	H	OPE	etv	214
1319	PORTST JOHNS	29E3139	31S3639	22	479.25	30	H	OPE	etv	55
1320	PORTST JOHNS	29E3139	31S3639	53	727.25	30	H	OPE	SBC3	55
1321	PORTST JOHNS	29E3139	31S3639	57	759.25	30	H	OPE	SBC2	55
1322	PORTST JOHNS	29E3139	31S3639	61	791.25	30	H	OPE	SBC1	55
1323	PORTST JOHNS	29E3139	31S3639	65	823.25	36	H	OPE	TBNC	55
1324	POSTMASBURG	23E0359	28S1919	21	471.25	6	V	OPE	MNET	10
1325	POSTMASBURG BEESHOEK	23E0120	28S1827	21	471.25	6	V	OPE	MNET	10
1326	POTCHEFSTROOM	27E0432	26S4146	63	807.25	20	V	OPE	MNET	28
1327	POTGIETERSRUS	29E1410	24S0924	4	175.25	50	H	OPE	SBC2	138
1328	POTGIETERSRUS	29E1410	24S0924	7	199.25	50	H	OPE	SBC1	138
1329	POTGIETERSRUS	29E1410	24S0924	10	223.25	40	H	OPE	MNET	138
1330	POTGIETERSRUS	29E1410	24S0924	13	247.43	50	H	OP	SBC3	138
1331	POTGIETERSRUS	29E1410	24S0924	44	655.25	53.9	H	OPE	etv	153
1332	PRETORIA	27E5903	25S4120	65	830	22.8	V	OPE	R 702	10
1333	PRETORIA	27E5903	25S4120	5	183.25	50	V	OPE	SBC2	103
1334	PRETORIA	27E5903	25S4120	8	207.25	50	V	OPE	SBC1	103
1335	PRETORIA	27E5903	25S4120	11	231.25	50	V	OPE	SBC3	103
1336	PRETORIA	27E5903	25S4120	21	471.25	49.3	H	OPE	MNET	120
1337	PRETORIA	27E5903	25S4120	25	503.25	44.5	H	OPE	CSN	120
1338	PRETORIA	27E5903	25S4120	29	535.25	51.4	H	OPE	etv	132
1339	PRETORIA NORTH	28E1007	25S4125	50	703.25	21	V	OPE	MNET	19
1340	PRETORIA NORTH	28E1007	25S4125	54	735.25	21	V	OPE	CSN	19
1341	PRETORIA NORTH	28E1007	25S4125	37	599.25	17	V	OPE	etv	23

Table C.18: Analogue entries considered (16 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1342	PRETORIA NORTH	28E1007	25S4125	40	623.25	17	V	OPE	SBC2	23
1343	PRETORIA NORTH	28E1007	25S4125	46	671.25	17	V	OPE	SBC3	23
1344	PRETORIA NORTH	28E1007	25S4125	52	719.25	17	V	OPE	SBC1	23
1345	PRIESKA	29E4007	22S4425	39	615.25	7	V	OPE	MNET	0
1346	PRIESKA	22E4425	29S4007	39	615.25	0	V	LI	MNET	10
1347	PRIESKA	22E4425	29S4007	43	647.25	0	V	OPE	SBC1	10
1348	PRIESKA	22E4525	29S4007	47	679.25	0	V	OPE	SBC3	10
1349	PRIESKA	22E3657	29S4052	6	191.25	40	V	OPE	SBC2	257
1350	PRIESKA	22E3657	29S4052	9	215.25	40	V	LIC	etv	257
1351	PRINS ALBERT	22E0149	33S1408	54	735.25	13	V	LI	MNET	10
1352	PUNDA MARIA * T123	30E5913	22S4331	6	191.25	15	V	OPE	SBC2	90
1353	PUNDA MARIA * T123	30E5913	22S4331	9	215.25	15	V	OPE	SBC1	90
1354	QAMATA	27E2742	31S5950	28	527.25	7	V	OPE	SBC2	10
1355	QUDENI	30E5159	28S3803	21	471.25	41.8	V	OPE	SBC1	102
1356	QUDENI	30E5159	28S3803	25	503.25	41.8	V	LIC	SABC2	102
1357	QUEENSTOWN	26E4705	31S4356	4	175.25	50	H	OPE	SBC1	138
1358	QUEENSTOWN	26E4705	31S4356	7	199.25	50	H	OPE	SBC2	138
1359	QUEENSTOWN	26E4705	31S4356	10	223.25	40	H	OPE	TBNC	138
1360	QUEENSTOWN	26E4705	31S4356	22	479.25	53.6	H	OPE	SBC3	153
1361	QUEENSTOWN	26E4705	31S4356	34	575.25	53.6	H	OPE	etv	153
1362	QUEENSTOWN DORP	26E5243	31S5503	39	615.25	23	V	OPE	MNET	27
1363	QWA QWA RES 23	28E4804	28S3230	54	735.25	5.1	V	OPE	SBC2	0
1364	QWA QWA RES 23	28E4804	28S3230	58	767.25	4.8	V	OPE	SBC1	0
1365	QWA QWA RES 23	28E4804	28S3230	58	767.25	5.1	V	OPE	SBC1	0
1366	QWA QWA RES 23	28E4804	28S3230	54	735.25	4.8	V	OPE	SBC2	10
1367	QWAQWA BERGOORD O74	28E5343	28S4057	43	647.25	18	V	OPE	SBC1	10
1368	QWAQWA BERGOORD O74	28E5343	28S4057	47	679.25	18	V	OPE	SBC2	10
1369	QWAQWA BERGOORD O74	28E5343	28S4057	51	711.25	21	V	OPE	SBC3	10
1370	QWAQWA WITSIESHOEK	28E5049	28S3102	36	591.25	20	V	OPE	SBC1	32
1371	RADIO IMPACT	28E1029	25S4126	66	834.4	13	V	OPE	RIMP	30
1372	RADIO TODAY	28E0027	26S1131	20	844.5	20	V	OPE	RTMR	10
1373	RADIO VOLKSTEM	27E0155	27S5406	66	831.8	43	V	OPE		10
1374	RADIO702 STUDIO	28E0316	26S0632	20	828	28	V	OPE	R 702	10
1375	RADIO702 STUDIO	28E0316	26S0632	66	831.5	27	V	OPE	R 702	10
1376	RAWSONVILLE GEVONDEN	19E1610	33S4210	59	775.25	6	V	OPE	SBC2	25
1377	REITZ	28E2700	27S4731	39	615.25	7	V	OPE	MNET	10
1378	REIVILO C70	24E1029	27S3355	53	727.25	4.8	V	OPE	sbc3	10
1379	REIVILO C70	24E1029	27S3355	55	743.25	4.8	V	OPE	MNET	10
1380	RHODES DONKERHOEK	27E5236	30S5152	44	655.25	10	V	OPE	SBC2	10
1381	RICHARDS BAY	32E0624	28S4710	43	647.25	22.8	V	OPE	MNET	12
1382	RICHMOND GAME VALLEY	30E0438	29S5445	47	679.25	5.1	V	OPE	SBC2	10
1383	RICHMOND KAAP C34.1	23E5747	31S2518	47	679.25	3	V	OPE	SBC2	10
1384	RICHMOND KAAP C34.1	23E5756	31S2525	26	511.25	6	V	LIC	ETV	30
1385	RICHMOND KAAP C34.1	23E5756	31S2525	43	647.25	6	V	LIC	SBC1	30
1386	RICHMOND KAAP C34.1	23E5756	31S2525	51	711.25	6	V	LIC	SBC3	30
1387	RICHTERSVELD KHUBUS	16E5940	28S2622	30	543.25	7	V	LIC	SBC2	10
1388	RICHTERSVELD KHUBUS	16E5940	28S2622	34	575.25	7	V	LIC	SBC3	10
1389	RIEMVASMAAK SENDING	20E1949	28S2737	53	727.25	6	V	LIC	SBC1	10
1390	RIEMVASMAAK SENDING	20E1949	28S2737	57	759.25	6	V	LIC	SBC2	10
1391	RIEMVASMAAK SENDING	20E1949	28S2737	61	791.25	6	V	LIC	SBC3	10
1392	RIEMVASMAAK SENDING	20E1949	28S2737	65	823.25	6	V	LIC	ETV	10
1393	RIEMVASMAAK VREDESVA	20E1101	28S3010	53	727.25	9	V	LIC	SBC1	10
1394	RIEMVASMAAK VREDESVA	20E1101	28S3010	57	759.25	9	V	LIC	SBC2	10
1395	RIEMVASMAAK VREDESVA	20E1101	28S3010	61	791.25	9	V	LIC	SBC3	10
1396	RIEMVASMAAK VREDESVA	20E1101	28S3010	65	823.25	9	V	LIC	ETV	10
1397	RIETFONTEIN	20E0616	26S4448	21	471.25	11.5	V	LIC	SBC1	40
1398	RIETFONTEIN	20E0616	26S4448	25	503.25	11.5	V	LIC	SBC2	40
1399	RIETFONTEIN	20E0616	26S4448	29	535.25	11.5	V	LIC	SBC3	40
1400	RIETFONTEIN	20E0616	26S4448	33	567.25	11.5	V	LIC	ETV	40
1401	RIETSPRUIT MINE	29E1131	26S1032	55	743.25	4	V	OPE	SBC3	28
1402	RIETSPRUIT MINE	29E1131	26S1032	59	775.25	4.8	V	OPE	MNET	28
1403	RIETSPRUIT MINE	29E1131	26S1032	63	807.25	4	V	OPE	SBC2	28
1404	RIETSPRUIT MINE	29E1131	26S1032	67	839.25	4	V	OPE	SBC1	28
1405	RIVERSDAL	21E1535	34S0603	21	471.25	7	V	OPE	MNET	10
1406	RIVERSDAL	21E1535	34S0603	25	503.25	7	V	OPE	SBC3	10
1407	RIVERSDAL JONGENFNTN	21E1958	34S2548	26	511.25	4.8	V	OPE	SBC2	10
1408	RIVERSDAL JONGENFNTN	21E1958	34S2548	30	543.25	4.8	V	OPE	SBC1	10
1409	RIVERSDALE	21E1535	34S0603	21	471.25	6	V	OPE	M-NET	10
1410	RIVERSDALE	21E1535	34S0603	25	503.25	9	V	OPE	SBC3	10
1411	RIVERSDALE	21E0741	34S0107	8	207.25	36	H	OPE	SBC1	138
1412	RIVERSDALE	21E0741	34S0107	13	247.43	43	H	OPE	SBC2	138
1413	RIVERSDALE	21E0741	34S0107	36	591.25	45	H	LIC	etv	153
1414	RIVIERSONDEREND	19E5504	34S5252	21	471.25	4.8	V	OPE	SBC3	15
1415	RIVIERSONDEREND	19E5454	38S0805	21	471.25	10	V	OPE	SBC3	15
1416	RIVIERSONDEREND	19E5454	38S0805	25	503.25	10	V	LIC	ETV	15
1417	ROBERTSON ROOIBERG	19E4646	33S4455	56	751.25	1.1	V	OPE	SBC2	38
1418	ROOSSENEKAL MAPOCHS	29E5456	25S1151	38	607.25	3	V	OPE	MNET	10
1419	ROOSSENEKAL MAPOCHS	29E5456	25S1151	42	639.25	3	V	OPE	SBC2	10
1420	ROOSSENEKAL MAPOCHS	29E5456	25S1151	46	671.25	3	V	OPE	SBC3	10
1421	ROOSSENEKAL MAPOCHS	29E5456	25S1151	50	703.25	3	V	OPE	SBC1	10
1422	RUSTENBURG	27E0706	25S3656	56	751.25	40	H	OPE	SBC2	98
1423	RUSTENBURG	27E0706	25S3656	60	783.25	40	H	OPE	SBC3	98
1424	RUSTENBURG	27E0706	25S3656	64	815.25	40	H	OPE	SBC1	98
1425	RUSTENBURG	27E0706	25S3656	68	847.25	40	H	OPE	etv	98
1426	RUSTENBURG CASHAN	27E1433	25S4126	54	735.25	20	V	OPE	MNET	25
1427	RUSTENBURG PLATINM A	27E2013	24S4820	49	695.25	13	V	OPE	MNET	34
1428	RUSTENBURG PLATINUM	27E0907	24S5639	55	743.25	9	V	OPE	MNET	10
1429	RUSTNBG PLAT AMANDLB	27E2013	24S4820	28	527.25	13	V	OPE	MNET	34
1430	RUSTNBG PLAT SWRTKLP	27E0907	24S5639	55	743.25	7	V	OPE	MNET	10

Table C.19: Analogue entries considered (17 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1431	SABIE	30E4534	25S0744	54	735.25	14	V	LIC	SBC3	12
1432	SABIE	30E4534	25S0744	56	751.25	20	V	OPE	SBC2	12
1433	SABIE	30E4534	25S0744	64	815.25	20	V	OPE	etv	12
1434	SABIE	30E4534	25S0744	68	847.25	14	V	OPE	MNET	12
1435	SABIE * T112.1	30E4534	25S0744	60	783.25	15	V	OPE	SBC1	12
1436	SABIE * T112.1	30E4534	25S0744	68	847.25	13	V	OPE	MNET	12
1437	SABIE LINK T112.1	30E3710	25S0856	52	719.25	12	V	OPE	SBC1	10
1438	SABIE BERGVLIET	30E5148	25S0155	44	655.25	8	V	OPE	SBC2	10
1439	SABIE BERGVLIET	30E5148	25S0155	48	687.25	8	V	OPE	SBC1	10
1440	SABIE DOORNHOEK	30E3710	25S0856	40	623.25	12.5	V	OPE	SBC2	10
1441	SABIE HEBRON	30E5246	25S0755	63	807.25	4	V	OPE	SBC2	10
1442	SABIE HEBRON	30E5246	25S0755	67	839.25	8	V	OPE	SBC1	10
1443	SABIE MAUCHSBERG	30E5559	24S5942	26	511.25	3	V	OPE	SBC1	10
1444	SABIE RAMANAS	31E0027	24S5234	49	695.25	10	V	OPE	SBC2	20
1445	SAPA NETWORK STL	28E0246	26S1220	66	835	20	V	OPE	RNRS	10
1446	SASOLBURG	27E4935	26S4745	37	599.25	17	V	OPE	MNET	50
1447	SASOLBURG	27E4935	26S4745	41	631.25	17	V	OPE	MNET	50
1448	SASOLBURG	27E4935	26S4745	45	663.25	17	V	OPE	MNET	50
1449	SCARBOROUGH C.P.	18E2046	34S1037	56	751.25	14	V	OPE	MNET	20
1450	SCARBOROUGH C.P.	18E2046	34S1037	60	783.25	14	V	OPE	SBC2	20
1451	SCARBOROUGH C.P.	18E2046	34S1037	64	815.25	14	V	OPE	SBC1	20
1452	SCARBOROUGH C.P.	18E2046	34S1037	68	847.25	14	V	OPE	SBC3	20
1453	SCHWEIZER RENEKE	25E1307	27S0813	25	503.25	50	H	OPE	SBC1	253
1454	SCHWEIZER RENEKE	25E1307	27S0813	29	535.25	50	H	OPE	etv	253
1455	SCHWEIZER RENEKE	25E1307	27S0813	33	567.25	50	H	OPE	SBC2	253
1456	SCHWEIZER-RENEKE T82	25E2000	27S1049	53	727.28	14	V	OPE	MNET	10
1457	SEA POINT	18E2351	33S5433	40	623.25	26	V	OPE	SBC2	76
1458	SEA POINT	18E2351	33S5433	44	655.25	26	V	OPE	MNET	76
1459	SEA POINT	18E2351	33S5433	48	687.25	26	V	OPE	SBC1	76
1460	SEA POINT	18E2351	33S5433	52	719.25	26	V	OPE	SBC3	76
1461	SEA POINT	18E2351	33S5433	55	743.25	26	V	OPE	CSN	76
1462	SEA POINT	18E2351	33S5433	59	775.25	26	V	OPE	etv	76
1463	SECUNDA	29E1210	26S2940	68	847.25	20	V	OPE	MNET	18
1464	SENEKAL	27E3026	28S1519	38	607.25	33	H	OPE	SBC1	222
1465	SENEKAL	27E3026	28S1519	42	639.25	40	H	OPE	SBC2	222
1466	SENEKAL	27E3026	28S1519	46	671.25	40	H	OPE	etv	222
1467	SENEKAL O73	27E3627	28S1918	52	719.25	13	H	OPE	MNET	14
1468	SIBASA	30E2654	22S5657	38	607.25	22	V	OPE	MNET	25
1469	SIBASA	30E2654	22S5657	42	639.25	39	V	OPE	SBC2	51
1470	SIBASA	30E2654	22S5657	46	671.25	39	V	OPE	SBC1	51
1471	SIBASA	30E2654	22S5657	50	703.25	26.8	V	OPE	SBC3	51
1472	SIMONSTOWN	18E2537	34S1154	40	623.25	23.1	V	OPE	SBC3	21
1473	SIMONSTOWN	18E2537	34S1154	44	655.25	23.1	V	OPE	SBC2	21
1474	SIMONSTOWN	18E2537	34S1154	48	687.25	23.1	V	OPE	MNET	21
1475	SIMONSTOWN	18E2537	34S1154	52	719.25	23.1	V	OPE	SBC1	21
1476	SIMONSTOWN	18E2537	34S1154	56	751.25	23.1	V	OPE	etv	21
1477	SISHEN/KATHU ISCOR	23E0137	27S4454	37	599.25	13	V	OPE	MNET	100
1478	SISHEN/KATHU ISCOR	23E0137	27S4454	41	631.25	13	V	LIC	ETV	100
1479	SISHEN/KATHU ISCOR	23E0137	27S4454	45	663.25	13	V	LIC	SBC3	100
1480	SKUITBAAI	24E1458	34S0429	37	599.25	5.4	V	OPE	SBC2	18
1481	SKUKUZA	31E3541	24S5711	37	599.25	-3	V	OPE	SBC2	10
1482	SKUKUZA	31E3541	24S5711	41	631.25	7	V	LIC	SBC3	10
1483	SKUKUZA	31E3541	24S5711	45	663.25	-3	V	OPE	MNET	10
1484	SKUKUZA	31E3541	24S5711	49	695.25	-3	V	OPE	SBC1	10
1485	SLANGRIVIER	20E5126	34S0857	32	559.25	6	V	LIC	SBC3	14
1486	SLANGRIVIER	20E5126	34S0857	41	631.25	6	V	LIC	ETV	14
1487	SLURRY PPC 101	25E5024	25S4854	61	791.25	3	V	OPE	MNET	80
1488	SOMERSET EAST	25E3441	32S4245	53	727.25	17	V	OPE	SBC2	12
1489	SOMERSET EAST	25E3441	32S4245	57	759.25	17	V	OPE	SBC3	12
1490	SOMERSET EAST C9.1	25E3441	32S4245	57	759.25	17	V	OPE	SBC3	10
1491	SOMERSET EAST C9.1	25E3441	32S4245	61	791.25	9	V	OPE	SBC1	10
1492	SOMERSET EAST C9.1	25E3441	32S4245	65	823.25	12	V	OPE	MNET	10
1493	SOSHANGUVE LINK	28E0635	25S3055	66	833	20	H	OPE	RSHG	10
1494	SPRINGBOK	17E4829	29S3504	6	191.25	40	V	OPE	SBC2	226
1495	SPRINGBOK	17E4829	29S3504	9	215.25	40	V	OPE	SBC1	226
1496	SPRINGBOK	17E4829	29S3504	13	247.43	40	V	LIC	etv	226
1497	SPRINGBOK BERGSIG	17E5302	29S3920	40	623.25	0	V	OPE	SBC1	10
1498	SPRINGBOK BERGSIG	17E5302	29S3920	44	655.25	0	V	OPE	SBC2	10
1499	SPRINGBOK BERGSIG	17E5302	29S3920	48	687.25	0	V	OPE	SBC3	10
1500	SPRINGBOK BERGSIG	17E5302	29S3920	53	727.25	4.8	V	OPE	SBC1	10
1501	SPRINGBOK BERGSIG	17E5302	29S3920	57	759.25	4.8	V	OPE	SBC2	10
1502	SPRINGBOK BERGSIG	17E5302	29S3920	61	791.25	4.8	V	OPE	SBC3	10
1503	SPRINGBOK MATJIESKLF	17E5245	29S4011	40	623.25	0	V	OPE	SBC1	10
1504	SPRINGBOK MATJIESKLF	17E5245	29S4011	44	655.25	0	V	OPE	SBC2	10
1505	SPRINGBOK MATJIESKLF	17E5245	29S4011	48	687.25	0	V	OPE	SBC3	10
1506	SPRINGBOK MATJIESKLF	17E5245	29S4011	56	751.25	4.8	V	OPE	SBC1	10
1507	SPRINGBOK MATJIESKLF	17E5245	29S4011	60	783.25	4.8	V	OPE	SBC2	10
1508	SPRINGBOK MATJIESKLF	17E5245	29S4011	64	815.25	4.8	V	OPE	SBC3	10
1509	SPRINGBOK TOWN C41	17E5257	29S3931	23	487.25	11	V	OPE	SBC2	10
1510	SPRINGBOK TOWN C41	17E5257	29S3931	27	519.25	11	V	OPE	MNET	10
1511	SPRINGBOK TOWN C41	17E5257	29S3931	31	551.25	14	V	OPE	SBC1	10
1512	SPRINGBOK TOWN C41	17E5257	29S3931	35	583.25	14	V	OPE	SBC3	10
1513	SPRINGFONTEIN	25E4605	30S1548	23	487.25	8	H	LIC	SBC3	12
1514	SPRINGFONTEIN	25E4608	30S1614	37	599.25	40	H	OPE	SBC2	134
1515	SPRINGFONTEIN	25E4608	30S1614	45	663.25	40	H	LIC	etv	134
1516	SPRINGFONTEIN O48	25E4605	30S1548	27	519.25	8	H	OPE	SBC1	12
1517	ST HELENABAAI C11	18E0910	32S4620	53	727.25	20	V	OPE	MNET	20
1518	ST LUCIA	32E2455	28S2219	56	751.25	6	V	OPE	MNET	33

Table C.20: Analogue entries considered (18 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1519	STANDERTON	29E1251	26S5737	50	703.25	20	V	OPE	etv	12
1520	STANDERTON	29E1251	26S5737	56	751.25	20	V	OPE	SBC2	12
1521	STANDERTON	29E1251	26S5737	60	783.25	20	V	OPE	SBC1	12
1522	STANDERTON	29E1251	26S5737	64	815.25	20	V	OPE	MNET	12
1523	STANDERTON	29E1251	26S5737	68	847.25	20	V	OPE	SBC3	12
1524	STEELPOORT LEKGOBO	30E1135	24S4110	22	479.25	18.5	V	OPE	SBC2	10
1525	STEELPOORT LEKGOBO	30E1135	24S4110	26	511.25	18.5	V	OPE	MNET	10
1526	STEELPOORT LEKGOBO	30E1135	24S4110	30	543.25	18.5	V	OPE	SBC1	10
1527	STEELPOORT LEKGOBO	30E1135	24S4110	34	575.25	18.5	V	LIC	SBC3	10
1528	STEELPOORT MOKOME	30E0756	24S4650	24	495.25	13	V	LIC	SBC3	10
1529	STEELPOORT MOKOME	30E0756	24S4650	28	527.25	13	V	OPE	SBC1	10
1530	STEELPOORT MOKOME	30E0756	24S4650	32	559.25	13	V	OPE	SBC2	10
1531	STEELPOORT MOKOME	30E0756	24S4650	36	591.25	13	V	OPE	MNET	10
1532	STEELPOORT MONTROSE	30E0820	24S3707	38	607.25	8.5	V	OPE	SBC3	10
1533	STEELPOORT MONTROSE	30E0820	24S3707	42	639.25	7	V	OPE	MNET	10
1534	STEELPOORT MONTROSE	30E0820	24S3707	46	671.25	8.5	V	OPE	SBC2	10
1535	STEELPOORT MONTROSE	30E0820	24S3707	50	703.25	8.5	V	OPE	SBC1	10
1536	STEINKOPF	17E4419	29S1454	38	607.25	6	V	LIC	SBC1	20
1537	STEINKOPF	17E4419	29S1454	42	639.25	6	V	LIC	SBC2	20
1538	STEINKOPF	17E4419	29S1454	46	671.25	6	V	LIC	SBC3	20
1539	STEINKOPF	17E4419	29S1454	50	703.25	6	V	LIC	ETV	20
1540	STEINKOPF	17E4419	29S1454	54	735.25	6	V	LIC	MNET	20
1541	STEINKOPF HENKRIES	18E0500	28S5837	31	551.25	4	V	OPE	SBC2	10
1542	STEINKOPF VIOOLSDRIF	17E3705	28S4615	31	551.25	0	V	OPE	SBC2	10
1543	STELLA	24E5208	26S3319	56	751.25	7	V	OPE	MNET	0
1544	STELLA	24E5208	26S3319	56	751.25	7	V	LI	MNET	12
1545	STELLENBOSCH	18E5211	33S5456	48	687.25	20	V	OPE	etv	29
1546	STELLENBOSCH	18E5211	33S5456	52	719.25	20	V	OPE	CSN	29
1547	STELLENBOSCH	18E5211	33S5456	56	751.25	20	V	OPE	SBC2	29
1548	STELLENBOSCH	18E5211	33S5456	60	783.25	20	V	OPE	SBC1	29
1549	STELLENBOSCH	18E5211	33S5456	64	815.25	20	V	OPE	MNET	29
1550	STELLENBOSCH	18E5211	33S5456	68	847.25	20	V	OPE	SBC3	29
1551	STERKSPRUIT	27E2143	30S3159	45	663.25	12	V	LIC	SBC3	15
1552	STERKSPRUIT	27E2143	30S3159	49	695.25	12	V	LIC	ETV	15
1553	STERKSPRUIT	27E1614	30S4144	37	599.25	43	V	OPE	SBC1	60
1554	STERKSPRUIT	27E1614	30S4144	41	631.25	43	V	OPE	SABC2	60
1555	STEYNSBURG C35.3	25E4838	31S1755	43	647.25	5.1	V	OPE	SBC2	8
1556	STEYNSBURG C35.3	25E4838	31S1755	47	679.25	5.1	V	OPE	SBC1	8
1557	STEYNSBURG C35.3	25E4838	31S1755	51	711.25	5.1	V	LIC	SBC3	8
1558	STEYTLERVILE	24E2041	33S1900	56	751.25	4.8	V	OPE	SBC1	10
1559	STEYTLERVILE	24E2041	33S1900	60	783.25	4.8	V	OPE	SBC2	10
1560	STEYTLERVILE	24E2041	33S1900	64	815.25	4.8	V	OPE	SBC3	10
1561	STEYTLERVILE BIKAMMA	24E0857	33S1158	49	695.25	1.1	V	OPE	SBC2	10
1562	STEYTLERVILLE DE DAM	24E3839	33S1651	30	543.25	3	V	OPE	SBC2	10
1563	STEYTLERVILLE NORSPT	24E2227	33S1840	35	583.25	0	V	OPE	SBC2	10
1564	STILBAAI	21E2525	34S2155	52	719.25	5.1	V	LIC	SBC2	30
1565	STILBAAI C4	21E2525	34S2155	40	623.25	8	V	OPE	MNET	30
1566	STILBAAI C4	21E2525	34S2155	44	655.25	5.1	V	OPE	SBC1	30
1567	STILBAAI C4	21E2525	34S2155	0	687.25	5.1	V	LIC	SBC3	30
1568	STILBAAI JONGENSFONT	21E1958	34S2548	22	479.25	7	V	LIC	SBC3	10
1569	STILBAAI JONGENSFONT	21E1958	34S2548	26	511.25	7	V	OPE	SBC2	10
1570	STILBAAI JONGENSFONT	21E1958	34S2548	30	543.25	7	V	OPE	SBC1	10
1571	STILBAAI MELKHOUTFNT	21E2433	34S2000	24	495.25	4.8	V	LIC	SBC3	10
1572	STILBAAI MELKHOUTFNT	21E2433	34S2000	28	527.25	4.8	V	LIC	SBC2	10
1573	STILBAAI MELKHOUTFNT	21E2433	34S2000	32	559.25	4.8	V	LIC	SBC1	10
1574	STOFFBERG	29E4800	25S2503	21	471.25	6.5	V	OPE	SBC2	10
1575	STOFFBERG	29E4800	25S2503	25	503.25	7	V	OPE	SBC1	10
1576	STOFFBERG WELGEVOND.	29E5354	25S2829	63	807.25	1.1	V	OPE	SBC2	10
1577	STORMS RIVER BOSKOR	24E5208	26S3319	56	751.25	0	V	OPE	MNET	0
1578	STORMS RIVER BOSKOR	23E4851	33S5820	38	607.25	3	V	LIC	SBC2	20
1579	STORMS RIVER BOSKOR	23E4851	33S5820	42	639.25	3	V	LIC	MNET	20
1580	STORMS RIVER BOSKOR	23E4851	33S5820	46	671.25	3	V	LIC	SBC3	20
1581	STORMS RIVER BOSKOR	23E4851	33S5820	50	703.25	3	V	LIC	SBC1	20
1582	STORMS RIVER BOSKOR	23E4851	33S5820	57	759.25	3	V	LIC	ETV	20
1583	STRAALHOEK	29E5053	30S2049	53	727.25	40	V	OPE	SBC1	65
1584	STRAALHOEK	29E5053	30S2049	57	759.25	40	V	OPE	SBC2	65
1585	STRANDFONTEIN CP	18E1343	31S4525	30	543.25	-3	V	OPE	SBC1	37
1586	STRANDFONTEIN CP	18E1343	31S4525	31	551.25	-3	V	OPE	SBC2	37
1587	STRUISBAAI	20E0256	34S4821	29	535.25	6	V	OPE	MNET	10
1588	SUIDRAND (KROONSTAD)	27E1416	27S4118	23	487.25	24	V	OPE	SBC2	19
1589	SUIDRAND (KROONSTAD)	27E1416	27S4118	27	519.25	24	V	OPE	SBC1	19
1590	SUIDRAND (KROONSTAD)	27E1416	27S4118	31	551.25	24	V	OPE	SBC3	19
1591	SUIDRAND (KROONSTAD)	27E1416	27S4118	67	839.25	24	V	OPE	MNET	19
1592	SUNNINGHILL	28E0400	26S0200	42	639.25	30	V	LIC	ODTT	10
1593	SUNNYSIDE	28E1224	25S4553	38	607.25	30	V	OPE	etv	168
1594	SUNNYSIDE	28E1224	25S4553	46	671.25	30	V	OPE	CSN	168
1595	SUNNYSIDE	28E1224	25S4553	55	743.25	30	V	OPE	SBC2	168
1596	SUNNYSIDE	28E1224	25S4553	59	775.25	30	V	OPE	SBC3	168
1597	SUNNYSIDE	28E1224	25S4553	63	807.25	30	V	OPE	SBC1	168
1598	SUNNYSIDE	28E1224	25S4553	67	839.25	30	V	OPE	MNET	168
1599	SUPINGSTAD	26E0137	24S4720	56	751.25	31	V	LIC	SBC1	28
1600	SUPINGSTAD	26E0137	24S4720	60	783.25	31	V	LIC	SBC2	28
1601	SUTHERLAND C22	20E3959	32S2328	53	727.25	6	V	OPE	SBC2	13
1602	SUTHERLAND C22	20E3959	32S2328	57	759.25	6	V	LIC	SBC1	13
1603	SUTHERLAND C22	20E3959	32S2328	61	791.25	6	V	LIC	ETV	13
1604	SUTHERLAND C22	20E3959	32S2328	65	823.25	6	V	LIC	SBC3	13
1605	SUTHERLAND ELANDSRIV	20E4531	31S5656	35	583.25	7	V	OPE	SBC2	10
1606	SUTHERLAND MERINO	20E4925	32S2047	36	591.25	3	V	OPE	SBC2	10
1607	SUTHERLAND MID RIETR	20E5129	32S0449	25	503.25	6	V	OPE	SBC2	10

Table C.21: Analogue entries considered (19 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1608	SUTHERLAND OBSVATORY	20E4838	32S2241	46	671.25	5.1	V	OPE	SBC2	10
1609	SUTHERLAND RHEBOKSFT	20E3010	32S2052	48	687.25	11	V	OPE	SBC2	10
1610	SUTHERLAND RHEN RIV.	20E4129	32S1032	27	519.25	5.1	V	OPE	SBC2	0
1611	SUTHERLAND TAFELBRGP	21E0546	32S1511	57	759.25	6	V	OPE	SBC2	10
1612	SUTHERLAND VYFFONTN	20E3502	32S2518	29	535.25	-10	H	OPE	SBC2	10
1613	SUTHERLAND WELG DE-K	20E4755	32S4039	33	567.25	4.1	V	OPE	SBC2	10
1614	SUURBERG	25E3429	33S1455	55	743.25	46	H	OPE	etv	192
1615	SUURBERG	25E3429	33S1455	59	775.25	46	H	OPE	SBC2	192
1616	SUURBERG	25E3429	33S1455	63	807.25	46	H	OPE	SBC1	192
1617	SUURBERG	25E3429	33S1455	67	839.25	46	H	OPE	SBC3	192
1618	SUURBRAAK	20E3946	34S0035	56	751.25	4	V	LIC	SBC1	10
1619	SUURBRAAK	20E3946	34S0035	58	767.25	4	V	LIC	SBC2	10
1620	SUURBRAAK	20E3946	34S0035	60	783.25	4	V	LIC	SBC3	10
1621	SUURBRAAK	20E3946	34S0035	64	815.25	4	V	LIC	ETV	10
1622	SUURBRAAK	20E3946	34S0035	68	847.25	24	V	LIC	MNET	10
1623	SWARTBERG BATHURST	29E2525	30S0125	39	615.25	2	V	OPE	SBC2	10
1624	SWARTBERG THE FIRS	29E1035	30S0905	60	783.25	5.1	V	OPE	SBC2	10
1625	SWARTMFOL KWASIPUNGA	31E1202	27S5152	40	623.25	-1	V	OPE	SBC2	10
1626	SWARTRUGGENS	26E4809	25S4059	32	559.25	27	V	OPE	SBC2	51
1627	SWARTRUGGENS	26E4809	25S4059	36	591.25	27	V	LIC	etv	51
1628	SWELLENDAM	20E2803	34S0034	21	471.25	12	V	LIC	ETV	10
1629	SWELLENDAM	20E2803	34S0034	21	471.25	12	V	OPE	SBC3	10
1630	SWELLENDAM	20E2803	34S0034	25	503.25	12	V	LIC	SBC2	10
1631	SWELLENDAM	20E2803	34S0034	29	535.25	12	V	LIC	SBC1	10
1632	TABLE MOUNTAIN	18E2413	33S5725	56	751.25	27.7	V	OPE	SBC3	11
1633	TABLE MOUNTAIN	18E2413	33S5725	60	783.25	24.7	V	OPE	CSN	11
1634	TABLE MOUNTAIN	18E2413	33S5725	64	815.25	27.7	V	OPE	etv	11
1635	TABLE MOUNTAIN	18E2413	33S5725	24	495.25	27	V	OPE	SBC2	13
1636	TABLE MOUNTAIN	18E2413	33S5725	28	527.25	27	V	OPE	SBC1	13
1637	TABLE MOUNTAIN	18E2413	33S5725	36	591.25	27	V	OPE	MNET	13
1638	TARKASTAD C27.3	26E1547	32S0045	24	495.25	7	V	OPE	MNET	20
1639	TARKASTAD C27.3	26E1547	32S0045	28	527.25	7	V	OPE	SBC2	20
1640	TARKASTAD C27.3	26E1547	32S0045	32	559.25	7	V	OPE	SBC3	20
1641	TARKASTAD C27.3	26E1547	32S0045	36	591.25	7	V	OPE	SBC1	20
1642	TAUNG	24E3700	27S3130	43	647.25	32.4	H	OPE	SBC1	155
1643	TAUNG	24E3700	27S3130	47	679.25	32.4	H	OPE	SBC2	155
1644	THABAZIMBI	27E3651	24S2759	6	191.25	51.8	V	OPE	SBC2	195
1645	THABAZIMBI	27E3651	24S2759	9	215.25	41.8	V	OPE	SBC1	195
1646	THABAZIMBI	27E3651	24S2759	38	607.25	51.3	H	OPE	etv	214
1647	THABAZIMBI	27E3651	24S2759	42	639.25	51.3	H	OPE	SBC3	214
1648	THABAZIMBI II	27E2436	24S3621	40	623.25	4.8	V	OPE	SBC2	10
1649	THABAZIMBI II	27E2438	24S3620	44	655.25	16	V	OPE	MNET	10
1650	THABAZIMBI ISCOR	27E2436	24S3621	42	639.25	14.8	V	LIC	SBC3	10
1651	THABAZIMBI MUNICIPAL	27E2438	24S3620	40	623.25	16	V	OPE	SBC2	10
1652	THABAZIMBI MUNICIPAL	27E2438	24S3620	44	655.25	16	V	OPE	MNET	10
1653	THE BLUFF	31E0046	29S5440	37	599.25	34	V	OPE	SBC2	32
1654	THE BLUFF	31E0046	29S5440	39	615.25	31	V	OPE	CSN	32
1655	THE BLUFF	31E0046	29S5440	41	631.25	34	V	OPE	SBC1	32
1656	THE BLUFF	31E0046	29S5440	43	647.25	34	V	OPE	etv	32
1657	THE BLUFF	31E0046	29S5440	45	663.25	34	V	OPE	MNET	32
1658	THE BLUFF	31E0046	29S5440	49	695.25	34	V	OPE	SBC3	32
1659	THEUNISSEN	26E3450	28S1155	5	183.25	51	H	OPE	SBC2	257
1660	THEUNISSEN	26E3450	28S1155	8	207.25	51	V	OPE	SBC1	257
1661	THEUNISSEN	26E3450	28S1155	11	231.25	41	H	OPE	MNET	257
1662	THEUNISSEN	26E3450	28S1155	22	479.25	45.3	H	OPE	SBC3	268
1663	THEUNISSEN	26E3450	28S1155	26	511.25	45.3	H	OPE	etv	268
1664	THOHOYANDOU (SIBASA)	30E2650	22S5657	38	607.25	20	V	OPE	MNET	20
1665	TOLWE	28E2729	23S0459	39	615.25	42	V	OPE	SBC1	43
1666	TOLWE	28E2729	23S0459	43	647.25	42	V	OPE	SABC2	43
1667	TOUWSRIVER * C12.3	20E0113	33S2059	28	527.25	10.8	V	OPE	SBC1	13
1668	TOUWSRIVER LINK C12	20E0244	33S2029	43	647.25	7	V	OPE	SBC1	15
1669	TOUWSRIVIER	20E0113	33S2059	24	495.25	13	V	OPE	SBC2	13
1670	TSHAMAVUDZI	30E3142	22S3915	53	727.25	24	V	OPE	SBC2	44
1671	TSHAMAVUDZI	30E3142	22S3915	57	759.25	24	V	OPE	SBC1	44
1672	TSHIKONDENI VENDA	30E5541	22S3131	22	479.25	14	V	LIC	MNET	10
1673	TSHIKONDENI VENDA	30E5541	22S3131	26	511.25	14	V	OPE	SBC1	10
1674	TSHIKONDENI VENDA	30E5541	22S3131	30	543.25	14	V	OPE	SBC2	10
1675	TSHIKONDENI VENDA	30E5541	22S3131	34	575.25	14	V	OPE	SBC3	10
1676	TSHIKONDENI VENDA	30E5541	22S3131	54	735.25	10	V	LI	MNET	10
1677	TSOLO	28E4500	31S1851	31	551.25	7	V	OPE	SBC2	10
1678	TUGELA FERRY	30E2636	28S4438	21	471.25	17	V	LIC	MNET	15
1679	TUGELA FERRY	30E2636	28S4438	23	487.25	17	V	LIC	SBC1	15
1680	TUGELA FERRY	30E2636	28S4438	27	519.25	17	V	LIC	SBC2	15
1681	TUGELA FERRY	30E2636	28S4438	31	551.25	17	V	OPE	SBC3	15
1682	TUGELA FERRY	30E2636	28S4438	35	583.25	17	V	LIC	ETV	15
1683	TULBAGH	19E0354	33S1621	40	623.25	14	V	LIC	SBC3	10
1684	TULBAGH	19E0354	33S1621	43	647.25	8	V	OPE	MNET	10
1685	TYGERBERG	18E3546	33S5229	22	479.25	33	V	OPE	SBC2	75
1686	TYGERBERG	18E3546	33S5229	26	511.25	33	V	OPE	SBC1	75
1687	TYGERBERG	18E3546	33S5229	30	543.25	30	V	OPE	MNET	75
1688	TYGERBERG	18E3546	33S5229	34	575.25	33	V	OPE	SBC3	75
1689	TYGERBERG	18E3546	33S5229	42	639.25	30	V	OPE	CSN	75
1690	TYGERBERG	18E3546	33S5229	46	671.25	33	V	OPE	etv	75
1691	TZANEEN	30E0018	23S4706	56	751.25	51.8	H	OPE	SBC3	98
1692	TZANEEN	30E0018	23S4706	60	783.25	41.8	H	OPE	SBC1	98
1693	TZANEEN	30E0018	23S4706	64	815.25	51.8	H	OPE	SBC2	98
1694	TZANEEN	30E0018	23S4706	68	847.25	51.8	H	OPE	etv	98
1695	TZANEEN MAGOEBAKLOOF	30E0226	23S5116	28	527.25	-3	V	OPE	SBC2	10
1696	UBOMBO	32E0452	27S3342	37	599.25	40	H	OPE	SBC1	98
1697	UBOMBO	32E0452	27S3342	41	631.25	50	H	OPE	etv	98

Table C.22: Analogue entries considered (20 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1698	UBOMBO	32E0452	27S3342	45	663.25	50	H	OPE	SBC2	98
1699	UBOMBO	32E0452	27S3342	49	695.25	50	H	OPE	SBC3	98
1700	UGIE	27E5826	31S1128	68	850.55	24.8	V	OPE	SESO	10
1701	UGIE	28E1339	31S1240	32	559.25	9	V	LIC	etv	30
1702	UGIE	27E5826	31S1128	24	495.25	25.5	V	OPE	SBC2	52
1703	UGIE	27E5826	31S1128	28	527.25	25.5	V	OPE	SBC1	52
1704	UGIE	27E5826	31S1128	32	559.25	25.5	V	LIC	etv	52
1705	UGIE	27E5826	31S1128	36	591.25	25.5	V	LIC	etv	52
1706	ULUNDI	31E2409	28S2619	60	783.25	19	V	OPE	SBC3	15
1707	ULUNDI	31E2338	28S2700	6	191.25	40	V	OPE	SBC1	124
1708	ULUNDI	31E2338	28S2700	9	215.25	40	V	OPE	SBC2	124
1709	ULUNDI	31E2409	28S2619	56	751.25	19	V	OPE	MNET	150
1710	ULUNDI NDEVU N77	31E3925	28S1547	47	679.25	4.8	V	OPE	SBC2	10
1711	ULUNDI NDEVU N77	31E3925	28S1547	51	711.25	6	V	OPE	SBC1	10
1712	UMTATA	28E4436	31S3548	67	839.25	17	H	OPE	SBC1	40
1713	UMTATA	28E4436	31S3548	37	599.25	40	H	OP	SBC3	221
1714	UMTATA	28E4436	31S3548	45	663.25	40	H	OPE	etv	221
1715	UMTATA	28E4436	31S3548	55	743.25	30	H	OPE	MNET	221
1716	UMTATA	28E4436	31S3548	59	775.25	40	H	OPE	SBC2	221
1717	UMTATA	28E4436	31S3548	63	807.25	40	H	OPE	SBC1	221
1718	UMTATA LINK	28E2350	31S3333	33	567.25	6	V	OPE	SBC1	10
1719	UMTATAMT HOPE	28E5317	31S2658	11	231.25	23	V	OPE	SBC2	10
1720	UNDERBERG	29E3038	29S4757	37	599.25	6	V	OPE	SBC2	10
1721	UNDERBERG	29E3038	29S4757	41	631.25	6	V	OPE	SBC1	10
1722	UNDERBERG CASTLE END	29E1622	29S4447	31	551.25	-10	V	OPE	SBC2	10
1723	UNDERBERG DRKNSBGDNS	29E1447	29S4452	24	495.25	1.1	V	OPE	SBC2	10
1724	UNDERBERG DRKNSBGDNS	29E1447	29S4452	28	527.25	1.1	V	OPE	SBC1	10
1725	UNDERBERG LONGLANDS	29E3419	29S3445	39	615.25	1.1	V	OPE	SBC2	0
1726	UNDERBERG PIERRE MNT	29E4002	29S5313	51	711.25	5.1	V	OPE	SBC2	10
1727	UNDERBERG SANI PASS	29E2847	29S4021	21	471.25	11.5	V	OPE	SBC2	20
1728	UNDERBERG SNOW HILL	29E3347	29S4203	32	559.25	4	V	OPE	SBC2	10
1729	UNIONDALE	23E0307	33S4323	24	495.25	34	V	OPE	SBC2	47
1730	UNIONDALE	23E0307	33S4323	28	527.25	37	V	LIC	etv	47
1731	UNIONDALE TOWN	23E0735	33S3847	22	479.25	7	V	LIC	SBC1	9
1732	UNIONDALE TOWN	23E0735	33S3847	26	511.25	7	V	LIC	SBC3	9
1733	UNIONDALE TOWN	23E0735	33S3847	32	559.25	7	V	OPE	SBC2	9
1734	UNIONDALE TOWN	23E0735	33S3847	34	575.25	7	V	LIC	ETV	9
1735	UNIONDALE TOWN	23E0735	33S3847	36	594	30	V	OPE	SABC	9
1736	UPINGTON	21E4412	28S5256	7	199.25	50	H	LIC	etv	257
1737	UPINGTON	21E4412	28S5256	10	223.25	50	H	OPE	SBC2	257
1738	UPINGTON C57	21E1954	28S3009	4	175.25	16.5	H	OPE	SBC1	10
1739	UPINGTON TOWN	21E1217	28S3024	29	535.25	20	V	LIC	SBC3	30
1740	UPINGTON TOWN	21E1217	28S3024	33	567.25	20	V	LIC	ETV	30
1741	UPINGTON TOWN	21E1200	28S3025	21	471.25	26	V	OPE	MNET	33
1742	UPINGTON TOWN	21E1200	28S3025	25	503.25	26	V	OPE	SBC1	33
1743	UTRECHT	30E2048	27S3939	21	471.25	10	V	OPE	MNET	0
1744	UTRECHT	30E2048	27S3939	21	471.25	10	V	LI	MNET	10
1745	UTRECHT GOEDEHOOP	30E3340	27S4448	55	743.25	0	V	OPE	SBC2	10
1746	UTRECHT GOEDEHOOP	30E3340	27S4448	59	775.25	0	V	OPE	SBC1	10
1747	VAN RHYNSDORP	18E4124	31S4516	4	175.25	40	H	OPE	SBC1	195
1748	VAN RHYNSDORP	18E4124	31S4516	7	199.25	50	H	LIC	etv	195
1749	VAN RHYNSDORP	18E4124	31S4516	10	223.25	50	H	OPE	SBC2	195
1750	VANDERKLOOF	24E4422	30S0013	42	639.25	6	V	LIC	SBC1	10
1751	VANDERKLOOF	24E4422	30S0013	46	671.25	6	V	OPE	SBC2	10
1752	VANDERKLOOF	24E4422	30S0013	50	703.25	6	V	LIC	SBC3	10
1753	VANWYKSDORP	21E2817	33S4306	21	471.25	6.5	V	OPE	SBC2	10
1754	VERENA	29E0133	25S2910	66	832	20	V	OPE	RKRS	20
1755	VERENA	29E0133	25S2910	66	832	20	V	OPE	RKRS	20
1756	VERULAM	31E0220	29S3825	21	471.25	10	V	OPE	SBC2	13
1757	VERULAM	31E0220	29S3825	25	503.25	10	V	OPE	SBC1	13
1758	VERULAM	31E0220	29S3825	29	535.25	10	V	OPE	SBC3	13
1759	VERULAM	31E0220	29S3825	33	567.25	0	V	OPE	etv	13
1760	VICTORIA WEST	23E0636	31S2349	23	487.25	1.5	V	OPE	SBC2	10
1761	VICTORIA WEST	23E0636	31S2349	35	583.25	11.5	V	OPE	MNET	10
1762	VICTORIA WEST	23E1350	31S4115	9	215.25	27	V	OPE	SBC2	94
1763	VICTORIA WEST	23E1350	31S4115	39	615.25	27	H	LIC	etv	103
1764	VILLIERS	28E3656	27S0208	56	751.25	6	V	OPE	MNET	68
1765	VILLIERS	28E3656	27S0208	60	783.25	6	V	OPE	SBC3	68
1766	VILLIERS	28E3656	27S0208	64	815.25	6	V	OPE	SBC1	68
1767	VILLIERS	28E3656	27S0208	68	847.25	6	V	OPE	SBC2	68
1768	VILLIERSDORP	19E3025	33S5809	4	175.25	32.5	H	OPE	MNET	50
1769	VILLIERSDORP	19E3025	33S5809	7	199.25	50	H	OPE	SBC2	138
1770	VILLIERSDORP	19E3025	33S5809	10	223.25	40	H	OPE	SBC1	138
1771	VILLIERSDORP	19E3025	33S5809	57	759.25	50.5	H	OPE	etv	152
1772	VILLIERSDORP	19E3025	33S5809	61	791.25	50.5	H	OPE	SBC3	152
1773	VILLIERSDORP ELANDSK	19E1643	33S5428	21	471.25	4	V	LIC	ETV	10
1774	VILLIERSDORP ELANDSK	19E1643	33S5428	33	567.25	4	V	LIC	SBC3	10
1775	VILLIERSDORP TOWN	19E1658	33S5408	31	551.25	7.8	V	OPE	SBC3	23
1776	VILLIERSDP ELANDSKLF	19E1643	33S5428	25	503.25	4	V	OPE	SBC2	10
1777	VILLIERSDP ELANDSKLF	19E1643	33S5428	29	535.25	4	V	OPE	SBC1	10
1778	VOLKSRUST	29E5500	27S2138	37	599.25	17	V	LI	MNET	10
1779	VOLKSRUST	29E5500	27S2138	37	599.25	17	V	LIC	MNET	20
1780	VOLKSRUST	29E5315	27S1833	6	191.25	40	V	OPE	SBC2	164
1781	VOLKSRUST	29E5315	27S1833	9	215.25	40	V	OPE	SBC1	164
1782	VOLKSRUST	29E5315	27S1833	13	247.43	40	V	OPE	etv	164
1783	VOLKSRUST	29E5315	27S1833	54	735.25	38.7	H	OPE	SBC3	178
1784	VREDENBURG	17E5902	32S5502	27	519.25	19	V	OPE	MNET	24
1785	VREDENDAL	18E4124	31S4515	21	471.25	17	V	LI	MNET	0
1786	VREDENDAL	18E4124	31S4515	21	471.25	20	V	LI	MNET	8

Table C.23: Analogue entries considered (21 of 21)

Entry number	Transmitting station name	Longitude	Latitude	Channel	Frequency (MHz)	ERP (dBW)	Polarisation	Status	Program	Antenna height (m)
1787	VREDENDAL	18E4124	31S4515	25	503.25	17	V	OPE	SBC3	8
1788	VREDENDAL	18E4124	31S4515	29	535.25	17	V	LI	ETV	8
1789	VRYBURG T82	24E4309	26S5650	59	775.25	6	V	LIC	SBC3	30
1790	VRYBURG T82	24E4309	26S5650	63	807.25	15	V	OPE	MNET	30
1791	VRYHEID	30E4733	27S4427	43	647.25	10	H	OPE	SBC3	10
1792	VRYHEID	30E4623	27S4644	54	735.25	16	H	OPE	MNET	10
1793	VRYHEID	30E4738	27S4427	22	479.25	40	H	OPE	etv	134
1794	VRYHEID	30E4738	27S4427	39	615.25	40	H	OPE	SBC2	134
1795	VRYHEID	30E4738	27S4427	43	647.25	40	H	OPE	SBC3	134
1796	VRYHEID	30E4738	27S4427	47	679.25	40	H	OPE	SBC1	134
1797	VRYHEID	30E4738	27S4427	51	711.25	30	H	OPE	MNET	134
1798	VRYHEID GROOTGELUK	31E1828	27S5230	42	639.25	4	V	OPE	SBC1	10
1799	VRYHEID GROOTGELUK	31E1828	27S5230	50	703.25	4	V	OPE	SBC2	10
1800	VRYHEID LENJANE	30E5807	27S5300	41	631.25	1.8	V	OPE	SBC2	0
1801	VRYHEID SCHOONUITZGT	31E0639	28S1018	46	671.25	0	V	OPE	SBC2	10
1802	WAENHUISKRANS	20E1344	34S4027	24	495.25	7	V	OPE	SBC3	20
1803	WAKKERSTRM SKURWEKLP	30E1523	27S2847	41	631.25	4	V	OPE	SBC2	10
1804	WAKKERSTRM SKURWEKLP	30E1523	27S2847	49	695.25	4	V	OPE	SBC1	10
1805	WARDEN O74.3	28E5832	27S5002	25	503.25	8	V	LI	MNET	10
1806	WARDEN O74.3	28E5832	27S5002	29	535.25	5.1	V	OPE	SBC2	10
1807	WARDEN O74.3	28E5832	27S5002	33	567.25	7	V	OPE	SBC1	10
1808	WARRENTON	24E5056	28S0651	43	647.25	13	V	LI	MNET	10
1809	WATERVAL BOVEN	30E1949	25S3854	59	775.25	3	V	OPE	SBC1	10
1810	WATERVAL BOVEN	30E1949	25S3854	63	807.25	3	V	OPE	MNET	10
1811	WATERVAL BOVEN	30E1949	25S3854	67	839.25	3	V	OPE	SBC2	10
1812	WEAVINDPARK	28E1618	25S4352	23	490.55	20	V	OPE	TSWA	5
1813	WEAVINDPARK	28E1618	25S4352	66	834	20	V	OPE	JAKR	5
1814	WEAVINDPARK	28E1618	25S4352	66	834.75	20	V	OPE	JAKR	5
1815	WELKOM N/CAPE	20E3631	26S3251	23	487.25	17	H	LIC	SBC1	40
1816	WELKOM N/CAPE	20E3631	26S3251	27	519.25	17	H	LIC	SBC2	40
1817	WELKOM N/CAPE	20E3631	26S3251	31	551.25	17	H	LIC	SBC3	40
1818	WELKOM N/CAPE	20E3631	26S3251	35	583.25	17	H	LIC	ETV	40
1819	WELKOM SHOWGROUNDS	26E4504	27S5950	22	485.75	20	V	OPE	RGVL	20
1820	WELVERDIEND	27E1455	26S2647	4	175.25	50	H	OPE	SBC1	138
1821	WELVERDIEND	27E1455	26S2647	7	199.25	50	H	OPE	SBC2	138
1822	WELVERDIEND	27E1455	26S2647	10	223.25	50	H	OPE	SBC3	138
1823	WELVERDIEND	27E1455	26S2647	27	519.25	55.5	H	OPE	etv	153
1824	WEMMERSHOEK	19E0323	33S5107	54	735.25	6	H	LIC	SBC1	10
1825	WEMMERSHOEK	19E0323	33S5107	58	767.25	6	H	LIC	SBC2	10
1826	WEMMERSHOEK	19E0323	33S5107	62	799.25	6	H	LIC	SBC3	10
1827	WEMMERSHOEK	19E0323	33S5107	66	831.25	6	H	LIC	ETV	10
1828	WEPENER	27E0241	29S4348	37	599.25	8	V	LIC	MNET	10
1829	WEPENER WELBEDAM 050	26E5022	29S5405	31	551.25	4.8	V	OPE	SBC1	20
1830	WILLISTON	20E5508	31S2038	38	607.25	6	V	LIC	SBC1	12
1831	WILLISTON	20E5508	31S1931	42	639.25	27	H	OPE	SBC2	12
1832	WILLISTON	20E5508	31S2038	46	671.25	6	V	LIC	SBC3	12
1833	WILLISTON	20E5508	31S1931	50	703.25	27	H	LIC	etv	12
1834	WILLISTON	20E5508	31S2038	54	735.25	6	V	LIC	etv	12
1835	WILLISTON	20E5508	31S2038	58	767.25	6	V	LIC	MNET	12
1836	WILLISTON GROOTMKLIP	21E1819	31S0411	63	807.25	6	V	OPE	SBC2	10
1837	WILLISTON HEUNINGBRG	21E0026	30S5424	23	487.25	0	V	OPE	SBC2	10
1838	WILLISTON LUKASFNTN	21E1707	31S4457	29	535.25	19	V	OPE	SBC2	10
1839	WILLISTON OEST	21E0419	31S0031	42	639.25	3	H	OPE	SBC2	10
1840	WILLISTON TWEEMIK	21E0922	30S4110	26	511.25	7	V	OPE	SBC2	10
1841	WILLOWMORE	23E2736	33S1405	57	759.25	40	H	OPE	SBC2	72
1842	WILLOWMORE	23E2736	33S1405	61	791.25	40	H	LIC	etv	72
1843	WILLOWMORE C6	23E2736	33S1405	53	727.25	23.5	H	OPE	SBC1	10
1844	WILLOWMORE II	23E2944	33S1733	21	471.25	4	V	OPE	MNET	30
1845	WILLOWMORE II	23E2944	33S1733	25	503.25	4	V	OPE	SBC1	30
1846	WILLOWMORE II	23E2944	33S1733	29	535.25	4	V	LIC	SBC3	30
1847	WILLOWMORE STUDTIS	24E0642	33S3735	26	511.25	6	V	OPE	SBC2	10
1848	WINDYRIDGE(BISHO)	27E1404	32S4510	24	495.25	50	H	OPE	TBNC	125
1849	WINTERTON CATHKIN PK	29E2548	29S0015	42	639.25	4.5	V	OPE	SBC2	10
1850	WINTERTON CATHKIN PK	29E2548	29S0015	46	671.25	4.5	V	OPE	SBC1	10
1851	WITBANK LANDAU	29E1253	25S5644	56	751.25	3.4	V	OPE	SBC2	10
1852	WITBANK LANDAU	29E1253	25S5644	60	783.25	3.4	V	OPE	SBC1	10
1853	WITBANK LANDAU	29E1253	25S5644	64	815.25	3.4	V	OPE	MNET	10
1854	WITBANK LANDAU	29E1253	25S5644	68	847.25	3.4	V	OPE	SBC3	10
1855	WITSIESHOEK	28E5052	28S3102	24	495.25	24	V	OPE	SBC2	31
1856	WITSIESHOEK	28E5052	28S3102	28	527.25	24	V	OPE	SBC1	31
1857	WITSIESHOEK	28E5052	28S3102	32	559.25	24	V	OPE	etv	31
1858	WITZENBERG EBENHAEZR	19E1458	33S1002	46	671.25	3	V	OPE	SBC2	10
1859	WUPPERTAL	19E1458	32S1558	37	599.25	6	V	OPE	SBC2	10
1860	ZASTRON	27E0508	30S1709	37	599.25	7	V	LI	MNET	10
1861	ZEERUST	26E0400	25S3238	28	527.25	13	V	OPE	MNET	10
1862	ZEERUST	26E0252	25S5137	40	623.25	50	H	OPE	SBC3	252
1863	ZEERUST	26E0252	25S5137	44	655.25	50	H	OPE	SBC1	252
1864	ZEERUST	26E0252	25S5137	48	687.25	50	H	OPE	etv	252
1865	ZEERUST	26E0252	25S5137	52	719.25	50	H	OPE	SBC2	252
1866	ZEERUST (2)	26E0455	25S3344	24	495.25	0	V	OPE	SBC2	20