

Final report for the SKA Programme  
Development Office

## Study on the long-term RFI environment for the SKA radio telescope

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# 1 Executive summary

The Square Kilometre Array (SKA) Program Development Office (SPDO) at the University of Manchester commissioned Analysys Mason Limited ('Analysys Mason') to undertake an economic, technological and regulatory study of the long-term radio frequency interference (RFI) environment in sites of interest in relation to the planned SKA radio telescope. The objective of the study is to provide expert opinion on whether the telescope should be located in Africa or in Australasia.

This is the final report for this study. This report supplements the findings of expert panels that have been constituted to review specific aspects of the SKA project, such as the radio frequency interference/electromagnetic interference (RFI/EMI) and radio quiet zone (RQZ) environment in the two potential sites, and regulatory requirements. In particular, the SPDO commissioned this report to identify external market and technology developments in the area of commercial wireless systems, which might have a bearing upon the future RFI/EMI, RQZ and/or regulatory environments at the two sites.

The spectrum of interest to the SKA project includes spectrum within the 70MHz to 10GHz frequency range in ITU Region 1 (of which South Africa is a part) and ITU Region 3 (of which Australia is a part).<sup>1</sup> This spectrum encompasses bands that accommodate most of the major commercial uses of radio spectrum today, as well as military and government use (e.g. emergency services and transport), through to social and experimental uses (e.g. radio astronomy, earth exploration).

## 1.1 Summary of findings in relation to market and technology developments

Our review of longer-term changes to spectrum use and technology has highlighted the following points that are broadly applicable to both Australia and South Africa. We note that this is a snapshot of the situation at the time of producing this report in October 2011, which could change as a result of further market and technology developments in the future:

- We expect that three significant changes will happen to spectrum in the 300MHz to 10GHz frequency range in the next five to ten years:
  - A shift away from fixed, satellite and broadcasting spectrum use towards increasing amounts of spectrum being deployed for mobile broadband – the Australian Communications and Media Authority (ACMA) notes that an additional 150MHz of spectrum is expected to be required for mobile broadband use in future.

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<sup>1</sup> The ITU divides the world into three regions: ITU Region 1 comprises Europe, Africa, the Middle East, west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia, ITU Region 2 covers the Americas, Greenland and some of the eastern Pacific Islands and ITU Region 3 comprises most of the non-former-Soviet-Union Asia, east of and including Iran, and most of Oceania.

- Migration from analogue to digital broadcasting in VHF Band III and UHF Bands IV and V, including the release of digital dividend spectrum in the UHF band (in the 700MHz and 800MHz bands in Australia and South Africa, respectively), which the government in both countries expects to award for mobile broadband use.
- Migration of satellite systems from the 1GHz to 10GHz range towards next-generation Ka-band systems above 20GHz.
- Mobile operators are gradually migrating their 2G mobile systems in 900MHz and 1800MHz spectrum to 3G/4G. This will result in more intensive use of those bands and in a change of technology (to orthogonal frequency division multiple access (OFDMA)-based Long Term Evolution (LTE) systems).
- In the longer term, DTT services that use UHF Band IV will migrate from digital video broadcasting – terrestrial (DVB-T) to DVB-T2 technology using single-frequency networks, which potentially requires a more dense network than DVB-T with multiple-frequency network transmission (MFN). This will potentially affect emission levels in UHF spectrum, since the spectrum will be used more intensively. It is also possible that further migration to digital terrestrial television (DTT) will lead to more UHF spectrum being allocated for mobile broadband, which will increase the deployment of mobile broadband solutions in the market.
- There is likely to be some small improvement in the efficiency of wireless communications systems arising from increased use of ‘intelligent’ radios and more efficient modulation techniques – for example, future development of cognitive radio.
- Growth in use of various frequency bands for short-range devices (SRD) is one possible area of future change of relevance to the SKA environment; the most widely used SRD bands today are considered to be the 433MHz and 863–870MHz bands, and the 2.4GHz and 5GHz bands. Developments in machine-to-machine (M2M)<sup>2</sup> communications and UHF ‘white space’ devices<sup>3</sup> are examples of innovation taking place within the short-range device (SRD) sector that is likely to result in the frequency bands used by these applications being used much more intensively in future, leading to an increase in RF noise from those bands into neighbouring bands, and into astronomy environments.

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<sup>2</sup> M2M refers to technologies that allow both wireless and wired systems to communicate with other devices of the same ability. M2M typically uses a device (such as a sensor or meter) to capture an event (such as temperature, inventory level, etc.), which is relayed through a network (wireless, wired or hybrid) to an application, which translates the captured event into meaningful information (for example, items need to be restocked).

<sup>3</sup> White space devices refers to systems being designed to re-use the gaps between TV transmissions in UHF spectrum.

## 1.2 Summary of observations in relation to establishing and maintaining an RQZ

We note the following points based upon our review of the *Report of the Expert Panel on the RQZ and RFI regulation*, provided to us for this study, and the associated individual site submissions from the Australian and South African site proponents:

- International-imported interference from neighbouring countries may give rise to emissions in certain bands travelling across borders, especially broadcast TV where the high masts combined with the anomalous propagation phenomena can result in interference hundreds of miles from the transmitter. This is particularly relevant to the South African site, since South Africa shares a land border with various of its neighbouring countries. The nature of radio propagation is such that it is possible that transmitters installed in neighbouring countries could generate emissions that will cause interference in South Africa, for example.
- It may be prudent to seek a legal adviser, with experience of the legal system of the candidate countries, to assess the legislation referenced in responses and to confirm that the laws/regulations in force (on the statute) do indeed protect the respective RQZ and offer sufficient penalties or powers to resolve interference issues.
- It appears that further sanctioning of fracking could give rise to concerns for the SKA environment at both sites. However, there do not appear to be reports of mining interests wanting to develop within the established RQZ at the Australian site to date. In the case of South Africa, there have been reports that energy firms<sup>4</sup> are interested in prospecting for gas in the Karoo region. Any risk to the RQZ would depend on whether these prospects will be sanctioned, and also whether the fracking activity is far enough away from the SKA site to avoid potential disruption to the RQZ. However, reports suggest that the areas being explored are quite extensive, and that they may only overlap with the existing RQZ to a limited extent.

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<sup>4</sup>

<http://af.reuters.com/article/investingNews/idAFJOE72G0EZ20110317>.

## 2 Introduction

Analysys Mason Limited ('Analysys Mason') was commissioned by the Square Kilometre Array (SKA) Program Development Office (SPDO) at the University of Manchester to undertake an economic, technological and regulatory study of the long-term radio frequency interference (RFI) environment in sites of interest in relation to the planned SKA radio telescope. The objective of the study is to provide expert opinion whether the telescope should be located in Africa or in Australasia.

This document is the final version of Analysys Mason's report for this study. It has been produced based upon review of a draft version by the SPDO team.

### 2.1 Background

The SKA radio telescope is one of a suite of new, international telescopes that is being developed with the objective to probe the formation and evolution of physical properties of the Universe. Its design involves use of thousands of receivers linked together creating a uniquely large collecting area that surpasses radio telescopes in use around the world at the present time.

The selected site for the SKA project will be required to establish a radio quiet zone (RQZ) around the proposed centre of the array. The SKA Memo 73 laid down the basic features of, and the considerations and specifications for, such an RQZ. The RFI environment, now and in the future, within the RQZ depends significantly on the specifications set out in this Memo, and how much can be achieved and enforced in practice. Existing laws and new legislation will play a dominant role in protecting the SKA, as well as the effective management of local and regional radio spectrum.

One other area of interest in relation to the RFI environment is how radio systems will evolve in the longer term, and the implications that this will have for the usage of radio spectrum.

In this context, the SPDO at the University of Manchester asked Analysys Mason to provide an independent assessment of market and technology trends in relation to the use of radio spectrum from 300MHz to 10GHz.

### 2.2 Objectives and scope of this report

The objective of this report is to supplement the findings of expert panels that have been constituted to review specific aspects of the SKA's project, such as the RFI/EMI and RQZ environment in the two potential sites, and regulatory requirements.

In particular, the SPDO commissioned this report to identify external market and technology developments in the area of commercial wireless systems that might have a bearing upon the future RFI/EMI, RQZ and/or regulatory environments at the two sites. The SPDO's specific objectives in commissioning this study were to:

- gain an understanding of the factors that are likely to influence the RFI environment over the next 50 years – including economic, technological, demographic and regulatory factors
- determine the relative strengths and weaknesses of both candidate sites in terms of their long-term RFI environments.

## 2.3 Structure of this document

The remainder of this document is laid out as follows:

- **Section 3** outlines worldwide trends in specific areas of wireless spectrum
- **Section 4** discusses use of spectrum in Australia
- **Section 5** deals with use of spectrum in South Africa
- **Section 6** covers Analysys Mason's review of the responses received from the Australia and New Zealand SKA Coordination Committee and SKA South Africa to the requirements for RQZ Protection, stipulated by the SKA Siting Group (SSG) in its paper *Request for Information from the Candidate SKA sites* ('the RFI', ref: SSG-RFI-001 Rev D)
- **Section 7** presents our conclusions from the study.

The report includes the following annex containing supplementary material:

- **Annex A** gives an overview of spectrum allocations within the 70MHz to 10GHz range of interest to the SKA
- **Annex B** includes a list of abbreviations used throughout this document.

## 3 Worldwide trends in radio technology and spectrum

This section provides an overview of anticipated developments in wireless technology and radio spectrum utilisation in the next five to ten years which are relevant to the spectrum of interest to the SKA project (which covers the frequency range from 70MHz to 10GHz). It is structured as follows:

- Section 3.1 introduces the frequency range of interest to the SKA project and the various commercial wireless systems that use spectrum within this range
- Section 3.2 to Section 3.10 cover the relative market and technology developments in public mobile (cellular) networks, business radio (also referred to as private mobile radio), microwave fixed links, radio and TV broadcasting, satellite systems, programme making and special events (PMSE), science services, aeronautical and maritime radio and short-range devices
- Section 3.11 discusses applications for purposes other than communications, which can create electromagnetic interference, which can disrupt radio communications.

### 3.1 Introduction

The spectrum of interest to SKA, from 70MHz to 10GHz, encompasses bands that accommodate most of the major commercial uses of radio spectrum today, as well as military and government use (e.g. emergency services and transport), through to social and experimental uses (e.g. radio astronomy, earth exploration).

For the SKA, we are particularly interested in spectrum use within the 70MHz to 10GHz range in ITU Region 1 (of which South Africa is a part) and ITU Region 3 (of which Australia is a part)<sup>5</sup>.

Annex A of this report summarises the uses of radio spectrum in the 70MHz to 10GHz frequency range in the two ITU Region 1 and 3.

We have divided our analysis into different categories of wireless use (i.e. services). A service is a grouping of how spectrum is used. The services covered in the remainder of this section, which are the main categories of spectrum use in the 70MHz to 10 GHz frequency range, are:

- public mobile (cellular radio) networks
- business radio (also referred to as private mobile radio)
- microwave fixed links
- radio and TV broadcasting
- satellite (fixed and mobile) systems
- PMSE
- science services
- aeronautical and maritime
- SRDs (including those that are licence exempt).

<sup>5</sup> The ITU divides the world into three regions: ITU Region 1 comprises Europe, Africa, the Middle East, west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia, ITU Region 2 covers the Americas, Greenland and some of the eastern Pacific Islands and ITU Region 3 comprises most of the non-former-Soviet-Union Asia, east of and including Iran, and most of Oceania.

Additional services are listed in the ITU allocations provided in Annex A, but have a minimal impact on the long-term RFI environment (these services are unlikely to be subject to substantial technological, economic, demographic or regulatory change that would affect their contribution to the long-term RFI environment).

## 3.2 Public mobile (cellular radio) networks

Below we cover market and technology developments relating to public mobile, or cellular, radio networks.

### 3.2.1 Overview of the service

Public mobile or cellular radio networks deliver mobile communications services (voice, data or both) to the public, through a range of radio terminals (e.g. basic mobile phones, smartphones, laptops, tablet devices). Each operator that provides mobile services establishes a network of base stations, which are connected via fibre or microwave radio links to a core network. Microwave links used different frequencies to connect cellular base stations from those used to deliver the cellular service (microwave radio is covered separately in a subsequent section).

Infrastructure for a public mobile network is established and operated by a commercial mobile telecoms provider. Each operator that provides mobile services has its own network, although mobile virtual network operators (MVNO) have also emerged in recent years, which share infrastructure with other mobile telecoms providers. MVNOs do not have their own licensed radio spectrum, but use the radio access network and spectrum of another licensed network operator to provide services.

At a global level, the Radiocommunications sector of the International Telecommunications Union (ITU-R) co-ordinates spectrum arrangement and standards for public mobile services through its International Mobile Telecommunications (IMT) programme. IMT systems were originally referred to as ‘IMT-2000’ – considered to be the third generation (3G) of public mobile services, deployed in spectrum in the 2GHz range.<sup>6</sup> The term IMT today is considered to include all 3G and fourth-generation (4G) mobile services, which operate in a number of frequency bands around the world.

The frequency bands used by cellular mobile services vary across world regions. Early-generation (first and second generation) cellular systems typically operate in one or more of the following frequency bands: 850MHz, 900MHz and 1800MHz. 3G mobile networks were initially deployed using spectrum in the 1900MHz and 2100MHz bands; however, regulatory changes and technology developments in recent years have led to frequency bands previously assigned for 2G use (i.e. 850MHz, 900MHz, 1800MHz) being re-assigned or ‘re-farmed’ for 3G services. In addition to this, the ITU identified a number of additional bands for 3G/4G system use in different world regions at the World Radio Conferences (WRC) held in 2000 and 2007 (WRC-2000 and WRC-07), which include various globally as well as regionally identified bands.

<sup>6</sup> First-generation cellular refers to the early analogue cellular services that operated in the 1980s and early 1990s, which were superseded by second-generation, or 2G, systems during the 1990s. 2G services still operate today (although are gradually being migrated to 3G), many of these using the Global System for Mobile (GSM) standard.

Thus, the frequency bands identified for IMT systems by the ITU-R comprise various bands within the range of interest to the SKA:

- 450–470MHz
- 790–960MHz
- 1710–2025MHz
- 2110–2200MHz
- 2300–2400MHz
- 2500–2690MHz.

In addition, a number of bands are identified at a regional level:

- 698–790MHz (ITU Region 2)
- 610–790MHz (9 countries in ITU Region 3: Bangladesh, China, Republic of Korea, India, Japan, New Zealand, Papua New Guinea, Philippines and Singapore)
- 3400–3600MHz (over 80 administrations in ITU Region 1, plus 9 administrations in ITU Region 3 including India, China, Japan and the Republic of Korea).

Most public mobile broadband services use GSM/GPRS and wideband code division multiple access (W-CDMA)/high-speed packet access (HSPA) technologies for 2G/3G, and are currently migrating to Long Term Evolution (LTE) technologies for 3.5G and 4G services. We note that LTE uses a different air interface<sup>7</sup> from 2G or 3G and so its emission characteristics are different. In particular, the higher-speed services envisaged for 4G mobile means that LTE uses wider bandwidth channels, with higher-level modulation; this means that the bandwidth that LTE signals occupy is generally greater than for 2G or 3G, and also the waveform used may exhibit higher peaks of signal power.

Below we cover service and technology trends in public mobile communications in more detail.

### 3.2.2 Service trends

Demand for mobile communications has increased significantly in recent years, which has incentivised operators to migrate their networks from 2G and 3G to 4G, which enable higher peak data rates. Some of the factors driving spectrum demand from mobile operators include the increasing take-up of mobile broadband services, the increasing sales of smart phones, the rapid adoption of tablet devices like Apple's iPad, and the increasing development and roll-out of machine-to-machine (M2M).<sup>8</sup> This growth in spectrum demand from mobile operators has major implications in terms of the amount and type of wireless network traffic carried on public mobile networks – firstly, on average, data traffic exceeds voice traffic on mobile networks around the world, and secondly, the average volume of traffic

<sup>7</sup> The radio-based link between a base station and a mobile device.

<sup>8</sup> M2M refers to technologies that allow both wireless and wired systems to communicate with other devices of the same ability. M2M typically uses a device (such as a sensor or meter) to capture an event (such as temperature, inventory level, etc.), which is relayed through a network (wireless, wired or hybrid) to an application, which translates the captured event into meaningful information (for example, items need to be restocked).

per connection (i.e. per user) has grown significantly in recent years, to the extent that worldwide data traffic is exhibiting exponential growth.

Analysys Mason’s Research division forecasts that the mobile data traffic carried on public mobile networks worldwide will be seven times higher in 2016 than in 2011. This is viewed as a conservative assumption, and some industry forecasts suggest an even higher growth.

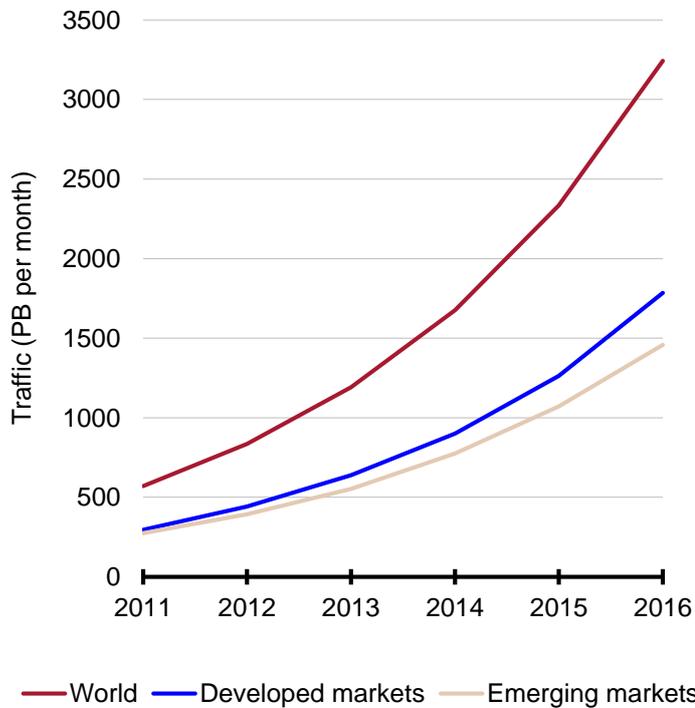


Figure 3.1: Worldwide traffic from mobile connections [Source: Analysys Mason]

Figure 3.2 below illustrates Analysys Mason’s view of the main factors driving this growth in mobile data traffic.

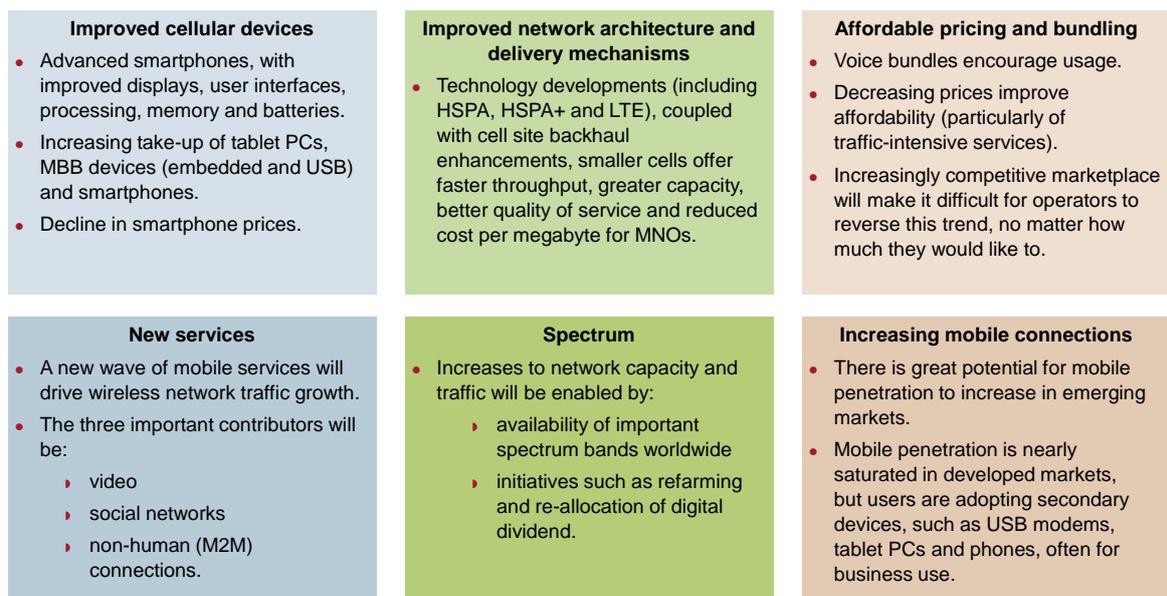


Figure 3.2: Market drivers contributing to the significant increase in mobile data traffic [Source: Analysys Mason]

The implication of this continual increase in mobile data volumes is that mobile network operators need to provide greater capacity within their networks to accommodate the traffic that is being generated.

Although operators worldwide are still deploying 3G networks in 2011, which provide greater capacity than 2G networks and allow mobile network operators (MNOs) to offer a broader range of services, operators with established 3G networks are either upgrading their networks to HSPA and HSPA+ or migrating to 4G (LTE). Other technology enhancements are also possible including use of smaller cells, multiple-input multiple-out (MIMO) antennas, and use of improved compression technologies (e.g. for video). However, base station technology is rapidly approaching the maximum data rate that a given bandwidth can carry, known as the Shannon Limit. There are therefore two primary methods of increasing capacity on an operator's network:

- **Increase site density** – This reduces the size of each site. This 'cell splitting' is the rationale behind the use of pico-cells and femto-cells, for example.
- **Make more spectrum available** – The combination of increasing demand for wireless data services and a finite resource such as spectrum affects a wide range of other radio sectors. The identification and release of new spectrum bands for mobile services often involves the re-configuration and re-farming of spectrum used by other services.

**Implications for the SKA project:** Increasing site density means that frequencies are being used more intensively than before (i.e. less 'white space'), giving rise to more noise and interference. Making more spectrum available means that existing services using some spectrum bands will be displaced in future in favour of more mobile broadband systems, changing the characteristics of use of some frequency bands and also affecting noise and interference levels.

Recent auctions of new mobile spectrum around the world have focussed on the award of spectrum in various bands above 2GHz (2.3GHz, 2.6GHz and 3.4GHz). These bands are suited to higher-speed and higher-capacity mobile broadband services, but were previously used for lower-capacity, longer-range wireless point-to-point links.

This means that operators will deploy an increasing number of wireless transmitters to be able to provide the high capacity and wide area coverage required from mobile networks – in contrast to point-to-point links which use a lower number of transmitters but operating at higher powers.

### 3.2.3 Technology trends

Various global technology standards are used to provide mobile and wireless broadband service. The main standards bodies working in this area are the Third Generation Partnership Project (3GPP) and the Institute of Electrical and Electronic Engineers (IEEE). The predominant standards in use around the world are the 3GPP UMTS/LTE standard, and the IEEE WiMAX (worldwide interoperability for microwave access) standard. Both UMTS/LTE and WiMAX are included in

the family of 3G/4G mobile standards recognised by the ITU-R and collectively referred to as IMT systems, as described previously.

The technologies used to provide public mobile services have evolved rapidly since cellular networks were first conceived. First-generation analogue technology was gradually displaced by the 2G digital GSM standard – originally developed in Europe but subsequently adopted worldwide – during the latter half of the 1990s, and the first 3G networks based on the UMTS standard developed by 3GPP were launched around 2002. Since then, there has been a progressive migration of users from 2G to 3G networks, although there remain a substantial number of users who rely solely on 2G networks. More recently, mobile operators have started to deploy LTE, which represents a further generational shift, from 3G to 4G. 3GPP is also developing the LTE standard.

All standards have similar goals in terms of improving spectrum efficiency and increasing data rates though use of wider bandwidth channels. Greater spectrum efficiency is achieved primarily through the use of higher-order modulation schemes and multi-antenna technologies such as MIMO. Whereas UMTS technology is considered to be 3G, and LTE is considered to be 4G, there are various standards in between these, often referred to as ‘3.5G’, including HSPA and HSPA+.<sup>9</sup> Mobile WiMAX is based on the IEEE802.11d standard, re-published as IEEE802.113, although this has more limited worldwide adoption than the 3GPP technologies (and is hardly used in some regions such as Europe). Work on a further evolution of the IEEE802.11e standard, called ultra-mobile broadband (UMB), was discontinued a few years ago, in favour of LTE. One distinction between 3GPP-based technologies such as UMTS and HSPA and WiMAX is that the former use frequency division duplex (FDD), whereas the latter uses time division duplex (TDD). This has a bearing upon the spectrum characteristics of the services: in the case of FDD systems, one block of frequencies provides the uplink and a separate block provides the downlink, whereas in the case of TDD systems, uplinks and downlinks are divided by time, not frequency. Peak-to-average power ratios are typically higher with TDD systems since a given bandwidth is accommodating both uplinks and downlinks.

An illustration of how mobile technologies have evolved over time, and the corresponding increase in user data rates, is shown below in Figure 3.3.

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<sup>9</sup> HSPA is an optimised UMTS standard that improves the data rate and efficiency of W-CDMA networks through use of improved modulation schemes.

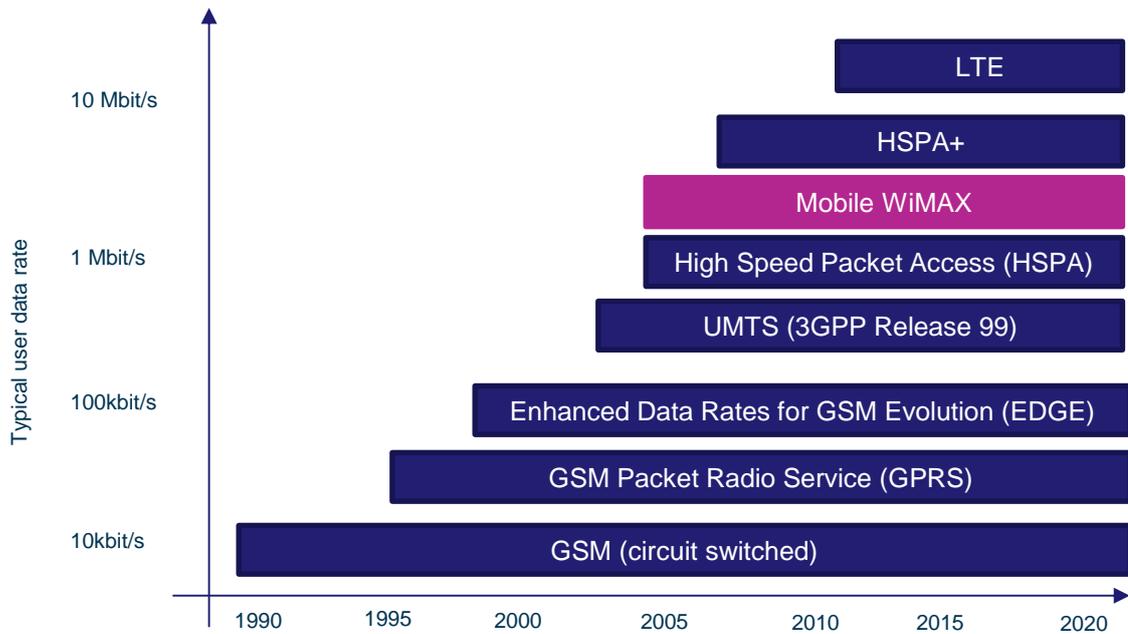


Figure 3.3: Evolution of European 2G and 3G public mobile technologies [Source: Analysys Mason]

A brief overview of this evolution is described in turn below.

### *GSM*

GSM networks have been in existence since 1991, and are now deployed in almost every country in the world. GSM networks are referred to as 2G cellular networks – since they replaced first-generation (analogue) networks that were initially launched during the 1980s.

GSM is a time division, multiple access (TDMA) technology which is deployed in the 900MHz and 1800MHz frequency bands in Europe. In some countries (e.g. Americas and parts of Asia), the 850MHz and 1900MHz bands have been used instead for 2G mobile services. Services delivered using GSM networks were largely voice and short messaging, and circuit mode data (at a speed of 9.6kbit/s). Most operators upgraded their GSM networks around ten years ago to include GPRS and/or EDGE overlay to deliver data services, as illustrated above.

### *GPRS and EDGE*

General packet radio service (GPRS) introduced Internet protocol (IP) packet data to public mobile, and as an overlay to GSM networks. It can provide data rates of up to 114kbit/s, and it uses the same Gaussian minimum shift keying (GMSK) modulation as GSM.

Enhanced data rates for GSM evolution (EDGE) is a further evolution of GSM, with data rates up to 236.8kbit/s. It can use higher order phase shift keying (PSK/8) modulation schemes to provide higher speeds. A number of mobile operators worldwide upgraded their GSM networks from GPRS to EDGE, within networks alongside the newer 3G services (see below).

### *3G UMTS*

3G or IMT-2000 is the term used to describe 3G public mobile technology, and has been standardised by 3GPP as the Universal Mobile Telecommunications System (UMTS).

3G is a significant step from GSM, and uses a W-CDMA or spread spectrum air interface rather than GSM's TDMA structure. The overall spectral efficiency of 3G was designed to be greater than GSM due to 3G's wider bandwidth channels and the higher level modulation schemes supported by its spread spectrum nature. Together, these allow greater data rates to be made available to the end user.

3G networks support voice and data, although often they are used as data only networks.

### *HSPA*

HSPA was developed as an extension to 3G/UMTS services around 2005, to provide higher-speed data connections. Basic UMTS has dedicated resource allocation per user, so it is not ideal for IP packet data. HSPA optimises the W-CDMA channel for IP data, and introduces a higher-level modulation scheme, 16QAM, with peak data rates of up to 14.4Mbit/s and 5.8Mbit/s in the downlink and uplink, respectively.

HSPA+ adds 64QAM to the downlink, increasing the data speeds yet again.

### *LTE*

LTE has been developed within the 3GPP standards process. The main driver for its development is the fast increase in the Internet, and the need for people to remain connected to a rich source of data, both within the home and when on the move. The data rates enabled by LTE will be comparable to those supported on fixed networks, with low latency, since this is required by many Internet applications.

LTE specification figures are peak downlink speeds of 100Mbit/s and uplink speeds of 50Mbit/s. LTE-Advanced will increase these to 1Gbit/s on the downlink and 500Mbit/s on the uplink. These very high rates are attainable only under optimal conditions very close to the base station; more typical rates are likely to be of the order of 10–20Mbit/s. A wide range of frequencies are planned, to include operation in all 'public mobile' bands specified by the ITU. This potentially means that operators of 2G and 3G mobile networks can re-farm existing spectrum in the 900MHz, 1800MHz, and 2100MHz bands, currently used for GSM/GPRS and UMTS/HSPA, to use LTE technology in the longer term.

Support for both TDD and FDD is included in the LTE specification; however, usage is set on a band-by-band basis. Most of the bands identified for IMT systems through the ITU-R have been configured as paired bands (for FDD) deployment. Notable examples of unpaired bands (suited for TDD) are 2.3GHz, 2570–2620MHz and 3.4–3.6GHz.

The LTE air interface is based on orthogonal frequency division multiple access technology (OFDMA). Since OFDMA operates with many modulated channels running at a slower speed, rather than one high-speed channel, it is able to cope well with signal path distortion and interference. By selecting a smaller number of sub-carriers the technology allows reduced channel width, at the expense of data throughput, or large channel widths with high data throughput. The ‘orthogonal’ part of OFDM means that the frequencies are at a set spacing; this does mean that the channel has to be contiguous, but can be made up of a number of sub-channels in different parts of the frequency band.

### *WiMAX*

WiMAX, also known as IEEE 802.16, was originally developed as a solution for the last-mile wireless broadband access. WiMAX was developed for fixed, nomadic and mobile applications. It has been developed by the IEEE in parallel with the UMTS/HSPA and LTE standards developed by 3GPP.

WiMAX uses multi-carrier OFDM, similar to LTE, which allows flexible channel widths, depending on the number of discrete carriers. It can operate on a wide range of frequencies, including 400MHz, 700MHz, 2.3GHz, 2.5GHz and 3.5GHz, and is TDD or FDD and with a number of channel sizes. Channel sizes for fixed WiMAX are 3.5MHz, 5MHz, 7MHz and 10MHz. Most network operators have chosen to deploy 5MHz or 10MHz variants.

The full range of WiMAX applications includes:

- public mobile broadband for mobile devices
- broadband wireless access for the last mile as an alternative to wired or satellite
- backhaul network for a public mobile network.

The network architecture for WiMAX is IP-based (like LTE), which makes it more suited to mobile data, rather than traditional voice, applications.

There have been a number of steps in the development of the 802.16 specification:

- 802.16d – known as fixed WiMAX, since it has no provision for mobility
- 802.16e – introduced mobility, known as mobile WiMAX
- 802.16m – advanced air interface with data rates of 100Mbit/s mobile and 1Gbit/s fixed (known as UMB) – this standard has subsequently been abandoned.

Mobile WiMAX is generally considered as an alternative to deploying LTE. In terms of future technology and spectrum choices, it is likely that mobile operators will seek the most efficient means to deliver the required capacity, both in terms of cost and time to market. Currently, LTE would appear to be the default upgrade for mass-market mobile services across much of the world. In view of this, it is considered unlikely that mobile WiMAX services will develop into a mass-market proposition in many countries, although may be used for niche services, particularly in rural areas.

### 3.2.4 Future spectrum demand

It is widely accepted that more spectrum beyond the bands already identified for IMT systems by the ITU-R will need to be made available to satisfy the increasing demand for mobile data traffic and enable universal mobile broadband access.

The GSM Association (GSMA), which is the industry body that represents the mobile industry worldwide, commissioned a study to assess the impact of the massive growth in mobile data traffic on the need for additional spectrum. The study stated the following:

“In the next 12 years, we will need **three times more spectrum (1.2GHz to 1.8GHz)** in each national market to accommodate data traffic demand and enable universal mobile broadband access. This demand for additional capacity means that re-farming of the 850MHz, 900MHz and 1800MHz bands for mobile broadband will not on its own be enough. Urgent licensing of additional spectrum in the 3G core band (1920–1980MHz, paired with 2110–2170MHz) and the 3G extension band (2500–2690MHz) is also needed.”<sup>10</sup>

This echoes an earlier study conducted by the ITU (2006)<sup>11</sup> which looked at the future spectrum requirements for public mobile services assuming the co-existence of 2G/3G/4G networks, and predicted that 1.5GHz to 2.5GHz of additional spectrum will need to be deployed in future.

This need for additional spectrum to accommodate growth in mobile data services is internationally recognised. The Federal Communications Commission (FCC) (the US regulator) published a white paper in 2010 that analyses the need for public mobile spectrum. The paper concludes the following:

“As smartphones, laptops, and other devices become increasingly integral to consumers’ mobile experiences, mobile data demand is expected to grow between 25 and 50 times current levels within 5 years.”<sup>12</sup>

Other regulators, such as the UK Office of Communications (Ofcom), have subsequently published similar statements regarding future spectrum requirements for mobile data and mobile broadband services. Ofcom has identified that a further 500MHz of spectrum will be required for mobile systems in the longer term, much of which it expects can be obtained through release of military spectrum for commercial use. This is similar to proposals put forward by the regulator in Australia, which are described later on in this report.

<sup>10</sup> GSMA, public policy, core and extension bands. Available at [http://www.gsmworld.com/our-work/public-policy/core\\_and\\_extention\\_bands.htm](http://www.gsmworld.com/our-work/public-policy/core_and_extention_bands.htm).

<sup>11</sup> ITU-R M 2078 (2006), *Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced, 2006*, [www.itu.int/itmt](http://www.itu.int/itmt).

<sup>12</sup> Federal Communications Commission (FCC) (October 2010), *Mobile Broadband: the benefits of additional spectrum*. Available at [http://transition.fcc.gov/Daily\\_Releases/Daily\\_Business/2010/db1021/DOC-302324A1.pdf](http://transition.fcc.gov/Daily_Releases/Daily_Business/2010/db1021/DOC-302324A1.pdf).

**Implications for the SKA project:** International proposals to make more spectrum available for mobile broadband services in future means that existing services using some spectrum bands within the frequency range of interest to the SKA will be displaced in future, changing the characteristics of use of some frequency bands and also affecting noise and interference levels.

Global decisions on the allocation of new bands for mobile services take place at ITU WRCs, which are held every three to four years. Agendas for the WRCs are set at the preceding WRC. The WRC in 2012 (WRC-12) will not be considering future spectrum allocations for IMT systems (since this is not on the agenda for that conference), but it is expected that the mobile industry will lobby for an agenda item to be included in the next conference, WRC-15/16, to consider the need for more spectrum to be identified for IMT systems. At this stage, it is not clear which bands might be considered, although one possibility is that further spectrum from the ultra-high frequency (UHF) range is allocated for mobile use, in view of the high demand for mobile frequencies below 1GHz in particular.

Allocation of additional UHF spectrum for mobile services would require further re-allocation of spectrum from broadcast networks, which is the incumbent user of UHF spectrum. This is considered below.

### 3.3 Broadcasting

Here we describe market and technology developments relating to TV and radio broadcasting.

#### 3.3.1 Overview of the service

Broadcast systems refer to the transmission and distribution of audio (sound) or video (picture) content to radio and TV audiences, respectively. The past decade has witnessed the development of a range of digital technologies and platforms for both audio and TV broadcasting, and switchover from analogue to digital radio systems and digital terrestrial television (DTT) is becoming increasingly widespread.

However, other TV broadcast platforms (satellite, cable, and IPTV) have developed alongside terrestrial broadcasting, and today offer a large number of high-definition (HD) programming channels typically as part of subscription-TV packages. As a result, it is widely considered that use of free-to-view broadcasting using DTT may decline in the longer term. This is further described elsewhere in this report.

TV broadcasting has historically used spectrum in the UHF range (470–862MHz) as well as in the very-high frequency (VHF) range (174–230MHz) in some countries. Analogue radio, or FM radio, uses frequencies from 87.5MHz to 108MHz. Digital radio typically uses VHF frequencies from 174–230MHz or frequencies from 1452–1492MHz.

Around the world, systems used for broadcasting are witnessing major migration from analogue to digital technology. Broadcasting typically includes three different forms:

- **Audio broadcast** – local, regional and national radio, traditionally broadcast over AM/FM frequencies but now being migrated to digital using digital audio broadcast (DAB) technology.
- **Television broadcast** – local, regional and national terrestrial TV, traditionally broadcast free-to-air (FTA) using analogue networks operating in UHF frequencies, but now being migrated to DTT using the digital video broadcast (DVB-T) standard.
- **Satellite broadcasting** – which includes audio and video services delivered via satellite networks to UK consumers, e.g. via the Sky platform.

One aspect of this migration from analogue to digital is that, because digital technologies are more efficient, spectrum can be released from the TV switchover process that is referred to as the ‘digital dividend’. In many countries in Europe, regulators have focussed their digital dividend on the 790–862MHz sub-band, which has been released as a result of TV switchover for mobile use, and has been auctioned in various European countries to date (e.g. Germany, Sweden, Italy and Spain). In Australia, the digital dividend is from 698–806MHz. It is not yet clear what digital dividend will be created in South Africa.

Over time, therefore, as these new services are rolled out, utilisation of the upper portion of UHF frequencies will change from traditional tower-based, broadcast transmission, to cellular-like wireless and mobile broadband services, deploying more intensive frequency re-use. This is relevant to the RFI environment since emission levels from bands used for mobile systems are different to those used for broadcasting (generally broadcasting towers use higher frequencies, but there are less of them, and their location is known, whereas mobile systems use many base stations, re-using frequencies intensively and connecting many users whose location is frequently variable).

Technology and spectrum for satellite services, including satellite broadcasting, is discussed elsewhere in this report. Below we deal with service and technology trends in terrestrial audio and TV broadcasting.

### 3.3.2 Service trends

In today’s market place, digital TV and digital radio is provided over the following alternative platforms:

- **Over the air (OTA) or linear TV** – this is the traditional method of receiving radio and TV broadcasting, via a VHF or UHF aerial. Historically, OTA TV broadcasting has been ‘free to air’, used for delivery of public service broadcasting (PSB) channels. Recent years have seen both radio and TV broadcasting technology moving from analogue (e.g. FM for radio and analogue terrestrial transmission for TV) to digital (e.g. DAB for radio and DVB-T or DTT for TV). The new platforms are increasingly being used to provide both PSB plus subscription-based (e.g. pay TV) services. Typically, it is the case that radio broadcasting uses FM or VHF frequencies, and TV broadcasting uses UHF frequencies.

- **Satellite** – satellite TV is delivered to homes using either fixed satellite services or broadcast satellite services in various frequency bands, principally 4–6GHz and 10–12GHz.
- **Cable** – traditional coaxial cable networks have been updated to provide digital cable services, which typically provide a mixture of TV, broadband and telephony services to subscribers living in urban areas in many countries around the world.
- **xDSL and fibre** – IPTV has become increasingly popular in recent years, delivered over broadband networks. The investment in fibre broadband networks that is taking place in many countries around the world has increased the capacity of fixed networks to deliver broadcasting services.

For the purposes of this report, we are mainly interested in the first two platforms, i.e. OTA and satellite, since both of those use radio frequencies for their transmission.

Although many DTT services initially used the DVB-T standard, the need for more programming capacity for HD programming resulted in the DVB-T standard being upgraded to DVB-T2, providing better capacity and quality of service. Typically, broadcasters are deploying DVB-T2 alongside DVB-T in UHF spectrum (or in some countries where DTT has not yet launched, the decision has been taken to launch immediately with DVB-T2 without DVB-T; this is the case in South Africa, for example).

In the medium term, it is expected that DTT platforms could become increasingly integrated with alternative broadcasting methods (particularly IPTV). In particular, the usage of hybrid TV (i.e. devices that enable TV over the internet (IPTV), via a broadband network, combined with linear TV, over DVB-T or DVB-T2) is expected to increase. Notwithstanding this, in the longer term, it is generally considered that a major factor threatening future demand for OTA TV services is the increasing roll-out of fibre networks and the resultant adoption of IPTV (IPTV) via broadband networks, in addition to catch-up TV services, also delivered via IPTV, as described above.

As IPTV becomes more established in the market place, there is a question as to whether there will continue to be high demand for DTT in some countries at all, or whether there will be migrating towards using IPTV over fibre networks. In this case, use of UHF spectrum to support traditional linear standard-definition (SD) or HD channels over DTT platforms would decline. Mobile operators, for example, are already lobbying for further UHF spectrum to be re-allocated from broadcast to mobile use, and various industry sectors are currently active in a number of trials around the world into use of what is referred to as TV white space, which is the gaps between DTT transmissions in UHF spectrum that can potentially be used for other, low-power, short-range services.

**Implications for the SKA project:** There is a strong likelihood of UHF spectrum being re-planned in the future, with pressure to release more spectrum from DTT use for mobile broadband services.

However, since DTT use is heavily influenced by government policy in respect of the provision of public service content on an almost universal basis, it can be expected that DTT services will not disappear completely from the market place. Hence, some residual use of UHF (and VHF) frequencies into the longer term can be expected.

IP-based delivery of services also poses a threat to the future of digital audio broadcasting, or digital radio. In general, the migration from analogue to digital is taking place much more slowly for radio services than for TV services. This is primarily due to the popularity of FM radio. However, some governments are now starting to review future use of FM frequencies with a view to switching-off analogue FM radio services at some point in the future. However, this is not expected to happen in many countries before 2016–2020.

### 3.3.3 Technology trends

As mentioned above, systems used for OTA broadcasting are witnessing major migration from analogue to digital technology. We briefly describe the technologies associated with audio, TV and satellite broadcasting below, as well as mobile TV – a modification to the digital TV standard to provide portable and mobile reception of streamed video.

#### *Audio broadcasting*

Audio broadcasting refers to local, regional and national radio stations, traditionally broadcasting analogue technology over AM/FM frequencies but now being migrated to digital using DAB technology.

DAB is a method used for the terrestrial digital transmission of radio signals, and allows for a much more efficient use of frequency spectrum than traditional analogue radio.

The following frequency bands and channel blocks are typically used by DAB around the world:

- 1.7MHz-wide VHF frequency blocks contained within the 174.168MHz to 239.968MHz range
- 16×1.7 MHz frequency blocks in the L-Band, contained within the 1452.192MHz to 1479.408MHz range.

The radio signals in DAB are transmitted using a single frequency network (SFN), and a number of digital programmes or services are transmitted in one block known as a multiplex, allowing these multiple programmes or services to be transmitted on a single frequency.

Since the DAB standard was established, a number of variations to the original standard have been developed, which include DAB+, IP over DAB (DAB-IP) and DMB:

- **DAB+** – is based on the original DAB standard but uses a more efficient audio codec.
- **DAB-IP** – is an enhancement of the DAB platform that makes the technology capable of broadcasting TV and other multimedia applications to mobile devices over an IP bearer.

- **DMB** – is a video and multimedia technology based on DAB. It offers a wide range of new services, such as mobile TV, traffic and safety information, interactive programmes, data information and many other applications (it is therefore also discussed below, where we describe technologies for mobile TV).

Although there are various versions of the DAB standard, as indicated above, they all use the same VHF frequencies, and so it is not expected that further frequencies will be required for DAB in future in other frequency bands.

Although DAB services are now well established in some countries, there are particular aspects of the analogue FM radio service (such as its coverage, and its support for small local radio stations) that has meant that migration of radio listeners from analogue to digital has not progressed as rapidly as the analogue to digital migration that has taken place in TV. However, this might evolve in future, particularly if further investment is made to ensure that DAB coverage is equivalent to existing FM services.

Therefore, it is expected that further digital radio network roll-out will take place in many countries over the next few years to improve the geographical coverage of existing digital services.

#### *TV broadcasting*

TV broadcasting refers to local, regional and national terrestrial TV, traditionally broadcast free-to-air using analogue networks operating in UHF frequencies, but now being migrated to DTT.

Different variants of DTT technology are used around the world. The DVB-T standard is the most prevalent, which was originally developed by the European Telecommunications Standards Institute (ETSI) and forms the basis of the ITU-R Geneva-06 Agreement and plan for use of frequencies for DTT in ITU-R Region 1 (which includes South Africa).<sup>13</sup> Other DTT standards include:

- **the Advanced Television Standards Committee (ATSC) standard** – used in the USA and South Korea, which is an evolution of the US analogue TV standard
- **the Integrated Services Digital Broadcasting (ISDB-T) standard** – used in Japan and parts of South America.

China has adopted its own standard: the Digital Terrestrial Multimedia Broadcast (DTMB) standard.

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<sup>13</sup> <http://www.itu.int/ITU-R/terrestrial/broadcast/plans/ge06/index.html>.

### *Satellite broadcasting*

Satellite broadcasting includes audio and video services delivered via satellite, typically using either 4–6GHz or 10–12GHz frequencies. Standards typically used include:

- **digital video broadcasting-satellite (DVB-S), or its second generation (DVB-S2)** – a forward error coding and modulation standard that has enhanced performance over the original DVB-S standard
- **digital video broadcasting return channel via satellite (DVB RCS)** – which provides a return channel to enable Internet access and other data services over satellite.

As described further in Section 3.5, a significant amount of convergence has taken place within the satellite sector, such that new satellite systems generally carry a range of telecoms and broadcast services. Thus, satellite broadcasting is not generally considered to be a distinct category of wireless use, and is more broadly covered by satellite services that carry varying payloads including broadcast, broadband and telecoms services.

### *Mobile TV*

Mobile TV refers to technologies specifically developed to broadcast TV channels to mobile users. There are typically two forms of mobile TV:

- **Streamed (real time) video** – is provided by technologies able to deliver ‘live’ TV in the same one-to-many broadcast format of DTT.
- **Non-real time video** – allows users to download selected video clips and programmes on demand, for example, and it operates using one-to-one rather than one-to-many network configuration.

There are a number of technologies that can be used to provide mobile TV services:

- **DVB-H** – this is a variant of the DVB-T standard, and has been designed specifically for broadcasting to mobile handsets
- **DVB-SH** – this is a hybrid satellite/terrestrial broadcast technology with satellite broadcasts being supplemented by terrestrial repeater stations; broadcasts are similar to the DVB-H standard (see above). The main candidate spectrum for this technology is the 2GHz S-band satellite allocations (1980–2010MHz and 2170–2200MHz). However, to date, no services are yet operational.
- **DMB** – this is a variant of the terrestrial DAB standard designed to support the broadcasting of data services including mobile TV. The technology has been adopted for commercial services in Germany and South Korea.
- **MediaFLO** – this technology has been developed by Qualcomm specifically for broadcasting TV channels to mobile handsets. The technology has been deployed in the USA, with services available via public mobile network providers Verizon and AT&T.

- **2.5G/3G** – mobile TV services can be delivered over existing cellular networks, on a unicast (one-to-one) basis. Current mobile TV service offerings are typically provided over 3G cellular networks.
- **Multimedia broadcast multicast services (MBMS)** – this is a specific adaptation of the UMTS (3G) standard to support broadcast services such as mobile TV. MBMS utilises the same spectrum as ‘standard’ 3G services and requires a mobile operator to allocate a portion of its existing 3G paired spectrum resource to support MBMS services.
- **Mobile WiMAX** – the mobile version of the WiMAX standard (802.16e) could be used to offer mobile TV services on a unicast basis – as for 3G networks.

Since DVB-H networks can share infrastructure with DVB-T, networks typically use spectrum in UHF bands IV and V (470–862MHz).

However, to date, dedicated mobile TV services using technologies such as DVB-H or MediaFLO have not been particularly successful in the market place, since consumers are becoming increasingly used to viewing video services via mobile devices (e.g. You Tube). This is delivered over mobile networks using 3G technologies in mobile spectrum.

### 3.3.4 Future spectrum demand

Owing to international band planning and end-user equipment restrictions, the frequencies used by broadcasting networks around the world cover a small number of bands. In most countries, frequencies used for digital TV are either in VHF Band 111 (174–230MHz) or UHF Bands IV and V (470–862MHz), using 6MHz or 8MHz unpaired (unidirectional) channels.

It is generally considered that the amount of spectrum allocated to broadcasting across audio and digital platforms is sufficient (and in some countries, there may be a surplus due to more limited use of terrestrial broadcasting, and increasing use of fibre and IPTV services).

However, the demand for terrestrial TV possibly changes when HD broadcasting is considered. Despite technological advancements enabling a larger number of HD channels per multiplex, HD broadcasting is severely restricted by the amount of spectrum available. However, this is not expected to justify needs for additional spectrum and it is more likely that, in the longer term, the amount of spectrum allocated for broadcasting use will decline.

Pressure to use spectrum more efficiently is also leading to some industry proponents developing solutions to use ‘TV white space’, utilising the gaps between UHF TV transmissions. Applications of white space spectrum might include M2M services, and wireless broadband networks for rural areas. Prospects to re-use TV white space for other applications have emerged in particular in the USA and UK, where the regulators have already published proposals to allow white space use to a ‘licence exempt’ basis, providing that devices operate at low powers and are managed via geo-location databases that will indicate the availability of channels at any given location, preventing interference to DTT. We are not aware that the regulators in Australia and South Africa have published any proposals for use of TV white space to date. This has implications for the SKA radio telescope since increasing use of TV white spaces will increase the level of emissions in UHF spectrum.

## 3.4 Fixed links

This section describes market and technology developments relating to microwave fixed links.

### 3.4.1 Overview of the service

Fixed links are wireless systems that operate between two fixed points using directional antennas. The links are normally digital and because they are used to provide backhaul infrastructure and local access they normally require a high level of availability (e.g. 99.99% or more). They normally provide two-way communications, although there are some uni-directional links used to provide, for example, links between studios and transmitter stations. Fixed links are deployed in preference to fibre due to their ease of deployment – it is not always practical to install fibre because of the terrain and fixed links provide a faster and cheaper option.

In some cases, local access is provided by point-to-multipoint links, and there is also growing interest in utilising this technology to provide the connectivity from cellular base stations into the backbone network.

### 3.4.2 Service trends

Fixed links can be deployed across a wide range of frequencies. Whilst there are no ‘ideal’ frequencies (the ideal frequency will depend on the exact requirement that is being met), some bands experience much higher demand than others due to their frequency characteristics, and availability of equipment. Historically, lower-frequency bands (below 7GHz) have tended to be more popular because of longer transmission distances. However, in recent years, demand in these bands has declined as a result of migration to fibre and low-cost wired Ethernet products.

Fixed links have allocations across the entire radiofrequency spectrum, from very low frequency (VLF) to extremely high frequency (EHF). The usage typically considered for fixed links are at UHF (400MHz and 900MHz bands) and the bands from 1.5GHz to 58GHz (often referred to as the microwave bands).

The main users of fixed links are typically:

- fixed-line operators
- fixed wireless network operators
- mobile operators
- utility companies.

Use of fixed links in the UHF spectrum below 1GHz is predominantly for narrowband applications including those that link land mobile base stations (point-to-point) and perform telemetry functions (often using point to multi-point architectures). At 400MHz and 900MHz, point-to-multi-point systems are typically systems in which a single central master station communicates with a number of outlying remote fixed stations. The predominant use of these systems is for data transmission, with typical applications including telemetry, supervisory control and data

acquisition (SCADA) systems, computer networking and alarm systems. Demand for spectrum for point to multi-point systems appears to be strong in the 400MHz and 900MHz bands, since various manufacturers make products that use those bands.

Above 1GHz, various bands are used both in point-to-point and point-to-multi-point architectures. The fixed links deployed in bands above 1GHz are generally used to provide backhaul connections for other networks (e.g. cellular or wireless broadband networks). Whilst fixed links have historically used bands between 1GHz and 3GHz, there has been increasing migration away from these bands, since frequencies in the 1–3GHz range have become widely used for mobile communications, as described in Section 3.2.4.

As a result, the 4–5GHz and 6–7GHz bands are becoming more popular for fixed link deployment below 10GHz, since bands between 1GHz and 3GHz are generally no longer available for fixed link use. Above 10GHz, bands such as 18GHz, 22–23GHz, 26–28GHz and 31GHz are also widely used for fixed links.

Overall, it seems that demand for fixed link spectrum is fairly static, and some of the larger users of fixed links (e.g. public mobile operators) are using alternative means of backhaul within their networks, such as fibre. There is some evidence of growing demand at much higher frequency ranges from mobile operators wanting high-capacity links to base stations, in particular because there is significantly more capacity available at these higher-frequency ranges (e.g. bands at 10GHz, 28GHz, 32GHz and 40GHz).

However, more intensive use of these bands in future is not relevant to the RFI environment for the SKA, since we understand that these bands are outside the range of interest.

### 3.4.3 Technology trends

The equipment that is now available in the fixed link market can be software defined so, for example, the available data rates can be modified but this will require a wider bandwidth channel. The design is such that it is relatively simple to develop equipment for new frequency bands but information provided in the past by vendors was that there is a need for a number of countries to be interested in opening a frequency band, plus commitment from potential users, before equipment would become available on the market. For this reason, fixed link deployment is generally concentrated in a number of frequency bands around the world.

Fixed link equipment can reduce the potential for interference into other fixed links and services by using Automatic Transmitter Power Control (TPC) which means that for most of the time the transmitter operates at less than maximum power and is only increased, for a short period of time, when there is fading on a path. This is relevant to the RFI environment for the SKA since it means that systems are not always operating at their highest licensed power levels, which reduces emission levels.

Fixed links are also now being sold with adaptive modulation which maximises the use of the available spectrum (bandwidth). The links are designed so that in periods of fading high priority traffic will still be supported at the required availability by using more robust modulation.

### 3.4.4 Future spectrum demand

Due to increasing deployment of fibre broadband in many countries, demand for fixed link spectrum has not grown in recent years and the market appears to be relatively static.

As a result, it is not widely envisaged that any new spectrum bands will be allocated for microwave links. Instead, it is anticipated that technology developments such as those described above will be used to increase the efficiency of usage within existing bands, so that any growth in demand can be accommodated within the current bands.

**Implications for the SKA project:** Technology developments might lead to more intensive use of fixed link spectrum (i.e. greater re-use), but there is unlikely to be long term demand to increase the bandwidth of spectrum allocated for fixed links, due to static demand.

## 3.5 Private mobile radio (PMR) or private business radio (PBR)

This section describes market and technology developments relating to private mobile radio.

### 3.5.1 Overview of the service

PMR usage<sup>14</sup> covers a large sector of society, generally used by a range of businesses and public bodies that use a private or public access radio network as part of doing business. Examples of usage include:

- an airport which uses radio for security, passenger management and airfield operations
- a retail shopping centre which uses radio for security
- a container port which uses voice radio for operations and security, and data radio for information and instructions
- a transport organisation with a fleet of buses, which uses voice for driver safety and operations, and data for location services and sign updates.

Private radio is either used for direct terminal-to-terminal in some of the more simple systems, or more commonly, a despatch type system, where the radio terminals work to or through a central base station. Systems may be a single site, or a large network of interconnected sites.

The blue light services (i.e. emergency services) are also users of business radio – originally using a variety of analogue PBR systems and, more recently, digital services such as digital terrestrial trunked radio (TETRA).

PBR users encompass a wide range of vertical sectors including aerospace, construction, transport, retail, utilities and security.

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<sup>14</sup> Also referred to as land mobile or private business radio (PBR) in some countries.

### 3.5.2 Service trends

Typical PBR systems support a number of unique features compared to public mobile networks:

- individual (point to point) calls as well as group (point to multi-point)
- pre-emptive priority access to bandwidth
- wide-area group calls (with restriction on coverage of a group)
- ambience and discrete listening for security services or blue light
- air interface encryption, and provision for end-to-end encryption (e.g. in TETRA)
- cost control in those systems where the user owns and operates the infrastructure or has a fixed price contract for networks access.

Despite the growth of cellular networks, there is still some demand for PMR. This is largely because PMR users typically demand a different service to that of cellular radio, and value the unique features that PBR offers, such as those listed above. Furthermore, operational requirements for PBR systems are usually different and users typically require a ‘closed’ system that supports specific call types such as push-to-talk, group calls, and direct (terminal-to-terminal) communication.

Despite this demand, PBR is widely considered as a niche use of radio spectrum for which demand is relatively constant. Therefore, from the SKA’s perspective, there is likely to be very limited changes to the way that PBR systems operate today in the next ten years (expect for a gradual migration to digital systems).

The spectrum requirements for PBR are varied, and flexible. Generally, services operate in bands below 1GHz typically using very narrow channel widths (e.g. 6.25kHz or 12.5kHz, and 25kHz for digital systems). Usage is primarily concentrated in the VHF and UHF bands, in addition to some low-frequency usage (e.g. around 130MHz and 140MHz), as indicated in Annex A.

Frequencies assigned for PBR use in the UHF spectrum around 400MHz are generally in high demand within urban areas, since the propagation and penetration into urban clutter is good, and terminal antennas are smaller and manageable. Frequencies in VHF (152MHz to 174MHz) are also popular, where greater range from the base sites can be achieved.

Demand for PBR channels varies greatly by user type. For the police, fire and ambulance services, PBR is a critical tool for their day-to-day operation and thus the preservation of life, prevention of crime, response to major incidents and the many other functions that the emergency services carry out. There is demand from the emergency services for additional spectrum for broadband private radio, which is being considered by a number of national regulators at present (and is considered below in relation to developments in Australia).

In comparison, private-sector users such as utilities, delivery and taxi companies largely make use of business radio as a means to increase efficiency and productivity, essentially as a business tool. Demand from these and other users seems unlikely to grow significantly.

### 3.5.3 Technology trends

Currently, most PBR systems use analogue technology. There is evidence of private radio users replacing old analogue networks with newer analogue versions, which has slowed the migration to digital technology.

While voice is still important to PBR users, a need for data to accompany or in some cases replace the voice is evident. This can range from messaging and location services through to IP packet data and video transmission.

Emergency services in many countries have identified a requirement for a broadband PMR solution, to meet their growing mobile data requirements. Operational requirements of the emergency services make sharing with public mobile networks difficult and therefore there is a preference for the emergency services to use their own networks. However, those networks could use similar technologies to that of public mobile networks – such as LTE. Developments such as this are already being actively progressed in other countries, such as the USA, where part of the released 700MHz band was earmarked for a mobile broadband network for public safety use.

Despite the slow take-up in recent years, there is now a general trend towards digital communications across all sectors of wireless use, and PMR is following the trend. New PMR standards such as digital mobile radio (DMR) and digital private mobile radio (dPMR) provide more efficient spectrum usage than analogue, and provide a route for current users to migrate to digital.

A summary of relevant technologies for PBR is provided below.

#### *TETRA*

TETRA has been available now for many years, and is a mature technology. It is a standard published by ETSI and used by many sectors of the PBR market around the world. Initially, public safety was the largest sector using TETRA technology, but in the last few years other sectors, such as transport and oil and gas, have increased their usage, and are growing faster.

TETRA enhanced data services (TEDS) allows for wider channels than the TETRA 25kHz channel, with channel bandwidths of 25kHz, 50kHz, 100kHz and 150kHz, and data rates up to 500kbit/s.

There are several TETRA networks being deployed in Europe and South Africa, where TETRA is deployed alongside other technologies such as WiMAX, to provide higher data rates in the urban areas. Several TETRA suppliers are now offering WiMAX equipment alongside TETRA within integrated units (although devices are currently separate).

## DMR

Digital mobile radio (DMR) is an ETSI standard for narrowband business radio applications using digital technology, and offers a lower cost alternative to TETRA to deploy digital PMR.

DMR is similar to analogue PBR in terms of its spectrum requirements. The standard has been designed to allow operation between 96MHz and 960MHz, and will accommodate any combination of frequency and duplex arrangement. There are options for a fixed channel plan with a set duplex spacing, and conventional mobile duplex direction, or a flexible channel plan where each logical channel has its own transmitter and receiver relationship, or a dynamic channel mode, which specifies discrete transmitter and receiver frequencies.

TETRA, by contrast, typically uses one of a number of defined bands between 300MHz and 960MHz. The frequency bands covered by a TETRA radio supplier are:

- 350–372MHz
- 380–430MHz
- 440–473MHz
- 806/825 paired with 851/870MHz.

### 3.5.4 Future spectrum demand

With the exception of emergency services, airport authorities and utilities, where additional spectrum demand is being driven by increasing use of wideband and broadband mobile data for larger PBR user groups, demand for PBR spectrum appears to be fairly static around the world and is not expected to growth significantly over the next decade.

Over the last few years there has been considerable technical work and lobbying activity around the world in relation to the release of additional harmonised spectrum for emergency services use. For other sectors of PBR use, demand is expected to remain fairly static (and may decline), suggesting only limited changes to the way that current PMR spectrum is used and deployed in the long term.

**Implications for the SKA project:** It is not envisaged that PBR systems to have a strong bearing upon the RFI environment, since it is expected that PBR system characteristics and usage to remain roughly the same in the future as it is today.

## 3.6 Satellite

This section describes market and technology developments relating to satellite systems.

### 3.6.1 Overview of the service

Satellite transmission offers the advantages of near global network coverage and high capacity, which is particularly favourable both for those living in areas out of reach of other terrestrial communications, or for international travellers. However, these advantages come at a correspondingly higher price for devices and services, owing to the high costs associated with launching and maintaining satellites.

Various services can be delivered over satellite networks, including telephony (fixed and mobile), broadband and TV.

Satellite spectrum usage can be divided into three service categories:

- mobile satellite services
- fixed satellite services
- broadcast satellite services.

However, a significant amount of convergence has taken place within the satellite market, mainly driven by the length of time it takes to place satellite capacity in orbit. This means that, once satellite systems are operational, satellite providers will seek to fill the available capacity with a range of services and so, at a service level, there is little distinction between the three types of satellite spectrum allocation that the ITU-R uses.

The high-powered signals that satellites require, and their global footprint, means that satellite services are subject to extensive international harmonisation, which limits the frequency bands in which they operate. Frequency bands and associated orbital arrangements are provided via the ITU-R. Once launched, it is extremely difficult to modify a satellite system and hence the systems typically remain in place for many years. Therefore, any changes to frequency allocations for satellite services are infrequent, and take many years to establish.

### 3.6.2 Service trends

Due to the price premium from using satellite services compared to other alternatives (such as fixed broadband networks or public mobile networks), demand for satellite spectrum is generally more limited compared to other service types, and is also largely limited to existing bands allocated within the ITU Radio Regulations<sup>15</sup>, due to the cost and complexity of launching new systems in new frequency allocations.

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<sup>15</sup> <http://www.itu.int/pub/R-REG-RR/en>

It is noted that in some parts of the world the implementation of national satellite systems have been progressed (e.g. Indonesia) to support general communications. However, in many countries around the world where there is widespread availability of terrestrial wireless networks, it is difficult to justify a national satellite system on a commercial basis, which is why regional and global systems predominate, with each system aiming to be as flexible as possible in order to exploit all available opportunities.

A brief summary of the various types of satellite service, the frequencies they use and service trends are provided below.

### *Fixed satellite services*

Historically, fixed satellites were used for the international point-to-point trunking of telecoms between countries. Originally, fixed satellite service providers were government-owned, but have been migrated to becoming commercial providers.

More recently, the advent of a global undersea fibre-optic network has reduced the need for satellites to provide point-to-point telecoms trunking, although they still provide some useful facilities in terms of redundant paths.

Fixed satellite services are also used to provide connectivity direct to businesses and consumers, by providing a fixed terminal (base station) to which users can connect via standard mobile phones.

Users include cruise and ferry operators, airlines, multi-national corporations, fuel stations and supermarkets. At a consumer level, fixed satellite services can be combined with broadcast satellite to provide a bundled service, or to provide high-speed broadband for more remote communities. Fixed satellite services are also used to provide trunking capacity to international telecoms carriers to carry international traffic. However, satellite trunking services are in decline, owing to the more economic use of fibre and fixed link (microwave) trunking.

One of the roles of fixed satellite services allocations is to support feeder links for other services. Most commonly, this is for satellites providing service links in the mobile and broadcast satellite services. In many cases, the feeder links use the standard C-band (4–6GHz), Ku-band (10–12GHz) and Ka-band (26–40GHz) allocations. However, there are other fixed satellite services allocations specifically designated for feeder links of other services, which operate in various other bands. Of interest to the SKA are only the C- and Ku-bands. It is noted that proposals for next-generation fixed satellite services focus on the Ka-band, which is outside the frequencies of interest for the SKA. Therefore, if Ka-band systems become more widespread in future, it is likely that use of existing C- and Ka-band systems will decline.

In addition to these TV-related applications, there is a certain amount of capacity that is used to support very small aperture terminal (VSAT) internal networks for companies, especially for global corporations.

### *Mobile satellite services*

In the same way that fixed satellite systems developed, the first mobile satellite organisation, Inmarsat, was an inter-governmental organisation. It has since made the transition to being a fully commercial company.

Inmarsat has continued to develop its global geostationary system with great success, while other geostationary systems have come into being as competition (e.g. Thuraya). More recently, there have been a number of non-geostationary systems that have tried to enter the marketplace. The most notable of these are Iridium, Globalstar and ICO. The ICO system was abandoned before it was fully launched, whereas Iridium and Globalstar are fully operational systems, each being based on a constellation of satellites in low earth orbit (LEO). Much of the use of these systems is governmental (e.g. military), rather than commercial. However, both Globalstar and Iridium are considering launching second-generation satellites.

Mobile satellite systems typically use spectrum in the 1–3GHz range, notably around 1.6GHz (Inmarsat) and 2.4GHz (Globalstar), and so they fall within the range of interest for the SKA.

Mobile satellite is a relatively niche market, primarily consisting of those in remote or other uncovered areas struggling to get access to mobile voice and data services through terrestrial mobile services. As such, the number of users is likely to remain relatively stable in the future. However, growth is anticipated in terms of the total usage per satellite subscriber, driven by increased demand for mobile data, similar to the sharp increases in terrestrial mobile data demand being experienced within the public mobile market.

### **3.6.3 Technology trends**

Recent technology trends within the satellite industry have been directed towards establishing broadband services direct to consumers' homes using fixed satellite spectrum allocations. This service has been promoted for some time using Ku-band capacity (10.7–12.75GHz), but with limited success. The more recent efforts are focussed on the potential of the Ka-band (26–40GHz) to deliver a more cost-effective service. It remains to be seen whether a business case can be sustained for this type of service when it is known that satellite connections are relatively more expensive than other forms of broadband or mobile connection.

There have also been activities mainly within Europe centred on the S-band mobile satellite services at 2GHz. There are two organisations – Inmarsat and Solaris (Eutelsat/SES Astra) – that have an intention to provide a hybrid terrestrial and satellite service using the 2GHz bands, although to date services have not been deployed.

### 3.6.4 Future spectrum demand

The main commercial satellite systems in operation today use the Ku-band at 10.7–12.75GHz and future satellite demand is likely to be concentrated within this band along with the Ka-band at 17.7–20GHz and 27.5–30GHz. Capacity within both bands is extensive and is thought to be sufficient to meet demand for a number of years to come.

Mobile satellite systems typically use spectrum in the 1–3GHz range, notably around 1.6GHz (Inmarsat) and 2.4GHz (Globalstar). Whilst there have been some attempts by the mobile satellite industry to seek additional spectrum for their services, the extra spectrum is generally needed to accommodate new satellite operators, rather than to expand existing services. However, the high cost associated with the launch of new satellites tends to limit this demand in practice.

The Ku-band is currently considered to be experiencing the fastest growth in satellite communications, and this is expected to continue well into the future. The widespread use of several communications solutions is expected in this band, including:

- TV distribution and broadcasting
- satellite news gathering (SNG)
- broadband
- VSAT data communications, including IP broadband and private networks, and international teleport services
- mobile TV.

**Implications for the SKA project:** It is likely that future investment in satellite systems will focus on Ka-band, which, from 17 to 30GHz, is outside of the frequency range of interest to the SKA.

## 3.7 PMSE

This section describes market and technology developments relating to programme making and special events (PMSE).

### 3.7.1 Overview of the service

Frequency bands designated for PMSE use are scattered right across the frequency range 40MHz to 50GHz. Many of the frequency bands available for PMSE use are also used for other services (such as military) with which PMSE services have been able to co-exist. PMSE encompasses various uses of spectrum that are broadly associated with programme making for TV, as well as supporting services for production and broadcasting of major events such as sports events, pop concerts and theatres.

The frequency range used for PMSE falls into two parts, with audio and data applications falling below 2GHz and video above 2GHz. Usage can be characterised in summary form as follows:

<i>Frequency</i>	<i>Application</i>
40MHz to 2GHz	Wireless microphones, in-ear monitors, audio links, remote control data links – mostly operating in VHF and UHF spectrum shared with DTT
2GHz to 50GHz	Video links (point-to-point and point-to-multi-point)

Figure 3.4: *PMSE spectrum and applications [Source: Analysys Mason]*

### 3.7.2 Service trends

The PMSE sector covers a diverse range of services, frequencies and users. Spectrum available for use by PMSE has generally declined in recent years to make way for other services with a greater impact on national economies, such as public mobile services. For example, PMSE use spectrum in the 2.5GHz band in various countries (including Australia), but this has now given way to IMT, following identification of the 2.5GHz band as an expansion band for 3G/4G services by the ITU-R at the WRC-2000. The amount of spectrum available for PMSE in UHF TV bands has also reduced as a result of the creation of the 700MHz and 800MHz sub-bands for public mobile use, which has reduced the amount of spectrum available to DTT that is shared with PMSE.

Demand for PMSE spectrum tends to be driven by short-term events (e.g. hosting of major sports or entertainment events at specific locations). Overall, demand for PMSE spectrum is generally expected to be constant. Where there is an excess in demand, this can normally be accommodated by temporary licences issued within bands shared with other services (e.g. PBR).

### 3.7.3 Technology trends

The move from analogue to digital has been relatively gradual for PMSE audio and video links, so in practice there is a mixture of both technologies in use today. The move has been slower for wireless microphones because of latency issues arising from processing delays. Recently, Qualcomm announced a digital wireless microphone chip that claims to provide good sound quality within existing 200kHz channels with similar latency for analogue systems.

A number of radio microphones can operate in the same area within an 8MHz DTT channel without degrading sound quality. The main change expected in future years is with digitisation of technology; it is possible that more devices can re-use the same channel. This will tend to increase the density of use at a given location, but is not anticipated to be a significant issue in terms of the SKA in view of the niche nature of PMSE services.

### 3.7.4 Future spectrum demand

With the exception of major international events (e.g. Olympics), demand for PMSE spectrum appears to remain relatively constant and is not expected to change significantly in future.

**Implications for the SKA project:** It is unlikely that developments in spectrum or technologies for PMSE will have a significant impact on the SKA environment.

## 3.8 Science services

This section describes market and technology trends in science services.

### 3.8.1 Overview of the service

Science services comprise radio astronomy, space research, Earth exploration satellite (EESS), space operations, meteorological aids, and standard frequency and time services. The frequency allocations for these services comprise a number of bands within the range from 9kHz to 275GHz. Science programmes in these areas are overseen by various national research bodies globally.

According to the ITU Radio Regulations, science services are defined as:

- systems for space operation, space research, Earth exploration and meteorology, including the related use of links in the inter-satellite service
- systems for remote sensing, including passive and active sensing systems, operating on both ground-based and space-based platforms
- radio astronomy and radar astronomy
- dissemination, reception and co-ordination of standard-frequency and time-signal services, including the application of satellite techniques, on a worldwide basis.

### 3.8.2 Market trends

The two largest users of spectrum within the science services community are radio astronomy and meteorological services. Other areas of use include communication with a range of satellite and space missions, and, specifically, spacecraft operation. Under the ITU Radio Regulations, all emissions are prohibited in many of the passive bands used by radio astronomy, EESS (passive) and space research (passive) services. Regulations also protect a number of frequencies used for space research communications. Many of these allocations are internationally harmonised and the frequencies used by passive services are largely determined by physics.

### 3.8.3 Technology trends

Development of the SKA telescope is a key example of technology trends in the area of science services, with the SKA expected to use many linked receivers to provide observation over a significant area, far in excess of the capabilities of current telescopes. This has bearings in terms of the requirements for RQZs around the telescope's installation.

The specific requirements that exist in relation to keeping radio astronomy frequencies as interference-free as possible are described in Section 6.

### 3.8.4 Future spectrum demand

Our comments here are based on the demands expressed in the agenda items for ITU-R WRC-12. These indicate the following future requirements:

- additional passive band allocations are being considered internationally (WRC-12, agenda item 1.6)
- a primary allocation at 22.55–23.15GHz for the space research service (Earth to space) as a companion band to 25.5–27.0GHz (space to Earth for data retrieval and voice/video communication to earth) sharing with various other satellite services (WRC-12, agenda item 1.11)
- protect fixed, fixed satellite and space research service from interference from aeronautical mobile services at 37–38GHz (WRC-12, agenda item 1.12)
- additional spectrum at VLF for lightning detection (WRC-12, agenda item 1.16)
- an increased allocation to the meteorological satellite service at 7850–7900MHz (WRC-12, agenda item 1.24)
- possible future need for use of meteorological radars in the 2.7–2.9GHz band.

## 3.9 Aeronautical and maritime

This section describes market and technology trends relating to aeronautical and maritime radio.

### 3.9.1 Overview of the service

Radio spectrum is used by the aeronautical and maritime communities for a number of applications:

- communications between the ground and aircraft/ships at MF, HF and VHF and satellite channels (in the L-band)
- ground-based navigation aids across the whole spectrum:
  - for aircraft, these include beacons, systems on the ground and aircraft that allow bearing and range to be measured, and landing systems; these facilities are supplemented by satellite navigation systems
  - for ships, these include beacons, satellite navigation systems and differential global positioning system (DGPS) channels

- ground-based radars used to inform air traffic controllers and to monitor surface movement at airports operating in the L-, S-, X- and Ku-band
- shore- and ship-based radars used to inform vessel traffic services (VTS) and ships' masters operating at the S- and X-band
- airborne systems including altimeters and weather radar
- distress and safety/search and rescue, widely based on specific frequencies associated with the applications listed in the bullets above, but also specific frequencies for devices such as emergency position indicating radio beacons (EPIRB).

Most of the spectrum used by aeronautical and maritime systems is internationally harmonised.

### 3.9.2 Service trends

There are several radio navigation systems that are used by aeronautical systems. The main one of these is radar. Most of these radars are pulsed systems and hence tend to have large bandwidths (proportional to the pulse width) and high out-of-band emissions. Design objectives for new radars have improved these out-of-band emissions, but until the older radars are replaced (which is a long term process due to the costs involved), these will have little effect on the bandwidth required for radar operation.

The civil air transport sector is expected to expand considerably over the next two decades. Construction in various countries of new airports and runways will be necessary, which may increase the number of radar systems in operation.

### 3.9.3 Technology trends

Below we give a list of some of the systems used for aeronautical and maritime services:

- **Air traffic control primary radar (ATC)** – is typically operated in the L-band (1250–1350MHz) and in the S-band (2700–2900MHz). These radar systems use high powers and occupy a wide bandwidth of spectrum. Interference with this type of radar has safety implications and so spectrum is protected through international agreements.
- **Distance measuring equipment (DME)** – is a transponder-based system used by aircraft to measure the distance from a fixed point. These systems use channels covering the bands 1025–115MHz and 962–1213MHz. The aircraft interrogates a ground station 'transponder' that replies with a specified delay. By measuring the round trip time, the distance from the transponder can be calculated.
- **Airport surface detection equipment (ASDE)** – is used at busy airports for detecting the position and movement of aircraft and service vehicles on the ground at airports. The ASDE radar works in the traditional radar manner of a pulse transmission and then listening for the reflected return. These radars are of moderate power and have high PRR and fast turning rate. The ASDE system tends to work in two bands: the Ku-band and the X-band (10–14GHz and 8–12GHz).

- **Airborne weather radar (AW)** – is intended to detect and display hazardous weather systems that present potential danger to aircraft in terms of rain, wind shear and microbursts. Two airborne weather radar systems are typically used today: high power systems and low power systems. The high-power system is expensive and is not often used, whereas the low-power system (100–200W) is generally used. Both these systems operate in the X-band (8–12GHz).

### 3.9.4 Future spectrum demand

The expected future growth in air traffic could in principle lead to an increase in requirements for spectrum to support communications, navigation and surveillance. At an international level, these developments are co-ordinated by the International Civil Aviation Organisation (ICAO). In practice, we understand that the approach that is being planned by ICAO is to accommodate demand for spectrum for air traffic management within existing aeronautical allocations by rationalising systems, making systems more spectrally efficient and, if possible, a greater reliance on satellite communications (both mobile and fixed satellite).<sup>16</sup> However, the full effect of changes such as these is not expected to be seen until much further into the future given the high cost and long lead times involved in planning these systems.

## 3.10 Short-range devices

This section covers market and technology trends relating to short-range devices.

### 3.10.1 Overview of the service

The term short-range device (SRD) refers to devices that are designed on the principle that they should present a low risk of interference with other radio services, because their transmitted power, and hence the transmission range, is low. SRD are typically operated under class licences<sup>17</sup>, or general wireless licence exemption, on the basis that low power transmitters providing short range communication do not typically require individual frequency coordination for interference management purposes. Typically, all users of SRDs of a given type operate in the same frequency band on a shared basis, and all are subject to the terms of the class licence or licence exemption in relation to the frequencies they use, the equipment standards employed and any other technical restrictions.

In some cases, SRDs may operate in the same frequency bands as other types of radio service, in which case interference is avoided by applying a very low-power limit within those bands. Examples of the latter include ultra wide band (UWB) devices, where the radiated power is spread over a frequency range of several GHz so that the power radiated in any individual, narrower frequency band is negligible.

<sup>16</sup> <http://www2.icao.int/en/home/default.aspx>.

<sup>17</sup> A class licence represents a licence for a group of systems of similar characteristics typically sharing the same spectrum band, as distinct from an individual licence, which licences an individual wireless system or user in a designated band

The operational range of an SRD depends on the application and may vary from a few millimetres in the case of some RF identification devices to hundreds of metres for wireless local area networks. In general, SRDs operate on a licence-exempt basis, meaning that the user does not need to obtain any approval in order to use the device as long as the devices conform to the relevant technical standards.

SRDs are used in a wide range of consumer and industrial applications, many of which have grown at a substantial rate in recent years as costs have fallen and performance has improved. Examples of the more common applications are shown below in Figure 3.5.

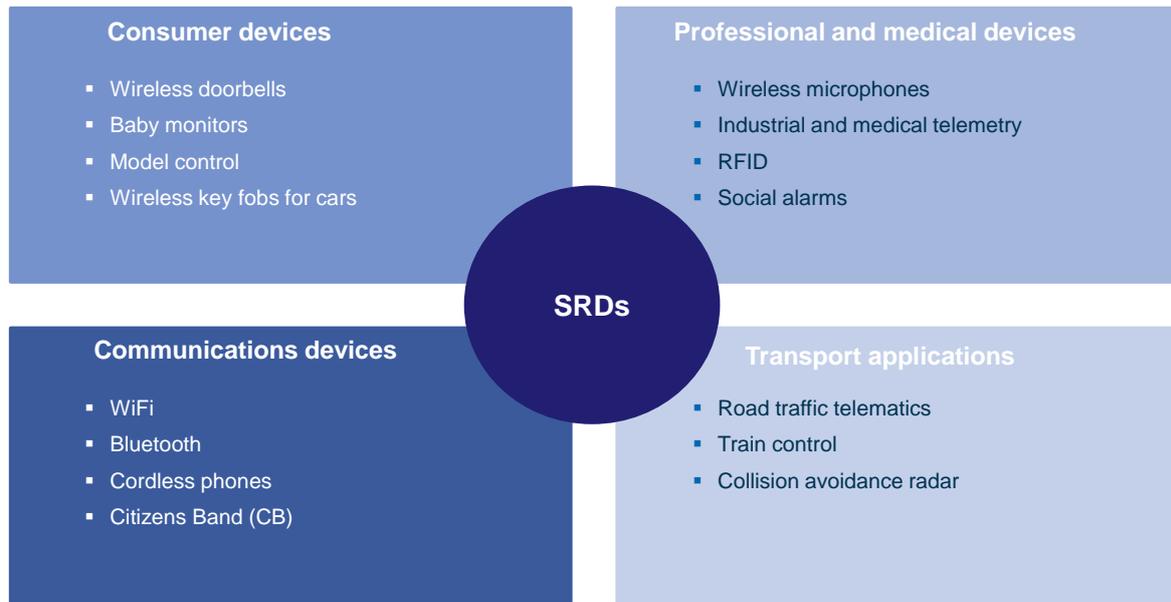


Figure 3.5: Example SRD applications [Source: Analysys Mason]

It is noted that SRDs typically employ 'listen before transmit' protocols in order to minimise interference between different SRD applications sharing the same frequency band, as well as to minimise interference to other radio users. However, listen before transmit protocols are of concern to passive radiocommunications services like radio astronomy<sup>18</sup> because devices using these protocols are designed to detect active transmitters within their vicinity, which does not provide any guarantee that devices will not operate close to a radio astronomy band. Additionally, because devices are not individually licenced, their location is unpredictable, and there are often a large number of SRDs operating within a shared frequency band in a given location. Accordingly, the high density of usage of these frequency bands can give rise to interference into other licensed bands and into radio astronomy bands.

**Implications for the SKA project:** Particular attention should be paid to growth in use of SRDs, as described in the next section of this report, given the somewhat unpredictable nature of where these devices might be used.

<sup>18</sup> A passive service is a receiver-only radiocommunications system

### 3.10.2 Service trends

SRDs are usually exempted from individual licences, and operate in spectrum commonly referred to as ‘licence exempt’, or ‘unlicensed’. Spectrum used for SRDs is distributed across the radio spectrum from 27MHz up to 70GHz (e.g. for vehicle radar systems).

In recent years, there has been particularly high use of unlicensed spectrum bands in the 2.4GHz (2400–2483.5MHz) and 5GHz (5150–5350MHz and 5725–5875MHz) ranges. These bands are used for wireless local area network (LAN) or WiFi technology, based upon the IEEE standards 802.11b/g and 802.11e. There is expected to be continued high demand for use of wireless LANs, and both the 2.4GHz and 5GHz bands are expected to exhibit high levels of spectrum utilisation. However, since systems use low power and transmit over short ranges, the potential for interference into the SKA environment is limited.

Other possible growth areas include:

- UHF white space devices, also referred to as TV band devices – there is particular industry interest from some major consumer telecommunications companies<sup>19</sup> associated with the use of UHF white space within the UHF TV broadcast band (470 – 790 MHz). Low power white space devices can be deployed where there are gaps in spectrum use due to the way that broadcast networks are planned so long as they do not cause interference to TV reception. Various industry trials are currently underway, particular within the USA, Singapore and various parts of Europe, to define concepts and devices that could make use of this UHF white space spectrum. These applications are also sometimes referred to as ‘Super WiFi’ and would offer similar functionality as WiFi, but transmit over longer ranges
- automotive applications, such as in-car monitoring systems, which use a range of frequency bands
- radio frequency identification devices (RFID), which are used in various machine to machine and other industrial processes to track machinery and equipment; these devices use spectrum in the 870–876MHz band and in the 900MHz band in some countries.

**Implications for the SKA project:** Growth in use of various frequency bands used for short range devices is being experienced, with the most widely used SRF frequency bands around the world today considered to be the 433 and 863-870 MHz, and the 2.4 GHz and 5 GHz bands. Developments of machine to machine communications, and UHF white space devices, are examples of innovation taking place within the SRD sector that is likely to result in the frequency bands used by these applications being used much more intensively in future, leading to an increase in RF noise from those bands in to neighbouring bands, and into astronomy environments.

<sup>19</sup> E.g. Microsoft, Google.

### 3.10.3 Technology trends

Over the past two decades there has been a growing trend from analogue to digital technology and towards the adoption of increasingly sophisticated interference-mitigation techniques. These developments have largely accompanied the introduction of new, harmonised frequency bands and technical standards for SRD applications, although legacy technologies continue to be widely deployed in the longer-established frequency bands. In some cases, global standards also apply, such as the IEEE 802.11 series of standards for wireless LANs.

Whereas the earliest low-power devices relied solely on transmission power limits to minimise the risk of interference, many current-generation devices deploy techniques such as duty cycle limits, spread spectrum transmission, ‘listen before talk’ protocols or dynamic frequency selection. This trend is set to continue, with more advanced cognitive technology expected to be deployed in the near future, which would allow SRDs to operate in some bands that are currently reserved exclusively for licensed applications. In our view, the development of cognitive radio is expected to be the most significant technology development in the SRD environment in the longer term.

As mentioned elsewhere in this report, the two most widely used licence-exempt bands around the world today are the 2.4GHz and 5GHz bands. Various technologies have been developed to use these bands, and are evolving further to support continuous access to spectrum on a shared, dynamic basis. The most widely used technologies to date have been frequency hopping (FH) and dynamic frequency selection (DFS), and are in widespread use within systems such as digital cordless telephony (DECT) – which uses DFS – and WiFi (IEEE802.11b,g and a systems) – which uses DFS, direct sequence spread spectrum (DSSS) and/or OFDM.

However, the IEEE 802.11 protocol has undergone various developments to increase system capacity and improve quality of service, improving the ability of devices to share the available channels within the available bands. As noted above, this standard is expected to evolve further to incorporate cognitive radio in the future, as illustrated below in Figure 3.6.

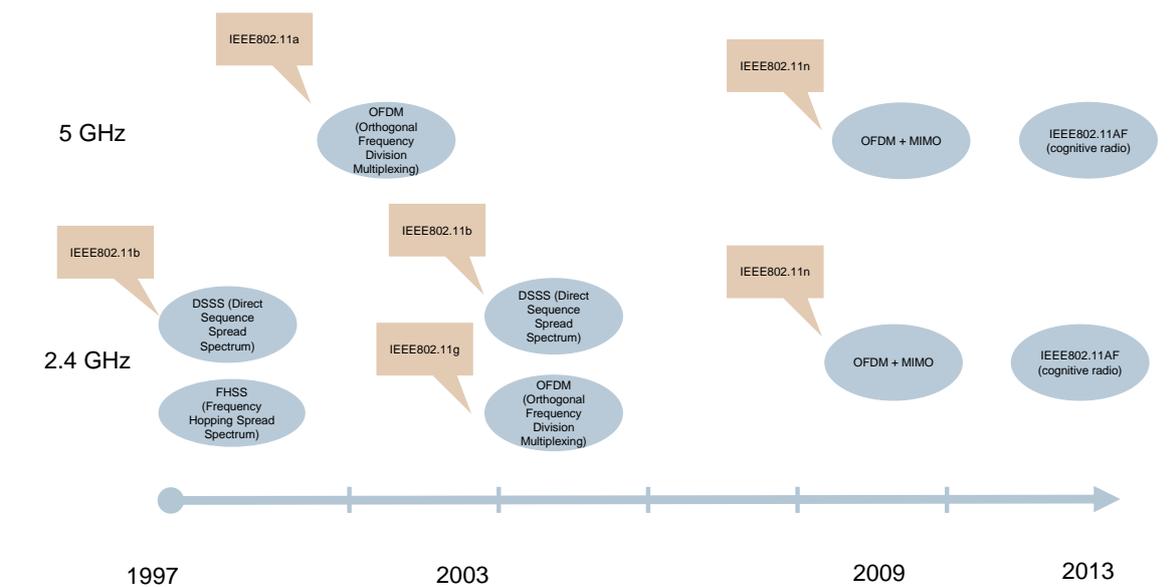


Figure 3.6: Evolution of WiFi technology [Source: Analysys Mason]

### 3.10.4 Future spectrum demand

The most intensively used SRD bands are probably the 433MHz, 870–876MHz, 2.4GHz and 5GHz bands. Until recently, the 433MHz band has been the principal frequency band for narrowband consumer SRDs such as wireless key fobs, burglar alarms, baby monitors and other similar applications. The limited bandwidth available has led to increasing congestion problems and hastened migration to the more recently introduced 863–870MHz band, particularly for more demanding applications such as burglar alarms. The capacity of this band is a lot higher than in the 433MHz band. However, it is expected that this band may become congested over time. This in turn will probably prompt migration to higher bands for such applications.

The 2.4GHz and 5GHz bands that are predominantly used by wireless local area networks (WLAN) will continue to be in strong demand particularly since WiFi is increasingly being used to offload mobile data traffic from public mobile networks (e.g. by smartphone users connecting over WiFi rather than over a 3G connection). It is likely that the take-up of the 5GHz band, which has considerably more capacity than the 2.4GHz band and is shared with some military and civil radar systems, will increase in response to growing congestion at the 2.4GHz band.

### 3.11 Applications used for purposes other than communications

We note that electromagnetic interference – disturbance that affects the performance of an electrical circuit – can be caused by a wide range of electrical and other devices emitting radiation that can disrupt radio communications using the same frequency. Examples of sources of electromagnetic interference include power transmission lines, electric motors and a wide range of domestic devices including microwave ovens, wireless doorbells, and many other forms of electrical hardware. Controlling emissions from consumer electronic and other electrical equipment is typically based upon including requirements within the standards for these devices in relation to electromagnetic interference (EMI) immunity.

In relation to the SKA project, the gas drilling technique referred to as ‘fracking’ is one aspect of EMI that is understood to have raised some concern. This refers to the process of hydraulic fracking, a method used when drilling underground to shatter rock in order to extract gas.

The technique has raised controversy recently as a result of reports that it can trigger minor earthquakes.<sup>20</sup> From the perspective of the SKA project, there is concern that gas exploration using fracking can give rise to electromagnetic interference that could affect the RQZ environment of the SKA.

Analysys Mason understands from the *Report of the Expert Panel on Radio Quiet Zone* and the RFI regulation provided to us by the SPDO in relation to this study that both sites have legal protection from interference produced by mining/industry in the form of existing RQZs. In South

<sup>20</sup> For example, see <http://www.bbc.co.uk/news/uk-14432401>.

Africa there also appears to be flexibility for the zone to be extended in a discretionary manner if concerns arise in relation to disruption to the SKA environment.<sup>21</sup>

**Implications for the SKA project:** It appears that further sanctioning of fracking could give rise to concerns for the SKA environment at either site. However, there do not appear to be reports of mining interests wanting to develop within the established RQZ at the Australian site to date. In the case of South Africa, there have been reports that energy firms<sup>22</sup> are interested in prospecting for gas in the Karoo region. Any risk to the RQZ would depend on whether these prospects will be sanctioned, and also whether the fracking activity is far enough away from the SKA site to avoid potential disruption to the RQZ. Reports suggest that areas being explored are quite extensive and may only overlap with the existing RQZ to a limited extent.<sup>23</sup>

<sup>21</sup> This is referred to in Section 1(c), page 8 of the report, in relation to the Astronomy Geographic Advantage Act in South Africa, and the Radiocommunications Act 1992 in Australia along with the MOU signed between the Australian and Western Australian Governments on radio quiet matters

<sup>22</sup> <http://af.reuters.com/article/investingNews/idAFJOE72G0EZ20110317>.

<sup>23</sup> For example, page 80 of the report at [http://www.golder.com/af/en/modules.php?name=Documents&op=viewlive&sp\\_id=82](http://www.golder.com/af/en/modules.php?name=Documents&op=viewlive&sp_id=82) shows a map of exploration areas overlaid with the AGA Act protected areas.

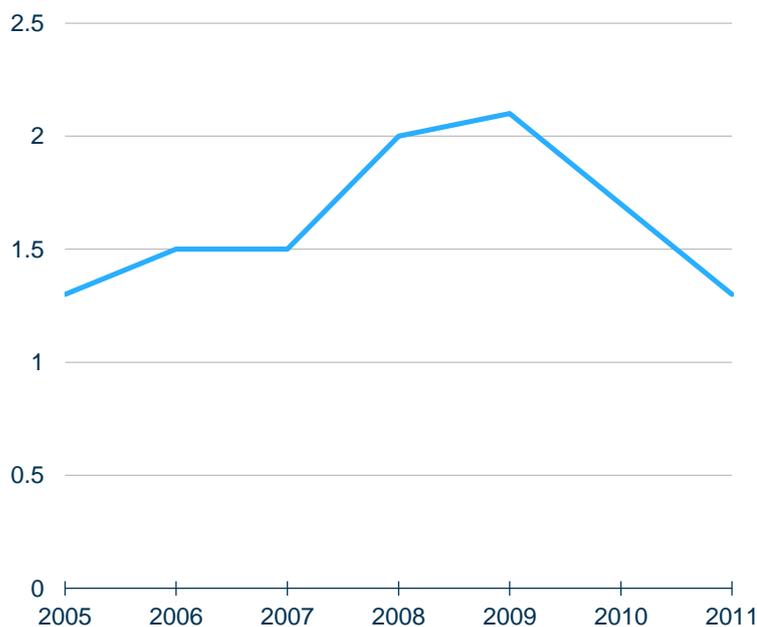
## 4 Use of spectrum in Australia

This section outlines a number of specific developments in relation to the utilisation of radio spectrum in Australia within the frequency bands of interest for the SKA telescope. It is structured as follows:

- Section 4.1 introduces demographic aspects of Australia
- Section 0 discusses developments relating to public mobile systems
- Section 4.3 discusses developments relating to business radio systems
- Section 4.4 discusses developments relating to broadcasting systems
- Section 4.5 discusses developments relating to fixed links
- Section 4.6 discusses developments relating to satellite systems.

### 4.1 Demographics of Australia

Australia has a population of 22 328 800, according to the World Bank.<sup>24</sup> The population of Australia has grown at a rate of between 1.5–2% per annum between 2005 and 2009, as illustrated below in Figure 4.1.



*Figure 4.1: Percentage population growth in Australia [Source: World Bank and Euromonitor]*

<sup>24</sup> Source: World Bank, World Development Indicators.

There has been a small shift in population away from rural areas to urban areas in recent years: 88% of the population in Australia lived in urban areas in 2005, rising to 89% in 2011 (see Figure 4.2).

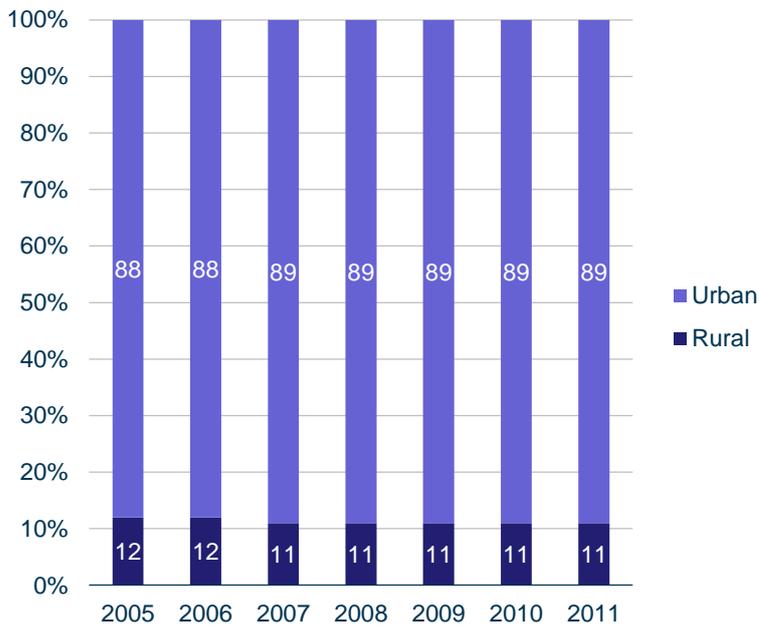


Figure 4.2: Distribution of urban/rural population in Australia [Source: World Bank and Euromonitor]

**Implications for the SKA project:** Relatively limited changes to the distribution of population in Australia in recent years.

## 4.2 Public mobile

The Australian Communications and Media Authority (ACMA) is responsible for managing the radio spectrum in Australia. There are three main licence types used for commercial mobile systems (covering public mobile and broadband wireless access):

- **spectrum licence** – this is usually a nationwide licence of a defined amount of spectrum, allocated to one or more operators (e.g. public mobile operators)
- **apparatus licence** – this is a licence in which individual transmitting apparatus (i.e. base stations) are licenced (i.e. based upon the location and power of individual transmitters)
- **class licence** – this refers to unlicensed spectrum, as described in Section 3.10; these bands can be used for broadband wireless access systems, often referred to as ‘nomadic wireless access’, using WiFi technology.

A summary of current spectrum assignments for public mobile and broadband wireless access services is provided below in Figure 4.3, based upon information published by the ACMA.

<i>Band</i>	<i>Licensing regime</i>	<i>Current usage</i>
825–845MHz/ 870–890MHz	Spectrum (paired spectrum)	Australia-wide mobile telephony (3G–W-CDMA)
890–915MHz/ 935–960MHz	Apparatus (paired spectrum)	Australia-wide mobile telephony (3G–W-CDMA) (GSM900)
915–928MHz	Class	WLAN and other low-powered devices
1427–1535MHz	Apparatus (paired spectrum)	Regional and remote areas – digital audio broadcasting and broadband wireless access in regional and remote areas (digital radio is not permitted within 200km of the capital city and other specified locations; broadband wireless access is not permitted in high- and medium-density areas)
1710–1785MHz/ 1805–1880MHz	Spectrum (paired spectrum)	Capital cities and regional areas, Australia-wide (restricted to the lower 15MHz in regional areas)—mobile telephony (GSM1800)
1900–1920MHz	Spectrum (unpaired spectrum)	Capital cities only – 3G and broadband wireless access services
	Apparatus (unpaired spectrum)	Regional and remote areas only – broadband wireless access
1920–1980MHz/ 2110–2170MHz	Spectrum (paired spectrum)	Capital cities and regional areas (restricted to the upper 20MHz) – 3G mobile telephony and broadband
	Apparatus (paired spectrum)	Regional and remote areas – 3G mobile telephony and broadband
2302–2400MHz	Spectrum (unpaired spectrum)	Australia-wide – broadband wireless access
2400–2483.5MHz	Class	WLAN, other low-powered devices (e.g. WiFi and Bluetooth)
3425–3442.5MHz/ 3475–3492.5MHz	Spectrum (paired spectrum)	Capital cities and major regional centres only – fixed wireless access/broadband wireless access
	Apparatus (paired spectrum)	Other regional and remote areas only – fixed wireless access/broadband wireless access
3442.5–3475MHz/ 3542.5–3575MHz	Spectrum (paired spectrum)	Capital cities and regional areas only – fixed wireless access/broadband wireless access
	Apparatus (paired spectrum)	Capital cities and regional areas only – fixed wireless access/broadband wireless access
3575–3700MHz	Apparatus (unpaired spectrum)	Regional remote areas – fixed wireless access/broadband wireless access
5150–5350MHz	Class	WLAN, other low-powered devices (e.g. WiFi)
5470–5725MHz	Class	WLAN, other low-powered devices (e.g. WiFi)
5725–5850MHz	Class	WLAN, other low-powered devices (e.g. WiFi and WiMAX)

Figure 4.3: *Spectrum allocations available for the deployment of commercial wireless systems in Australia [Source: ACMA]*

In terms of future developments, the ACMA has confirmed its intention to auction spectrum in two frequency bands suitable for public mobile services:

- **700MHz, comprising digital dividend spectrum from 698–806MHz** – including 2×45MHz of spectrum suitable for mobile operators to deploy LTE FDD systems, particularly to provide coverage into rural areas and deeper into buildings.<sup>25</sup>
- **2.5GHz, comprising spectrum from 2500–2690MHz** – including 2×70MHz of spectrum suitable for LTE FDD systems, particularly to provide additional capacity for mobile broadband services in urban areas.<sup>26</sup>

As noted elsewhere in this report, the take-up and use of mobile broadband services have increased significantly in many countries around the world over the past few years, as a result of the growing use of data-intensive devices such as smartphones and tablet PCs. This has led to mobile data traffic exceeding voice traffic on many mobile networks over the past year – five years ahead of earlier forecasts published by the ITU-R in preparation for the WRC-2007, which suggested that voice would remain the dominant use of mobile networks until 2015.<sup>27</sup>

Consequently, public mobile operators may increasingly need to adopt smarter and more efficient spectrum utilisation techniques to maximise the use of existing spectrum, as well as acquiring more spectrum from the ACMA spectrum awards identified above, as well as potentially in other new bands that the ACMA might identify in future.<sup>28</sup>

The ACMA has recognised the increasing demand for spectrum for mobile broadband services in its consultation paper on *Future spectrum requirements for mobile broadband*, published earlier this year<sup>29</sup>. This consultation paper considers frequency bands below 6GHz that could potentially be made available for future mobile broadband services, with the key objectives being to:

- identify baseline spectrum requirements for future mobile broadband services
- consider the needs of incumbent services
- consider strategies to be used to reduce the overall amount of spectrum that might be required
- gather information from stakeholders regarding the impact of emerging technologies and their associated benefits.

<sup>25</sup> The ACMA has announced its intention to award the 700MHz band in accordance with the Asia–Pacific Telecommunity Wireless Forum (AWF) preferred band plan, comprising 2×45MHz of paired spectrum with a 10MHz centre gap and two guard bands of 5MHz and 3MHz.

<sup>26</sup> The 2.5GHz band was previously used for electronic news gathering (ENG) – often referred to as PMSE – in Australia. We understand that some of those services could remain within the 2.5GHz band (using the unpaired block from 2570–2620MHz), which would result in 2×70MHz of paired spectrum being available, from 2500–2570MHz and 2620–2690MHz.

<sup>27</sup> ITU-R Report M.2072, *World mobile telecoms market forecast*, source: [www.itu.int/imt](http://www.itu.int/imt)

<sup>28</sup> Efficient spectrum use is typically achieved by optimising infrastructure deployments and leveraging improvements in technology, such as making use of femtocells, for example.

<sup>29</sup> <http://www.acma.gov.au/WEB/HOME/PAGE/PC=HOME>

The consultation paper highlights a requirement for 150MHz of additional spectrum being required by 2020, over and above that already available for wireless broadband services. Bands already identified to be assigned for mobile broadband use include those already in use for 2G/3G mobile, as well the two new bands planned for award in the short to medium term in the 700MHz and 2.5GHz bands range.

Beyond this, possible future candidate bands discussed in the ACMA consultation paper that could be considered to meet the 150MHz additional spectrum demand include the 1.5GHz band (comprising parts of the 1427–1510MHz band (currently used for point-to-point and point-to-multi-point fixed wireless systems and aeronautical telemetry), the 1980–2010MHz/2170–2200MHz band (allocated internationally for mobile satellite services), the 1675–1710MHz band (currently allocated to meteorological satellite services), and the remainder of the C-band (i.e. remaining parts of the 3400–4200MHz band not already included within existing wireless broadband spectrum defined in Figure 4.3 above).

For each of the possible candidate bands, the ACMA consultation paper invites industry to comment on the feasibility of use for mobile broadband services (including equipment availability), the impact on existing services, and the potential for improved sharing and/or re-planning of certain bands to make spectrum available.

Separately to this, the ACMA has considered requirements for spectrum below 1GHz for mobile broadband services. In May 2011 the ACMA published its second consultation paper *The 900MHz band – Exploring new opportunities*, which considers options to re-plan spectrum in the 820–960MHz range to make more bandwidth available for mobile services.<sup>30</sup> This second consultation paper proposes re-planning and re-assignment of existing GSM900 spectrum for 3G/4G use (involving re-planning of existing assignments into contiguous 2x5 MHz blocks).

It is expected that in the longer term, mobile operators will have access to a combination of frequency bands – 700MHz, 900MHz, 1800MHz and 2.5GHz – for mobile broadband services using HSPA and LTE technology. It is likely that in the short to medium term, operators will deploy different generations of cellular technology in parallel, to manage migration from GSM/GPRS to 3G and then to LTE. In the longer term, it is expected that all public mobile services will be migrated to LTE.

**Implications for the SKA project:** There is likely to be increasingly intensive use of all mobile frequency bands – 700MHz, 800MHz, 1800MHz and 2.5GHz – as networks are migrated from GSM and UMTS to LTE. Migration of other services to make way for mobile broadband network expansion is envisaged with the ACMA suggesting that up to 150MHz of spectrum might be re-purposes for mobile use with key candidate bands being 1.5GHz, 1980-2010/2170-2200MHz, 1675-1710MHz and 3.4-3.6GHz.

<sup>30</sup> Australian Communications and Media Authority (ACMA, May 2011), *The 900 MHz band—Exploring new opportunities. Initial consultation on future arrangements for the 900 MHz band*. Available at [http://www.acma.gov.au/webwr/\\_assets/main/lib312085/900mhz\\_review-exploring\\_new\\_opportunities.pdf](http://www.acma.gov.au/webwr/_assets/main/lib312085/900mhz_review-exploring_new_opportunities.pdf).

### 4.3 Business radio

There are six frequency bands generally used for business radio or PMR services in Australia:

- HF band (3–30MHz)
- VHF low band (29.7–45MHz)
- VHF mid band (70–87.5MHz)
- VHF high band (148–174MHz)
- 400MHz UHF band (403–430MHz and 450–520MHz)
- 900MHz UHF band (820–825MHz and 865–870MHz).

In addition to some of these bands, the Australian military deploys business radio-type systems in other parts of the spectrum, in particular 230–399.9MHz (which is in common with a number of other countries around the world).

The rail industry is an important user of the 400MHz band, especially in particular channels widely used by government rail authorities. Business radio systems deployed by the rail industry include train protection and command and control. Several other systems are also used to provide voice communications and monitor data, for example.

It is understood that congestion in some business radio frequency bands, especially in high-demand markets such as Sydney and Melbourne, is experienced and in those areas it is sometimes difficult to find available 25kHz channels. However, there are ways that the efficiency of business radio frequency assignments can be improved – for example, splitting 25kHz channels and/or using low-power assignments to meet the demand.

New technologies employing digital modulation schemes, particularly those employing trunking techniques, can improve the spectral efficiency and quality of business radio services, as described in Section 3.5.3.

As described in Section 3.5.4, therefore, given the possible improvements in spectrum efficiency that can be applied within existing business radio frequency bands, it is not expected that there will be significant changes to the amount or characteristics of spectrum used for such services in Australia in the future. Therefore, we do not anticipate substantial longer-term changes in this radio sector that will affect the SKA environment.

**Implications for the SKA project:** None envisaged.

## 4.4 Broadcasting

Spectrum used for broadcasting services is typically allocated at an international level by the ITU and therefore the spectrum used by current broadcasting services in Australia is similar to bands used around the world:

- 85-108MHz (VHF Band II) – FM radio transmitters are assigned frequencies in this band
- 174-230MHz (VHF Band III) – digital television transmitters and digital radio transmitters are assigned frequencies in this band
- 520-820MHz (UHF Bands IV and V) – digital TV transmitters are assigned frequencies in this band.

The main uses of each band are briefly described below.

### *VHF-FM radio broadcasting*

The VHF-FM band (VHF Band II 87.5–108MHz) is used for national, commercial and community radio broadcasting services, as well as low-power open narrowcasting (LPON) and high-power open narrowcasting (HPON) services. The VHF-FM band is considered by some broadcasters and the ACMA to be heavily congested in major cities and nearby regional areas. This view is supported by the difficulty the ACMA has experienced in planning additional services in many regional areas. The prices obtained for VHF-FM commercial radio broadcasting licences in major metropolitan markets are evidence of demand for additional FM broadcasting channels.<sup>31</sup> For example, the 2004 auctions of single FM licences in Melbourne, Brisbane and Sydney attracted winning bids of AUD52 million, AUD80 million and AUD106 million, respectively.

About 30% of the approximately 2235 broadcasting licences held in the VHF Band II are used for retransmission services.<sup>32</sup> Typically, retransmission services in this band serve small population centres in rural and remote areas and are fed via satellite. Despite the large number of retransmission licences, the majority of the Australian population receives VHF-FM services from a small number of high-power transmitting sites.

<sup>31</sup> Australian Broadcasting Authority (25 September 2003), *ABA – NR60/2003—Analogue commercial radio sector*. The ABA stated that from this date, it did not propose to allocate any further analogue commercial radio licences within five years of the last allocation in the ongoing round at that time. The last allocation was made for Melbourne in August 2004 (see '\$52 million bid for new Melbourne commercial radio licence', ABA Update, August 2004, Australian Broadcasting Authority, p. 7).

<sup>32</sup> Including commercial, community (both permanent and temporary community broadcast licences), national and retransmission services. Under Section 212 of the BSA, in addition to the retransmission of commercial broadcasting (within the licence area), national broadcasting and National Indigenous TV Ltd programming content, commercial broadcasters are permitted to retransmit their programme content outside their licence area with special written permission from the ACMA.

*VHF Band III digital radio broadcasting*

VHF Band III (174–230MHz) spectrum is used in the five metropolitan licence areas of Adelaide, Brisbane, Melbourne, Perth and Sydney to broadcast terrestrial digital radio services, sharing spectrum with digital TV services.<sup>33</sup>

*VHF/UHF TV broadcasting*

Analogue and digital TV broadcasting services in Australia are provided in VHF and UHF bands. Details of usage prior to the switch-off of analogue TV services are listed below (in line with most other countries, analogue to digital switchover in broadcasting is taking place in Australia and the analogue TV network will be switched off between 2010 and 2013):<sup>34</sup>

- VHF Band I (45–52MHz and 56–70MHz) – VHF channels 0, 1 and 2 for analogue TV
- VHF Band II (85–92MHz and 94–108MHz) – VHF channels 3, 4 and 5 for analogue TV (in a limited number of geographical areas; these channels are shared with extensive deployments of VHF-FM radio broadcasting services)
- TV channel 5A (137–144MHz) for analogue TV
- VHF Band III (174–230MHz) – VHF channels 6–9, 9A and 10–12 for analogue and digital TV services
- UHF Bands IV and V (520–820MHz) – UHF channels 28–69 for analogue and digital TV services.<sup>35</sup>

The most significant changes in the broadcasting market will be migration from analogue to digital transmission for both radio and TV broadcasting. For radio broadcasting, this may result in the expansion of digital radio services into regional areas. The deployment of DAB, DAB+ or other digital radio technologies in regional areas will change the use of VHF Band III in particular in future.

The Australian Government has set 2013 as the date by which the switchover to digital TV will be completed. The digital dividend, which refers to the spectrum freed up as a result of the switchover from analogue to digital TV, is estimated to 126MHz, which is to be allocated to new uses such as advanced mobile telecoms services, including mobile broadband (referred to as the 700MHz band, to be auctioned by the ACMA over the coming year, as described elsewhere in this report).

**Implications for the SKA project:** There will be substantial change to existing radio systems within VHF Band III and UHF Bands IV and V in future, as broadcasting systems are migrated from analogue to digital technology, and spectrum in the UHF band is freed up for mobile broadband use.

<sup>33</sup> This band was also used for analogue TV, although analogue services will be switched off in line with the digital switchover.

<sup>34</sup> <http://www.digitalready.gov.au/>.

<sup>35</sup> The ACMA's policy is, where practical, to avoid allocating digital services on channels 68 and 69.

## 4.5 Fixed links

The microwave fixed bands that are used in Australia are similar to those described previously in Section 3.4 and can be classified into four major categories of use:

- low-capacity long-haul links – deployed in the 1.5, 1.8, 2.1 and 2.2GHz bands
- high-capacity long-haul links – deployed in the 3.8, 6, 6.7 and 8GHz bands
- medium-capacity medium-haul links – deployed in the 7.5, 10 and 13GHz bands
- back-haul and urban networks – deployed in the 15, 18, 22, 38, 50 and 58GHz bands.

The 1.5GHz band is also used for digital radio concentrator systems (DRCS)/high-capacity digital radio concentrator systems (HCRC), which provide telephone services to remote and rural areas, as well as for the provision of broadband wireless access (BWA) services.<sup>36</sup>

Other microwave bands not listed above are used for TV outside broadcast (OB) services (2.5, 7.2 and 8.3GHz) or temporary links (49GHz). The 3.4GHz band (outside areas used for fixed links) also provides rural communities with fixed telephony and data communications service. The 2.5GHz band is currently used for electronic news gathering (ENG), but these services are being re-allocated to other bands, in order for the 2.5GHz band to be assigned for public mobile use, for LTE, as described above.

There is significant developments taking place to expand wireless broadband access services in remote and regional parts of Australia, which are unserved by fixed (cable and/or fibre) networks. For example, in July 2011, the ACMA auctioned forty licences in the 2.3GHz band for allotments covering regional rural areas of Australia. The winners of the auction were National Broadband Network (NBN) Co., Telstra and BKAL:

- NBN Co. is the Australian government's vehicle for providing a national wholesale broadband network. Its mandate is to provide fixed broadband coverage to 93% of Australians using fibre broadband, but have committed to providing wireless broadband to the remaining 7% where fixed broadband is not a viable solution. Of this, 4% is expected to be delivered by fixed wireless services and 3% by satellite services.<sup>37</sup> NBN Co. obtained 24 of the ACMA's recently awarded licences. This follows the company's recent acquisition of 2.3GHz and 3.4GHz spectrum from Australian TV broadcaster Austar in February 2011. The first roll-out of services on the newly acquired spectrum is expected to be delivered in 2012 and completed by 2015.
- The remaining licences in the 2.3GHz band were acquired by Telstra and BKAL.

<sup>36</sup> The DRCS system is a microwave point-to-multipoint system which concentrates the telecoms traffic of many users. A typical system comprises a central exchange which connects to the wired telephone network, repeater stations and remote stations. Subscribers are connected either to the repeater or a remote station, with a typical transmission link length between two stations of approximately 40–50km. DRCS is an ageing technology that is being replaced by HCRC.

<sup>37</sup> See <http://www.nbnco.com.au/>.

It is understood that the ACMA is also making additional spectrum available for wireless access services (WAS) in the 3.6GHz band (3575–3700MHz). This final release of spectrum in the 3.6GHz band will further support the deployment of broadband wireless and other WAS in regional areas of Australia.

In terms of other future changes to spectrum used for fixed links, the demand for mobile broadband communications services in rural and remote areas could result in the need for extra backhaul spectrum in the low-capacity bands identified above. Following international trends, the use of high-capacity radio technologies is also expected to increase in microwave bands above 15GHz.

As noted elsewhere in this report, some fixed link spectrum (in the 1.5GHz and 3.4–3.6GHz bands) is expected to be considered as future candidate bands for re-allocation to mobile broadband use. Other future developments in spectrum for fixed links (e.g. increasing use of 50GHz and 58GHz bands) are outside the frequency range of interest to the SKA, and therefore not relevant to this study.

## 4.6 Satellite

As described in Section 3.6, long-term forecasts for satellite spectrum demand in the 1990s never properly materialised, leading to an oversupply of capacity across the industry. However, the use of satellite spectrum has increased in the past decade and satellite services will be used in Australia by NBN Co. to deliver broadband services to the most remote areas.

Internationally, the major satellite operators of fixed satellite services and broadcasting satellite services are Intelsat, SES Global and Eutelsat, which operate primarily in the C-, Ku- and Ka-bands,<sup>38</sup> as described previously. Most Australian coverage comes from footprints of geostationary satellites serving the Asia–Pacific region operated by Intelsat/PanAmSat and Optus and, to a lesser extent, others including ASIASAT, APT Group and SES New Skies.

In the fixed satellite services and broadcasting satellite services markets, TV distribution and broadcasting is the dominant service, with much of the recent growth in satellite usage being attributable to the development of digital TV. Broadcasting to the public generally uses spectrum in the Ku-band, with utilisation of the C- and Ku-bands for contribution feeds. C-band satellite communications currently facilitate important applications including distance learning, tele-medicine, universal access and disaster recovery. C-band is also used for feeder links for mobile broadband services. The Ku-band is also used heavily for VSAT applications and some SNG and DTT broadcasting distribution.

The paired fixed satellite allocations 7250–7750MHz and 7900–8400MHz are designated to be used principally for government purposes.

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<sup>38</sup> C-band (4-6 GHz), Ku-band (10-12 GHz) and Ka-band (26-40 GHz) are the internationally agreed allocations for satellite services.

The major satellite operators of mobile satellite services in Australia are Inmarsat, Iridium, Globalstar, Orbcomm, Optus and Thuraya. These services primarily use spectrum in the L- and S-bands, in line with other countries around the world.

Factors that are expected to drive demand for satellite spectrum in Australia include increasing consumer demand for higher data rates and flexibility to accommodate various uses, as well as increasing government demand and investment in technology.

However, since satellite communications typically involve a 15-year investment cycle, internationally co-ordinated strategic planning is necessary so the industry can respond to spectrum allocation changes. Hence, it is unlikely there will be significant changes to spectrum used for satellite services in Australia, other than as part of wider international developments (as described in Section 3.6).

However, one area of development within the Asia–Pacific region is in TV distribution and broadcasting over satellite, which is used much more widely than in some other world regions (e.g. Europe). For example, the expansion of the Optus satellite fleet (D2 launched in 2007 and D3 launched in 2009), intended to support Foxtel’s HDTV and other satellite broadcasting services in the Asia–Pacific region, is an example of capacity planned to address the expected growth in demand. However, the D3 satellite uses 11.7–12.2GHz and 17.3–17.8GHz for TV broadcasts and broadcasting satellite services feeder links, respectively, so falls outside the frequencies of interest to the SKA.

**Implications for the SKA project:** None envisaged.

## 5 Use of spectrum in South Africa

This section outlines a number of specific developments in relation to the utilisation of radio spectrum in South Africa within the frequency bands of interest for the SKA radio telescope. It is structured as follows:

- Section 5.1 introduces demographic aspects of Australia
- Section 0 discusses developments relating to public mobile systems
- Section 5.3 discusses developments relating to business radio systems
- Section 5.4 discusses developments relating to broadcasting systems
- Section 5.4 discusses developments relating to fixed links
- Section 5.6 discusses developments relating to satellite systems.

Details on South Africa's spectrum allocation plan are not as comprehensive as for many other countries. Data comes primarily from the Independent Communications Authority of South Africa's (ICASA) website, the telecoms regulator in South Africa.<sup>39</sup>

### 5.1 Demographics of South Africa

South Africa has a population of 49 991 300, according to the World Bank.<sup>40</sup> The population of South Africa has dropped in the past two years, as shown below in Figure 5.1.

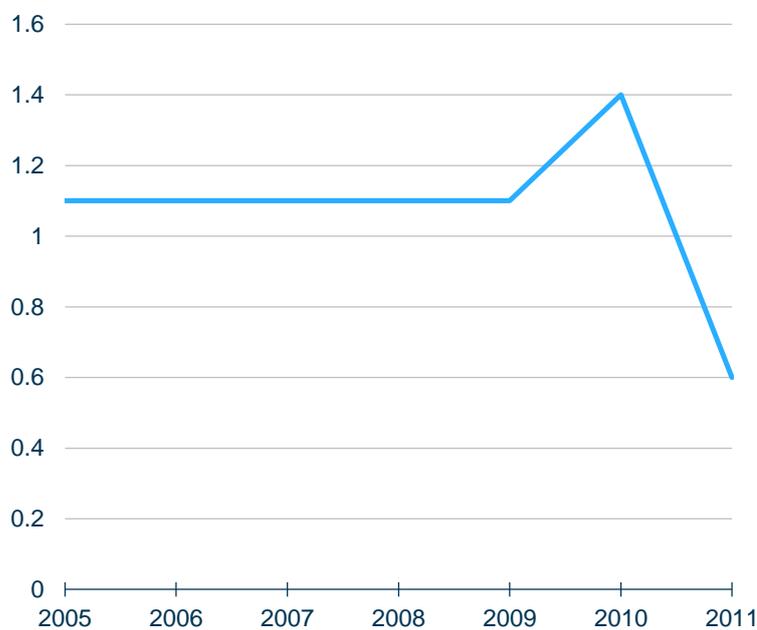


Figure 5.1: Percentage population change in South Africa [Source: World Bank and Euromonitor]

<sup>39</sup> <http://www.icasa.org.za/>.

<sup>40</sup> Source: World Bank, World Development Indicators.

The proportion of the South African population living in urban areas has increased by 3% over the same period (see Figure 5.2).

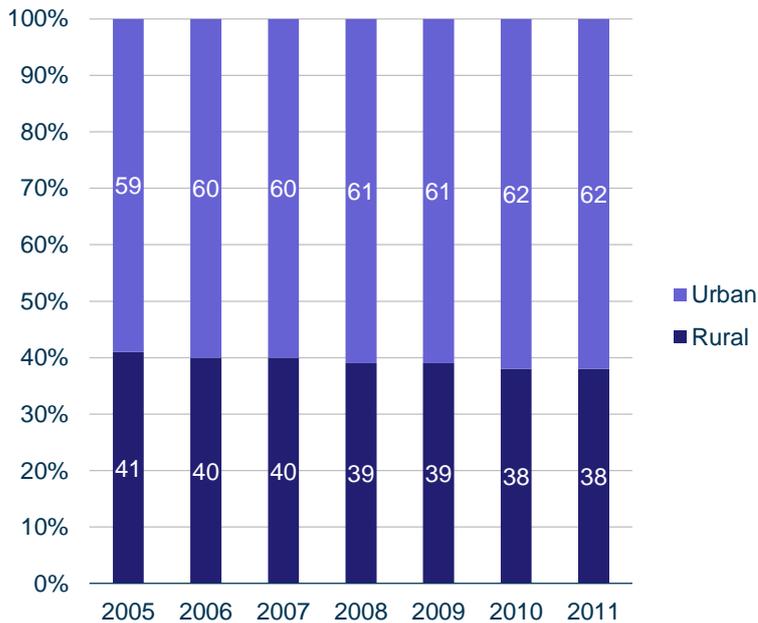


Figure 5.2: Urban/rural population distribution  
[Source: World Bank and Euromonitor]

## 5.2 Public mobile

The cellular operators in South Africa use similar spectrum to those in other world regions – mainly 900MHz, 1800MHz and 2.1GHz at present.

Mobile penetration in South Africa stood at over 96% of the population at the end of 2010, and mobile data traffic has increased rapidly in recent years. The first 3G services in Africa were deployed in South Africa in 2004, and the four providers in South Africa – Vodacom, MTN, Cell C, and Telkom – all have 3G coverage, and both Vodacom and MTN have launched HSPA+ networks capable of supporting speeds of up to 21Mbit/s.

However, broadband penetration in South Africa is limited to less than 5% of households, even after the introduction of ADSL in 2002 and wireless broadband technologies (3G and BWA) from 2005 onwards. Growth in the South African broadband market has been hampered primarily because of the monopoly position of the incumbent operator Telkom, resulting in a high price of connections due to a lack of competition. However, government initiatives such as the deployment of backhaul infrastructure, the liberalisation of the market through local loop unbundling (LLU) and the emergence of new wireless service providers are expected to drive broadband adoption, by-passing Telkom's monopoly. This is expected to lead to an increasing deployment of mobile broadband systems as well as fixed WAS (for fixed wireless broadband access).

The South African government published the South African National Broadband Policy in 2010<sup>41</sup>, identifying aims for and assigning roles to various stakeholders:

<sup>41</sup> <http://www.oecd-ilibrary.org/docserver/download/fulltext/5kg9sr5fmqwd.pdf?expires=1320085994&id=id&accname=guest&checksum=C37C9CD2B05A88BD1CE6035293BCDAF7>

- broadband is defined as ‘always on, high speed, multimedia capable connection’ of at least 256kbit/s download speed
- universal broadband access (15% household penetration, and broadband within 2km of any household) is targeted to be achieved by 2019
- a Broadband Inter-Governmental Implementation Committee is to oversee progress.

Although wireless broadband has grown robustly to date, it is expected that continued growth (and achievement of the targets set out in the policy) will require effort from all stakeholders including the government, the regulator, operators and end-user representatives to overcome barriers that still exist in the market.

LTE is in its infancy in South Africa, although MTN South Africa began work on a pilot network using LTE in the 1800MHz band in May 2011. At the same time, the company is stepping up the deployment of its own high-speed fibre-optic cables to its base stations, and plans to have as many as 1600 towers connected to fibre by the end of the year, from the current 600. MTN South Africa is building its LTE network using the 1800MHz band, which it traditionally used for voice services, while it waits for the regulator to auction off the 2.6GHz spectrum.

It is expected that mobile and wireless broadband operators will be keen to acquire new licences for 2.6GHz and 3.5GHz spectrum in order to launch 4G services. However, the auction of 2.6GHz and 3.5GHz spectrum has been delayed by the Government. ICASA originally published draft regulations for the award in 2009, which outlined the procedures and criteria under which vacant spectrum in the 2600MHz and 3500MHz frequency bands would be distributed. However, the initial attempt at allocating this spectrum did not proceed as planned, and the auction was postponed. At the time of producing this report, the said spectrum is scheduled to be auctioned in the next few months.

There have been recent calls from the mobile industry to auction the 2.6GHz and 3.5GHz spectrum at the same time as the digital dividend spectrum in the 800MHz band. The spectrum at 800MHz – more suited to wider coverage, as described previously in this report – and a combined spectrum auction would allow the 2.6GHz and 3.5GHz spectrum to be used for additional capacity, whilst the 800MHz band could be used to expand rural coverage and provide deeper in-building mobile broadband services.

In the longer term, it is expected that the South African market will experience similar growth in demand for mobile broadband services as has been experienced in other markets. Therefore, similar developments might be expected as those already taking place in Australia, described in Section 4, requiring the government to identify new spectrum that can be used to accommodate mobile broadband growth in the future. In terms of the implications for the SKA environment, these are likely to be similar to those described for Australia.

**Implications for the SKA project:** Similar to those described in relation to public mobile developments in Australia.

### 5.3 Broadcasting

Figure 5.3 lists the broadcasting bands that are included in the South African broadcasting frequency plans – which are similar to those used in Australia.

<i>Broadcasting bands</i>	<i>Range</i>	<i>ITU plan</i>
AM–MF audio broadcasting	535.5–1606.5kHz	Geneva plan of 1975
VHF/FM audio broadcasting	87.5–108MHz	Geneva plan of 1984
VHF television broadcasting	174–238MHz, 246–254MHz	Geneva plan of 2006
UHF television broadcasting	470–854MHz	Geneva plan of 2006

Figure 5.3: *Broadcasting frequency plans [Source: ICASA]*

South Africa’s first digital TV broadcasting signal was switched on in October 2008, with digital migration scheduled to be completed during 2012. The switchover to digital TV in South Africa will free up some spectrum for other uses (referred to as the digital dividend). Whereas the Australian digital dividend is in the 700MHz band, in South Africa it is in the 800MHz band (which is aligned with the digital dividend in ITU Region 1 countries, including Europe and Africa). However, the 700MHz and 800MHz bands are both expected to be used for similar services – essentially to extend LTE mobile broadband systems into rural areas.

Mobile TV services were introduced in 2007, and use a channel within UHF Bands IV and V (below 700MHz). It is understood that VHF Band III is also scheduled to be used for HDTV and interactive TV.

Similar to the situation occurring in many other countries, the digital dividend will result in spectrum from the broadcasting sector to be transferred to the telecoms sector. ICASA has estimated that the 790–862MHz band will be released at some point during 2012 for telecoms services once analogue broadcasting services have been switched off.

In line with similar developments taking place internationally, it is also expected that currently existing analogue radio broadcasts will migrate to digital. However, there should not be any significant changes in spectrum assignments for digital radio in South Africa, as the necessary sites and coverage requirements for digital radio should be relatively comparable to the requirements that currently exist for analogue services.

**Implications for the SKA project:** Similar to development around the world, it is expected that switchover from analogue to digital television in South Africa will create a digital dividend that will be made available for mobile broadband use. This will change the characteristics of use of the upper part of the UHF spectrum in the future.

## 5.4 Fixed links

The fixed service has allocations across various bands in South Africa, from very low frequency (VLF) to extremely high frequency (EHF).<sup>42</sup> Usage is concentrated at the UHF bands (400MHz and 900MHz) and at the bands from 1.5GHz to 58GHz, often referred to as the microwave bands.

The fixed service spectrum in the UHF bands is predominantly used by narrowband applications including those that link public mobile base stations and perform narrowband telemetry functions.

As described in previous sections, no significant changes are envisaged to fixed link spectrum usage at this time, and technology improvements have been made to allow for more intensive use of spectrum. However, since no significant increase in the demand for fixed links is foreseen, it is unlikely that any new spectrum will be assigned for fixed link use – a reduction in demand is more likely as mobile operators continue to migrate backhaul from wireless to fibre, in line with international trends, as previously discussed.

**Implications for the SKA project:** No significant implications identified.

## 5.5 PMR

South Africa appears to have followed international trends regarding deployment of PMR systems, with no specific changes in recent years to the spectrum allocation for PMR services.

## 5.6 Satellite

Satellite spectrum is currently concentrated in the C-band (3.6–4.42GHz and 5.85–6.725GHz) and in the Ku-band (10.7–14.5GHz). However, much of the spectrum used for next-generation Ka-band systems above 20GHz is currently being utilised for fixed point-to-point links in South Africa.

Across the frequency range typically utilised by satellite spectrum, there are two main changes expected over the next five to ten years. First, it is expected that some spectrum designated for fixed, satellite and broadcasting services will be re-purposed for mobile broadband as the proliferation of mobile broadband use continues to grow across South Africa, in line with international developments. This might affect spectrum in the 3–4GHz range, for example. Furthermore, it is expected that the current spectrum assignments for satellite spectrum will move to next-generation Ka-band systems above 20GHz.

**Implications for the SKA:** Longer term investment in satellite systems expected to focus on Ka-band, which is outside of the frequency range of interest to the SKA.

<sup>42</sup> VLF is notionally the frequency range 3–30kHz and EHF is notionally the frequency range 30–300GHz.

## 6 Assessment of RQZ proposals

This section covers Analysys Mason's observations on the report of the Expert Panel on Radio Quiet Zone and RFI provided to us by the SPDO for this project. This also refers to the responses from the Australia and New Zealand SKA Coordination Committee and SKA South Africa to the requirements for RQZ Protection, stipulated by the SKA Siting Group (SSG) in its paper Request for Information from the Candidate SKA sites ('the RFI', ref: SSG-RFI-001 Rev D).

In particular, candidate sites were asked to provide a report covering all aspects of the establishment of their RQZ, and specifically the requirements stated in the grey boxes in Sections 6.1 to 6.7 below, upon which we make any relevant observations we have noted from reviewing the report and associated submissions.

### 6.1 Requirement 1: Technical properties

A full multi-dimensional matrix of frequency range, maximum allowed emission levels as a function of frequency, and, if applicable, location within the RQZ. Note exceptions if applicable.

#### *Analysys Mason's observation*

The requirements for protection from radio interference are challenging and, as noted in the expert panel report, stem from threshold values defined in Recommendation ITU-R RA.769-2. Supporting legislation is in place at both sites to implement a RFQ based upon these threshold values.

We note that verification of complete compliance at the reference point would require a measurement device no less sensitive than a radio telescope. Conventional radio receivers and spectrum analysers cannot detect levels of interference at the stated threshold.

Thus, verification of compliance in **advance of construction** of a telescope would probably require collation of all relevant transmitter details within the protection zones and beyond, combined with a desktop analysis exercise using an appropriate ITU-recommended propagation model.

We also note that international imported interference may also need to be considered in certain bands, especially broadcast TV where high masts combined with anomalous propagation phenomena can result in interference hundreds of miles from the transmitter. This is particularly relevant to the South African site, since South Africa shares a land border with various neighbouring countries. The nature of radio propagation is such that it is possible that transmitters installed in neighbouring countries could generate emissions that will cause interference in South Africa, for example.

### 6.1.2 Australia and New Zealand SKA Coordination Committee

The response includes a table of frequency bands (100MHz to 25250MHz) against restriction and co-ordination zones (100km to 260km radii; equivalent to an area from 31 416km<sup>2</sup> to 212 372km<sup>2</sup>) against thresholds (-214dBm/Hz to -236dBm/Hz).

The response notes that the tabulated protection is not afforded across the entire protection zone but at the core of the Murchison Radio-astronomy Observatory (MRO). The restriction and coordination zones are centred on MRO.

### 6.1.3 SKA South Africa

The response includes a graph of threshold (-225dBm/Hz to -260dBm/Hz) against frequency (70MHz to 25250MHz).

Three concentric restriction areas are noted: Karoo Central Astronomy Advantage areas KCAAA1, KCAAA2, and KCAAA3 are centred on the SKA South Africa site. These areas are not circular but rather irregular polygons of six to eight sites.

KCAAA1, KCAAA2 and KCAAA3 have a total protected area of 123 456km<sup>2</sup>, 79 963km<sup>2</sup> and 44 602km<sup>2</sup>, respectively.

The protection reference point is referred to as the Karoo Core Centre (21.3880 degrees East and 30.7148 degrees South) at a height of 10 metres.

## 6.2 Requirement 2: Timelines

The timeline for establishing the RQZ, identification of phases if applicable, and a summary of items remaining to be done to establish the RQZ in practice. Note that the target lifetime of the SKA facility and the associated RQZ is 50 years from commencement of operation.

### *Analysys Mason's observation*

The expert panel report notes that RQZ legislation and timelines have been mostly established jointly at each site. In South Africa, this is based on the Astronomy Geographic Advantage Act of 2007, and in Australia, the Radiocommunications Act of 1992 and more recently a MOU between the Australian and Western Australian Governments on radio quiet matters.

### 6.2.2 Australia and New Zealand SKA Coordination Committee

The establishment of the Mid West Radio-quiet Zone involves three phases:

- **Phase 1: Establishment of a robust legislative framework enabling creation of the Mid West Radio-quiet (1999–2001)** – Since 2001, both the Australian and Western Australian governments have introduced and enforced radio-quiet protections over the Mid-West region of Western Australia in the vicinity of Australia's candidate SKA site.

- **Phase 2: Initial protection for the Mid-West RQZ (2001–2011)** – Both Australia’s national science agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and the ACMA have worked with industry groups (including mining companies) and individuals on affected licence applications since 2005. They have established a database of technical guidelines to help licence applicants understand the radio-quiet regime and develop technical solutions that minimise any radio-frequency impact of their activities on the MRO.
- **Phase 3: Creating a collaborative implementation regime (2011 onwards)** – In June 2011, the Australian and Western Australian governments signed an additional inter-governmental radio-quiet specific memorandum of understanding (2011 MOU), supported by a management framework, providing the policy context for co-existence between radio astronomy and adjacent industry in the Mid-West. This has been the culmination of work throughout 2010 and 2011 between the governments, the ACMA, CSIRO, the local community and mining stakeholders in the Mid-West region of Western Australia.

### 6.2.3 SKA South Africa

The protection scheme for a radio astronomy facility is established through the promulgation of appropriate declarations and regulations made in terms of the Astronomy Geographic Advantage Act No. 21 of 2007 (the AGA Act). Four related declarations and regulations have been enacted, with a further ten scheduled for enactment before the end of December 2011.

Following the promulgation of the declarations and regulations described above, the required protection within the declared Astronomy Advantage Areas (AAAs) is implemented by the Astronomy Management Authority in a two-stage process.

- The **first stage** of implementation involves a review of all existing infrastructure and activities for which regulations have been promulgated. This includes:
  - radio telecoms infrastructure
  - power generation and transmission infrastructure
  - transport infrastructure
  - mining and exploration activities
  - heavy industry
  - any other activities that may result in the generation of radio frequency interference.
- The **second stage** is management of the AAAs on an on-going basis in accordance with the relevant regulations, where all new radio telecoms and other infrastructure and activities will be subject to the protection requirements of the SKA and will be subject to compliance certification by the Astronomy Management Authority before the activity commences.

### 6.3 Requirement 3: Legislation

Describe the way the RQZ is based on local and national laws, how it will be enforced, and the mandates and roles of local and national authorities and the SKA organisation in maintaining and overseeing the RQZ.

At what level of government can a decision be made to amend or overturn the legislation governing the RQZ for the SKA?

All relevant official documents issued by the site proponent and authorities shall be included the Annex to the report.

#### *Analysys Mason's observation*

As noted in Section 6.1, compliance with threshold values for radio astronomy operation is challenging and would probably require collation of all relevant transmitter details within the protection zones and beyond, combined with a desktop analysis exercise using an appropriate ITU-recommended propagation model. However, since the characteristics of radio use will change in future, any measurements or predictions of RF interference will only give a snapshot of the current RF environment, and would need to be repeated at regular intervals to ensure that the RQZ conditions are being enforced. Since radio astronomy is a passive service, it is not granted an individual licence by the national regulatory authority and hence compliance with RQZ requirements will be based upon the legislation that the two countries have defined, as detailed in the expert panel report.

It is noted that in countries such as the UK, the regulator has established 'Recognised Spectrum Access' is in place providing some equivalence to an individual wireless telegraphy licence (with an appropriate licence fee) whereby receive-only users of radio spectrum can obtain some protection from interference. This is understood to be specific to the UK however and does not apply in other countries.

We note that it may be prudent to seek a legal adviser, with experience of the legal system of the candidate countries, to assess the legislation referenced in responses and to confirm that the laws/regulations in force (on the statute) do indeed protect the respective RQZ and offer sufficient penalties or powers to resolve interference issues.

#### 6.3.2 Australia and New Zealand SKA Coordination Committee

The response lists extensive legislation in force to protect the proposed SKA site.

- Australian government – ten protective measures listed
- New Zealand government – three protective measures listed
- Western Australian Government – two additional protective measures listed.

Enforcement and the mandates and roles of local and national authorities are discussed at length.

Although external web links available for some of these legislative measures within the response document, not all (with the exception of the MoU MRO SKA) are included as an integral part of the response, in an annex to the report.

The response notes that the Australian government will consider further regulatory protection if necessary, including legislation to protect against incidental emissions (p.29).

The question in the requirement ‘At what level of government can a decision be made to amend or overturn the legislation governing the RQZ for the SKA?’ does not appear to have been directly addressed.

### 6.3.3 SKA South Africa

The protection scheme for a radio astronomy facility is established through the AGA Act (2007) attached to the response, stating that where there is a conflict between the AGA Act (2007) and other legislation, the former will prevail.

The response also refers to the following South African acts and regulations, all attached to the response:

- Broadcasting Act
- Electronic Communications Act
- Independent Communications Authority of South Africa Act
- Radio Frequency Spectrum Regulations.

The following legislation in neighbouring countries is also referenced and attached to the response:

- Botswana (four items)
- Ghana (three Items)
- Kenya (two items)
- Madagascar (Three items)
- Mauritius (two items)
- Mozambique (two items)
- Namibia (one item)
- Zambia (two items).

The question in the requirement “At what level of government can a decision be made to amend or overturn the legislation governing the RQZ for the SKA?” does not appear to have been directly addressed.

## 6.4 Requirement 4: Spectrum management

The ‘quality’ of the RFI environment generally, and of the RQZ for the SKA specifically, is influenced both in critical and in subtle ways by the spectrum management regimes in place for the host country and any other countries where remote stations of SKA2 are situated. Please provide information on the following topics:

a) Organisation of spectrum management by applicable administrations

Describe the way spectrum management is handled in the applicable country(ies).

b) Empowerment of the SKA

Describe how, and to what degree, the SKA organisation will be able to manage the quality of the RQZ in case of violations, or if there is pressure from other parties to compromise that quality in any way.

c) Specific measures of radio interference protection

Describe any specific, dedicated measures already taken or considered to improve the RFI/EMI environment both within the RQZ and outside.

d) Remote stations

Describe plans and prospects for the establishment of radio protection zones around remote stations (size, frequencies, etc.).

### *Analysys Mason’s observation*

As noted in the expert panel report, arrangements are in place in both countries with a view to preserving an interference-free environment at the SKA site. However, we note that the means of enforcing these arrangements may require further legal advice to the SPDO, as indicated in the previous section.

### 6.4.2 Australia and New Zealand SKA Coordination Committee

ACMA is responsible for the regulation of radio communications in Australia. ACMA is a statutory authority within the Australian government portfolio overseen by the Minister for Broadband, Communications and the Digital Economy. It acts in accordance with the objects of the Radiocommunications Act 1992, principles of administrative law and ACMA’s Spectrum Management Principles. One of ACMA’s four main responsibilities is managing access to the radio frequency spectrum. As such, ACMA has been involved in the Mid-West RQZ planning for the Australian SKA site since its inception in the 1990s.

In New Zealand, the radiofrequency spectrum is managed by the Ministry of Economic Development (MED) through the Radiocommunications Act 1989 and the Radiocommunications Regulations 2001.

The response re-states that Australia has a strong tradition of support for radio astronomy, and a well-organised astronomy community.

As well as the regulations that have been implemented, CSIRO, in collaboration with governments and industry stakeholders, is undertaking a number of other measures to ensure the balanced maintenance of radio-quiet on the MRO:

- co-ordination of assignment of FM frequency bands and other radiocommunications signals between stakeholders in the region; this is possible because of the distance between towns and the sparse population between towns, which results in only low-power transmitters being deployed in the area, which will not interfere with each other
- development of technical advisory guidelines for mining companies and pastoralists detailing acceptable equipment to use within the Mid-West RQZ
- development of technical solutions in collaboration with particular companies to ensure that any radio emissions do not cause unacceptable RFI
- careful placement of array-stations to ensure full compliance with EMI and receiver threshold buffer zone masks
- creation of no-fly zones over the MRO, as already exist over CSIRO's radio astronomy national facilities on the east coast of Australia
- community and stakeholder education, including with Murchison Shire Council and pastoral stakeholders, and other surrounding Councils
- managing the Boolardy Station pastoral activity and working with other pastoralists to ensure radio-quiet compliant operations
- road signage for the four to five vehicles per day that use the roads within 50km of the RQZ.

### 6.4.3 SKA South Africa

ICASA is the regulator for the South African communications, broadcasting and postal services sector. It was established by an Act of statute, the Independent Communications Authority of South Africa Act of 2000, as amended.

ICASA's mandate is set out in the Electronic Communications Act for the licensing and regulation of electronic communications and broadcasting services, and by the Postal Services Act for the regulation of the postal sector.

Enabling legislation also empowers ICASA to monitor licensee compliance with license terms and conditions, develop regulations for the three sectors, plan and manage the radio frequency spectrum as well as protect consumers of these services.

## 6.5 Requirement 5: Spectrum usage

A Radio Quiet Zone also concerns a localised management of the radio interference environment. Influences from remote areas will be felt inside the RQZ. Therefore current and future spectrum usage is a very relevant aspect of the environment for the SKA. The RFI measurement campaign carried out at the core locations, roughly in the middle of the RQZ's, has provided a snapshot of that environment in 2010. An assessment of future trends in spectrum usage is therefore important.

Describe the local and national plans for licensed and unlicensed use of the spectrum in terms of foreseeable introduction of new services or devices, termination of services. The introduction of digital, and phasing out of analogue, broadcasting is an example.

### *Analysys Mason's observation*

We note that the expert panel report highlights a number of possible changes to radio use in future years, including discontinuation of analogue broadcasting and migration to digital, increasing use of cellular radio and a possible decline in use of microwave radio links in favour of fibre-based systems. These broadly align with the market and technology developments we have described in Sections 3 to 5 of this report.

We note the expert panel has not referred to possible developments in short range device use that we have described in Section 3.10, which could lead to increasing use of unlicensed or licence-exempt uses of radio spectrum, giving rise to possible increases in interference in selected bands.

### 6.5.2 Australia and New Zealand SKA Coordination Committee

ACMA continually monitors future spectrum developments in Australia. ACMA has identified a number of planned changes in radio spectrum usage over the coming years. These are described in comprehensive detail in the five-year *Spectrum Outlook*, issued annually.

The following issues from the 2011–2015 *Spectrum Outlook* are particularly relevant to the protection of the RQZ:

- support for radio astronomy
- digital TV transition
- digital dividend and mobile broadband
- national broadband network
- 400MHz review.

### 6.5.3 SKA South Africa

The information provided below applies only to South Africa and mostly to the Northern Cape Province. With the very low level of economic activity in the Northern Cape, frequency spectrum use is also at a relatively low level in the most popular parts of the frequency spectrum. Use of other frequency spectrum is sporadic, and will be attended to in implementing the regulations for the Karoo Central AAAs.

Current usage and future improvements are summarised as follows:

- broadcasting: VHF-FM (87.5MHz to 108MHz) migration below 100MHz
- broadcasting: VHF-TV (174MHz to 254MHz) and UHF-TV (470MHz to 862MHz) – migration to digital TV. Investigation of an alternative solution that would result in the complete removal of all terrestrial broadcasting transmitters in the Central AAA, with broadcasting services delivered through DTH satellite solutions in progress
- GSM Mobile Cellular Communications (880MHz to 915MHz, 925MHz to 960MHz) base station modifications
- private radio communications (146MHz to 174MHz, 406MHz to 470MHz) migration to 66–88MHz
- public trunked radio communications (254MHz to 259.4MHz, 262MHz to 267.4MHz) to be phased out
- Transnet Ltd operates a single railway line running through the Karoo Central AAA. It has a commitment to support the SKA and has recently replaced and upgraded its radio communication systems, at its own cost, for EUR1 million (covered)
- the aeronautical radio communications and navigation services are provided by ATNS (a state-owned entity) and include voice communications in the frequency band 108MHz to 137MHz, secondary surveillance radar on 1030/1090MHz and distance measuring equipment (DME) on 1019/1201MHz. The intention is to impose an over-flight restriction over at least the Karoo Core AAA.

## 6.6 Requirement 6: Relevant activities

Describe the way the site proponent interacts with spectrum management bodies, such as ITU, WP7D, CRAF, IUCAF, RAFCAP, other.

### *Analysys Mason's observation*

The expert panel report acknowledges that the relevant activities of SKA coordination committees in the countries representing both candidate sites have contributed significantly to spectrum-management decisions in support of radio astronomy and in improving the prediction of interference between radio systems within their countries and at an international level via the ITU.

We note one activity area of concern being that of proposed further exploration for gas using fracking techniques, and the possibility of this giving rise to electromagnetic disturbance that

might disrupt the RQZ. This is described in Section 3.11 of our report. In that section, we conclude from our review of the expert panel report and published reports regarding gas prospecting that both sites have legal protection from interference produced by mining/industry in the form of the existing radio-quiet zones described in the site submissions. In South Africa there also seems to be flexibility for the zone to be extended if required. We note that there do not appear to be any public reports of energy companies wanting to develop fracking activities within the established radio-quiet zone area of the Australian site. For South Africa, there are reports that energy companies are interested in exploration in the Karoo area. The risk in South Africa therefore centres on whether fracking will be sanctioned in future, and if the prospecting in areas far enough away from the SKA site to avoid disruption to the radio quiet zone environment.

### 6.6.2 Australia and New Zealand SKA Coordination Committee

CSIRO, as a key stakeholder in the Australia/New Zealand SKA bid, has been active in ITU for several decades, particularly in the work of ITU-R Study Group 7 (science services), Working Party 7D (radioastronomy) and Study Group 3 (radiowave propagation):

- Dr Tasso Tzioumis of CSIRO is currently the Chairman of ITU-R WP 7D (since September 2009), responsible for leading ITU activities in spectrum management issues for radio astronomy.
- Mr Richard Jacobsen of CSIRO was the rapporteur to WRC-97 and WRC-2000 for the chapter on science services, including radio astronomy topics, and in this role was responsible for achieving consensus among numerous stakeholders on the science service material in the Conference Preparatory Meeting (CPM) report. Mr Jacobsen was also Vice-Chairman of ITU-R Study Group 7 from 2000 to 2007.
- Mrs Carol Wilson of CSIRO has been the Chairman of ITU-R Working Party 3M (propagation prediction for fixed and satellite services and interference analysis) since 2002 and Vice-Chairman of Study Group 3 since 2007. Mrs Wilson is also active in WP 7D and is the rapporteur for developing a report on RQZ.

Dr Tzioumis, Mr Jacobsen and Mrs Wilson have also been active participants in ITU-R WRCs over the past decade. They are also very active in national spectrum-management activities including the development of the Australian position to international meetings. In all these roles, Australia in general and CSIRO in particular have contributed significantly to spectrum-management decisions in support of radio astronomy and in improving the prediction of interference between radio systems.

### 6.6.3 SKA South Africa

Relevant activities are summarised as follows:

- **South African Ministry of Communications** – The Ministry includes the Office of the Minister of Communications and the Department of Communications that determines government policy in the electronic communications sector by means of legislation (Electronic Communications Act), compliance with the provisions in the legislation and policy directives in accordance with the legislation. It also provides governance to the state-owned entities in its portfolio, including the South African Post Office (SAPO), South African Broadcasting Corporation (SABC), Sentech (signal distributor), National Electronic Media Institute of South Africa (NEMISA), Universal Service and Access Agency of South Africa (USAASA), Domain Name Authority (.zaDNA) and ICASA.
- **Ministry of Science and Technology** – The Ministry governs development with respect to the MeerKAT and the SKA projects, and interacts with the Ministry of Communications on matters of common interest to ensure the harmonious development of these projects.

A committee of delegates from the Department of Communications and the Department of Science and Technology, SASPO, ICASA, SABC, Sentech and the National Association of Broadcasters in Southern Africa meet at defined intervals to discuss matters concerning broadcasting and the protection of radio astronomy.

The relationship and interaction between South Africa SKA and ICASA is facilitated by the following:

- an agreement between the Department of Science and Technology and ICASA on co-operation with regards to the South African SKA bid proposal, entered into on 2 November 2004; a copy of the agreement is attached to the response
- the ICASA Special Committee for SKA Matters, established in terms of Section 17 of the ICASA Act and in which the Department of Science and Technology and SASPO participate
- the participation in ICASA public enquiries and other forms of interaction.

The response also details relevant international spectrum management bodies:

- South African World Radiocommunication Conference (WRC-12) preparatory meetings
- ITU Working Party 7D (ITU WP7D)
- Committee for Radio Astronomy Frequencies (CRAF)
- Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Science (IUCAF)
- Inter-departmental Task Team (to look at the potential environmental and radio impact of hydraulic fracturing, commonly known as ‘fracking’).

## 7 Conclusion

This section outlines our conclusions from the study, as well as the next steps required to complete our review.

### 7.1 Summary of conclusions from our market and technology review

Our review of longer-term changes to spectrum use and technology, as described in Sections 3, 4 and 5 of this report, highlight the following developments, which are broadly applicable to both Australia and South Africa. Note that this is a snapshot of the situation at the time of producing this report in October 2011, which could change in future years as a result of further market and technology changes:

- Across the 300MHz to 10GHz frequency range, three significant changes are expected to take place in the next five to ten years:
  - a shift away from fixed, satellite and broadcasting spectrum use towards increasing amounts of spectrum being deployed for mobile broadband – as noted by ACMA in Australia, an additional 150MHz of spectrum is expected to be required for mobile broadband use in future
  - migration from analogue to digital broadcasting in VHF Band III and UHF Bands IV and V, including release of digital dividend spectrum in the UHF band (in the 700MHz and 800MHz band in Australia and South Africa, respectively), expected to be awarded by the government in both countries for mobile broadband use
  - migration of satellite systems from the 1GHz to 10GHz range towards next-generation Ka-band systems above 20GHz.
- No significant changes are expected to spectrum usage for private business radio, other than migration from analogue to digital (e.g. TETRA or similar) systems, which is already taking place.
- Mobile operators are gradually migrating 2G mobile systems in 900MHz and 1800MHz spectrum to 3G/4G. This will result in more intensive use of those bands and in a change of technology (to OFDMA-based LTE systems).
- In the longer term, DTT services that use UHF Band IV will migrate from digital video broadcasting – terrestrial (DVB-T) to DVB-T2 technology using single-frequency networks, which potentially requires a more dense network than DVB-T with multiple-frequency network transmission (MFN). This will potentially affect emission levels in UHF spectrum, since the spectrum will be used more intensively. It is also possible that further migration to digital terrestrial television (DTT) will lead to more UHF spectrum being allocated for mobile broadband, which will increase the deployment of mobile broadband solutions in the market.

- No significant changes are expected to fixed link spectrum usage – technology improvements are being made to allow more intensive use spectrum, but no significant increase in demand is expected (and some reduction is foreseen due to mobile operators migrating backhaul from wireless to fibre).
- There is likely to be some small improvement in the efficiency of wireless communications systems arising from increased use of ‘intelligent’ radios and more efficient modulation techniques – for example, future development of cognitive radio.
- Growth in use of various frequency bands used for short range devices one possible area of future change of relevance to the SKA environment, with the most widely used SRF frequency bands around the world today considered to be the 433 and 863-870 MHz, and the 2.4 GHz and 5 GHz bands. Developments of machine to machine communications, and UHF white space devices, are examples of innovation taking place within the SRD sector that is likely to result in the frequency bands used by these applications being used much more intensively in future, leading to an increase in RF noise from those bands in to neighbouring bands, and into astronomy environments.

We note that the future changes we have identified in this report are broadly in line with the changes identified by the Australia and New Zealand SKA Coordination Committee and SKA South Africa in response to the requirements for the RQZ and in the corresponding expert panel report (as described in Sections 6.5.1 and 6.5.2 of this report).

## 7.2 Summary of observations in relation to establishing and maintaining an RQZ

Based upon our review of the *Report of the Expert Panel on the RQZ and RFI regulation*, provided to us for this study, and the associated individual site submissions from the Australian and South African site proponents, we have noted the following points, which may be of relevance to the SDPO to consider alongside the expert panel report:

- We note that international imported interference from neighbouring countries may give rise to emissions in certain bands travelling across borders, especially broadcast TV where high masts combined with anomalous propagation phenomena can result in interference hundreds of miles from the transmitter. This is particularly relevant to the South African site, since South Africa shares a land border with various neighbouring countries. The nature of radio propagation is such that it is possible that transmitters installed in neighbouring countries could generate emissions that will cause interference in South Africa, for example
- We have noted that it may be prudent to seek a legal adviser, with experience of the legal system of the candidate countries, to assess the legislation referenced in responses and to confirm that the laws/regulations in force (on the statute) do indeed protect the respective RQZ and offer sufficient penalties or powers to resolve interference issues

- It appears that further sanctioning of fracking could give rise to concerns for the SKA environment at either site. However, there do not appear to be reports of mining interests wanting to develop within the established radio quiet zone at the Australian site to date. In relation to South Africa, there have been reports that energy firms<sup>43</sup> are interested in prospecting for gas in the Karoo region. Any risk to the RQZ would depend on whether these prospects will be sanctioned, and also whether the fracking activity is far enough away from the SKA site to avoid potential disruption to the RQZ. However, reports suggest that areas being explored are quite extensive, may only overlap with the existing radio-quiet zone to a limited extent.

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<sup>43</sup><http://af.reuters.com/article/investingNews/idAFJOE72G0EZ20110317>

# Annex A Band-by-band review of current spectrum use in 70MHz to 10GHz

A brief overview of spectrum allocations within the 70MHz to 10GHz range of interest to the SKA is provided below.

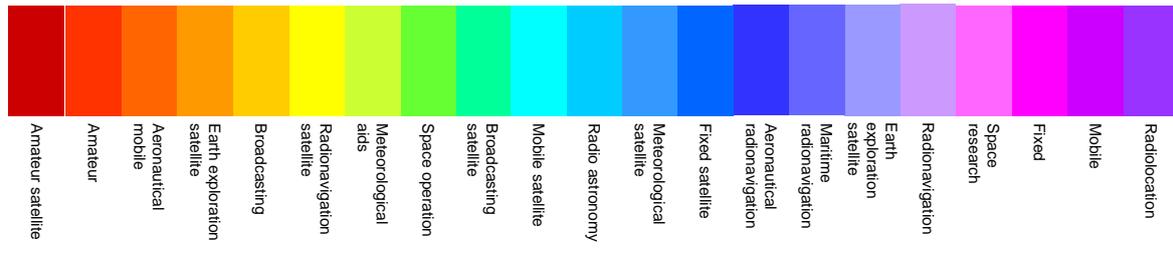


Figure A.1: Key for spectrum allocation diagrams [Source: Analysys Mason]

## A.1 68-108MHz

This band is predominantly allocated to broadcasting in ITU Regions 1 and 3. Usage includes land mobile radio (PBR), amateur radio and PMSE. The frequency band 55.75MHz to 68MHz is assigned for the so-called ‘Band 1’, which was previously used for analogue TV in many countries around the world.

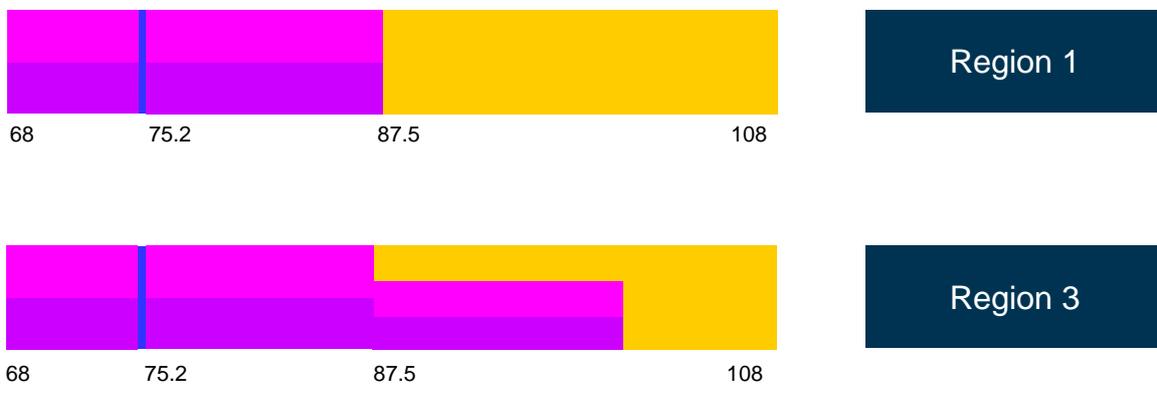


Figure A.2: VHF Band I [Source: Analysys Mason]

### A.2 108–146MHz

Spectrum in this range is allocated to aeronautical mobile and aeronautical radionavigation, as well as to various other services.

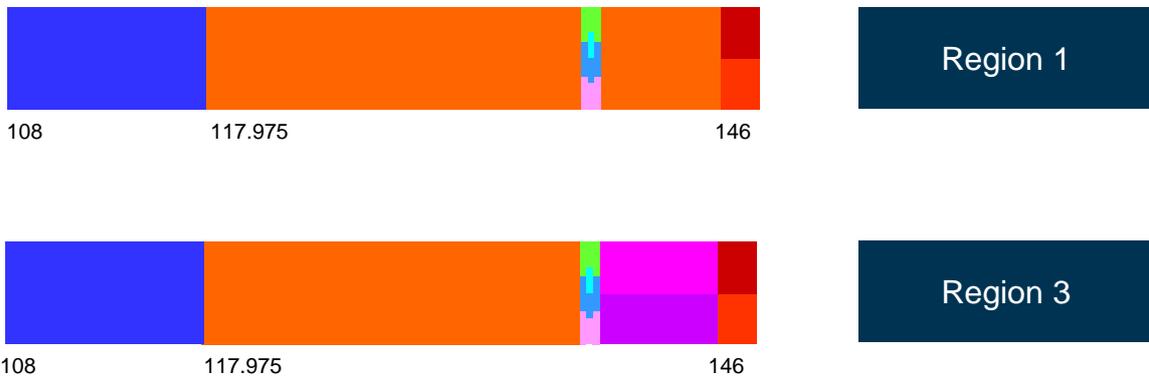


Figure A.3: 108–146MHz [Source: Analysys Mason]

### A.3 146–322MHz

This range includes spectrum allocated to broadcasting (VHF Band III) for digital radio and digital TV, as well as spectrum allocated to fixed and mobile services.

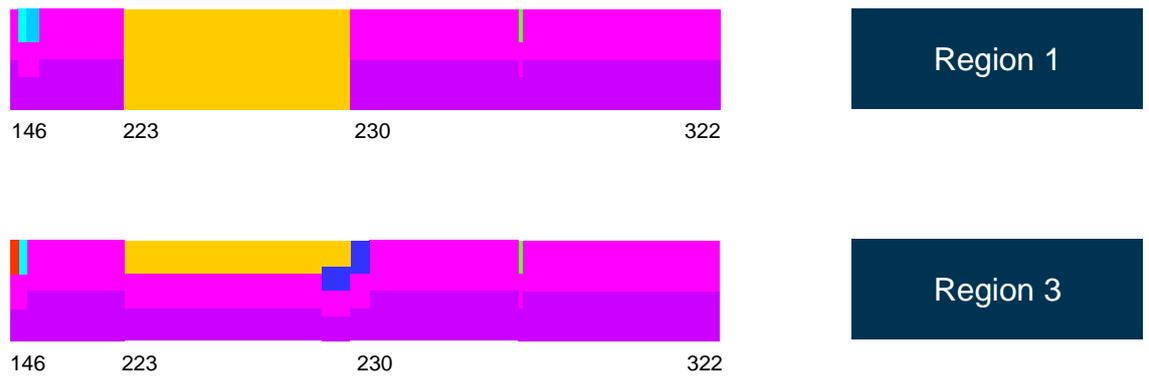


Figure A.4: 146–322MHz [Source: Analysys Mason]

### A.4 322–420MHz

Most of the spectrum in this range is allocated to fixed and mobile services, as well as radio-navigation (i.e. defence use).

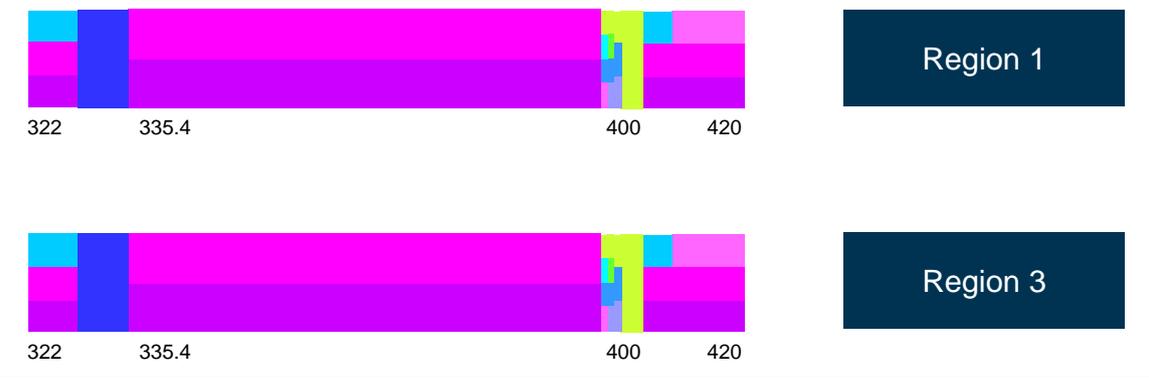


Figure A.5: 322–420MHz [Source: Analysys Mason]

### A.5 420–470MHz

Most of the spectrum from 420MHz to 470MHz is used by land mobile radio (PBR and paging), PMSE, emergency services and defence.



Figure A.6: 420–470MHz [Source: Analysys Mason]

### A.6 470–870MHz

This is the main band used for DTT broadcasting (UHF Bands IV and V), including spectrum that has been released as digital dividend, now being assigned for mobile broadband use.

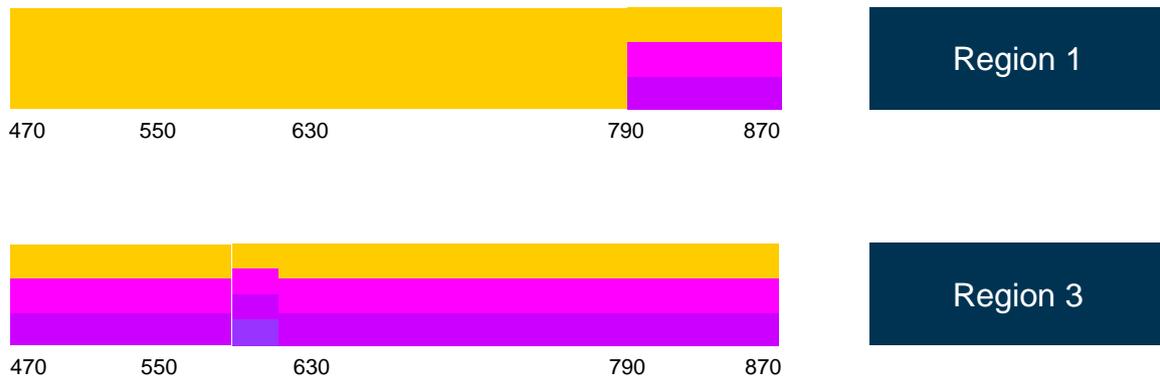


Figure A.7: 470–870MHz [Source: Analysys Mason]

### A.7 870–1492MHz

The spectrum from 870MHz to 1.5GHz is used extensively for defence use and for a range of commercial wireless systems, including GSM, GSM-R and fixed links. The 1.5GHz band (1452–1492MHz) is used for either fixed links or digital radio.

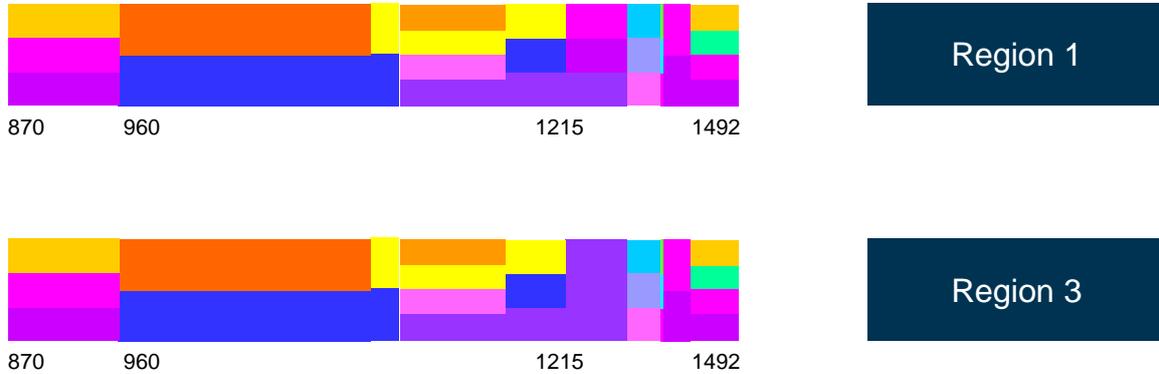


Figure A.8: 870-1492MHz [Source: Analysys Mason]

### A.8 1492–1980MHz

The spectrum between 1.5GHz and 2GHz is also extensively used for commercial wireless systems including GSM, mobile satellite, fixed links and cordless telephones (DECT). PMSE has access to some spectrum within this range.

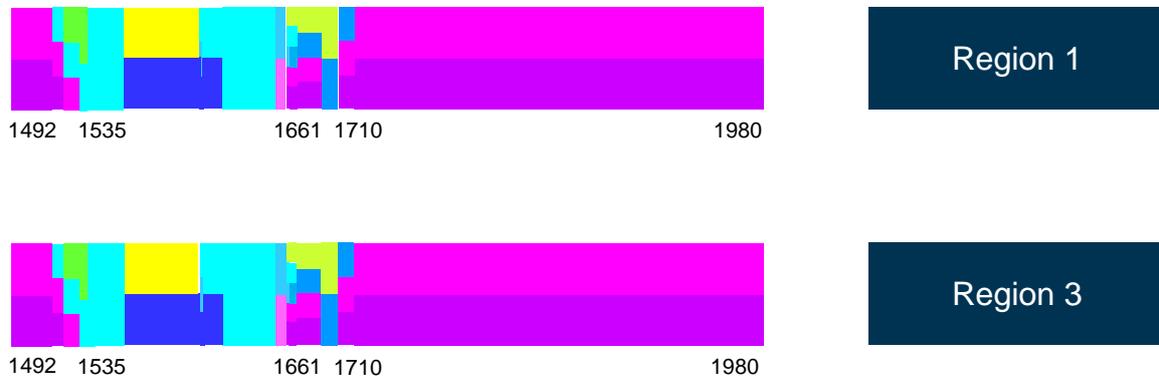


Figure A.9: 1492–1980MHz [Source: Analysys Mason]

### A.9 1980–2500MHz

Spectrum in the 2GHz range forms the main IMT/3G frequency allocations used by 3G mobile operators in Australia and South Africa. PMSE and mobile satellites also use some spectrum in this range and some spectrum is held by the government (e.g. for defence).

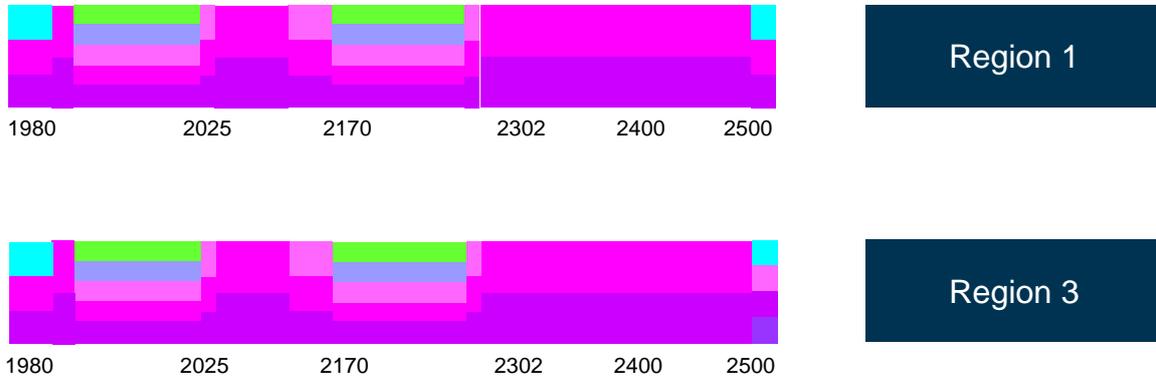


Figure A.10: 1980–2500MHz [Source: Analysys Mason]

### A.10 2500–5470MHz

Spectrum between 2GHz and 5GHz accommodates a mix of commercial and government uses. The 2500–2690MHz band was formerly used for PMSE (wireless cameras and video links); however this spectrum has been identified for award for mobile broadband in both Australia and South Africa in line with international trends. This frequency range also accommodates S-band radar including maritime and aeronautical radar as well as defence use. Parts of the 3GHz to 4GHz band are shared between defence systems, satellite, fixed links, amateurs and fixed wireless for commercial wireless services.

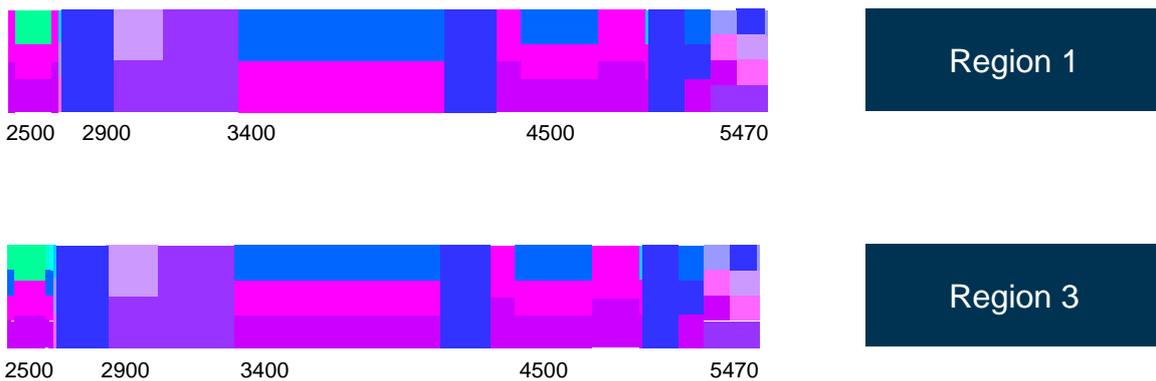


Figure A.11: 2500–5470MHz [Source: Analysys Mason]

### A.11 5470–10450MHz

Spectrum between 5GHz and 6GHz is allocated to the mobile service and used for wireless LAN (based on the IEEE 802.11a standard and WiMAX). Above this, spectrum is used for fixed links, PMSE and government use (e.g. defence).

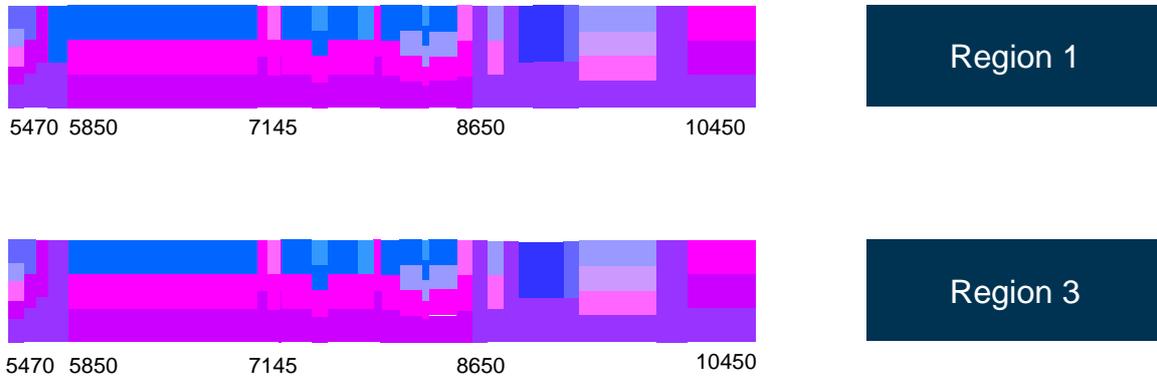


Figure A.12: 5470–10450MHz [Source: Analysys Mason]

## Annex B Abbreviations used in this report

<b>AAA</b>	Astronomy Advantage Areas
<b>ACMA</b>	Australian Communications and Media Authority
<b>ASO</b>	Analogue switch-off
<b>C-Band</b>	A band of frequencies used for satellite systems around 4-6GHz
<b>COFDM</b>	Coded orthogonal frequency division multiplexing
<b>CSIRO</b>	Commonwealth Scientific and Industrial Research Organisation
<b>CRAF</b>	Committee for Radio Astronomy Frequencies
<b>DAB</b>	Digital audio broadcasting
<b>dB</b>	Decibel
<b>dBm</b>	Decibels referenced to 1 milli-Watt
<b>DMB</b>	Digital multimedia broadcasting
<b>DSO</b>	Digital switch-over
<b>DTT</b>	Digital terrestrial TV
<b>DVB-H</b>	Digital video broadcasting - handheld
<b>DVB-SH</b>	Digital video broadcasting – satellite handheld
<b>DVB-T</b>	Digital video broadcasting – terrestrial
<b>DVB-T2</b>	The second generation of the DVB-T standard
<b>EMC</b>	Electromagnetic compatibility
<b>EMI</b>	Electromagnetic interference
<b>EPIRB</b>	Emergency position indicating radio beacons
<b>FCC</b>	Federal Communications Commission
<b>FDD</b>	Frequency Division Duplex
<b>GE-06</b>	Geneva-06 – the digital broadcasting plan of the ITU-R
<b>GHz</b>	Giga Hertz
<b>GPRS</b>	GSM Packet Radio Service
<b>GSM</b>	Global System for Mobiles – the second generation (2G) of cellular mobile telephony
<b>GSM-R</b>	GSM Railways (an adapted version of the GSM standard, used in rail networks for track to train communication)
<b>HD</b>	High definition
<b>ICASA</b>	The regulator for the South African telecommunications sector
<b>IMT</b>	International Mobile Telecommunications
<b>IP-TV</b>	Internet Protocol Television
<b>ITU-R</b>	The Radiocommunications Bureau of the International Telecommunications Union
<b>Ka-Band</b>	A band of frequencies used for satellite systems from 26-40GHz
<b>KCAAA</b>	Karoo Central Astronomy Advantage areas

<b>Ku-Band</b>	A band of frequencies used for satellite systems from 10-12GHz
<b>LTE</b>	Long Term Evolution
<b>MFN</b>	Multiple frequency network transmission
<b>MHz</b>	Mega Hertz
<b>MPEG2/MPEG4</b>	Compression standards
<b>MRO</b>	Murchison Radio-astronomy Observatory
<b>MUX</b>	Multiplex
<b>PBR</b>	Private Business Radio
<b>PMR</b>	Private Mobile Radio
<b>PMSE</b>	Programme Making and Special Events
<b>PSB</b>	Public Service Broadcaster
<b>QAM</b>	Quadrature Amplitude Modulation
<b>QPSK</b>	Quadrature phase shift keying
<b>RF</b>	Radio frequency
<b>RFI</b>	Radio frequency interference (also Request for Information)
<b>RQZ</b>	Radio quiet zone
<b>SAPO</b>	South African Post Office
<b>S-Band</b>	A band of frequencies used by satellite systems around 2GHz
<b>SD</b>	Standard definition
<b>SFN</b>	Single frequency network transmission
<b>SMG</b>	Satellite News Gathering
<b>SSG</b>	SKA Siting Group
<b>SKA</b>	Square Kilometre Array
<b>SPDA</b>	SKA Program Development Office
<b>TDD</b>	Time Division Duplex
<b>TETRA</b>	Trans-European Trunked Radio
<b>TPC</b>	Transmit Power Control
<b>VHF</b>	Very high frequency
<b>UHF</b>	Ultra high frequency
<b>UMTS</b>	Universal Mobile Telecommunications System
<b>WiMAX</b>	Wireless Interoperability for Microwave radio
<b>3G</b>	Third generation telecommunications
<b>3GPP</b>	Third Generation Partnership Project – a standards committee responsible for developing 3G and 4G mobile standards
<b>4G</b>	Fourth generation telecommunications