# CASE NOTES: CONSIDERING POSSIBLE REGULATORY APPROACHES TO TELEVISION WHITE SPACES (TVWS): A VIEW FROM SOUTH AFRICA

**William Stucke**[1]
*Electronic Communications Sector Specialist, Johannesburg, South Africa*

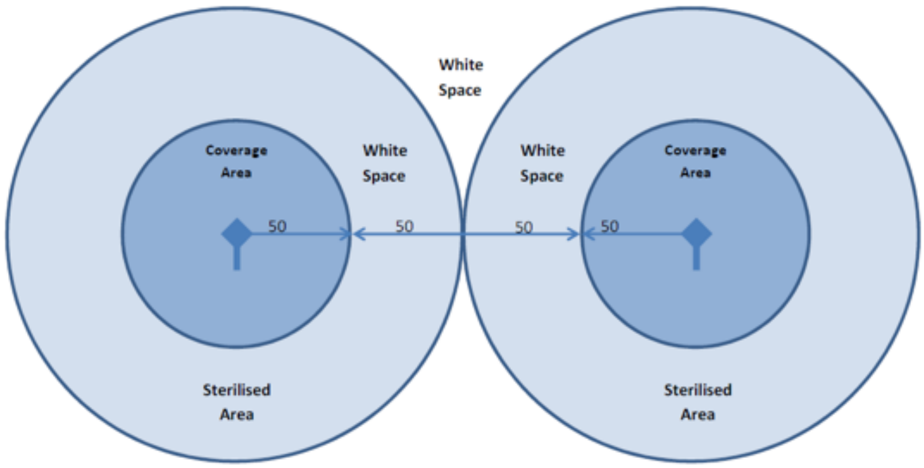
ABSTRACT
South Africa is one of the countries in the SADC region carrying out research and tests of television white space (TVWS) technology. TVWS technology, and dynamic spectrum management generally, have the potential to increase significantly the usage of valuable spectrum, that is considered to be scarce, and hence reduce the perceived scarcity. In so doing, TVWS technology has the potential to facilitate greater coverage and penetration of broadband in South Africa. However, this requires a paradigm shift from the traditional manually approved spectrum licensing process, usually on an exclusive basis, to an automated, dynamic process, where spectrum is shared between many users, some of whom will be assigned a higher priority than others. This can be achieved using a geo-location database, which implements complex radio propagation modelling and assigns permissions to use spectrum according to rules specified by the regulator. This, however, requires a new regulatory approach to spectrum assignment. A multi-level use approach is proposed ranging from protected exclusive, through protected secondary. to unprotected licence-exempt. None of these uses may cause interference to a higher level.

## INTRODUCTION

Regulators around the world, including those in the SADC region and on the African continent, are working to develop technical, economic and regulatory models for the use of television white spaces (TVWS). ICASA, the South African national regulator, is a member of the regional regulatory association, the Communications Regulatory Authority of Southern Africa (CRASA), and is leading this work in the region in partnership with the CSIR[2] Meraka Institute.

TV white spaces are those TV channels that are unused in a particular spectrum band licensed for broadcasting or other purposes at a particular place. Careful calculation (Korowajczuk, 2011, Ch. 6). indicates which channels could be used for secondary broadband purposes. This is typically achieved with a geo-location white space database (GL-WSDB), which carries out calculations based on the known radio characteristics (transmitter power, antenna gain, type, orientation and height) of licensed (primary) spectrum users. Given the radio characteristics of the desired white space devices (WSDs), it is possible to authorise these devices to operate in specific channels, at specific locations, at specific times, with allowed transmitter power. This is enabled partly by the disparity between typical TV broadcast transmitters, which have antennae on very high towers transmitting tens of kilowatts, compared to a typical WSD, which produces a few watts into a relatively low antenna. The WSD is therefore unlikely to produce a powerful enough signal to cause detectable interference to consumers watching television nearby, even on the same or an adjacent channel. Furthermore, any particular frequency channel used for television broadcasting requires a large geographical separation before that frequency can be re-used, leaving large areas of "white space". See Figure 1, below, which depicts typical co-channel television transmitters, their coverage areas and the white space resulting. Typical distances shown are in kilometres.

FIGURE 1: TYPICAL BROADCAST TRANSMITTER COVERAGE AND STERILISATION AREAS




Source: William Stucke, 2013

In addition, in the case of analogue television transmissions, only every fourth channel is used at a single transmission site, in order to avoid adjacent channel interference, as all transmitters typically feed into a single

1 Stucke was a Councillor at the Independent Communications Authority of South Africa (ICASA), the national regulator for the broadcasting, telecommunications and postal sectors, until end 2014. The views expressed here are his own. william@stucke.co.za.

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antenna system, so adjacent channels are similarly available. After the transition to digital terrestrial television (DTT), this will remain true in South Africa, although the requirement is no longer absolute.

The UHF and VHF television bands are currently used primarily by broadcasters, with several secondary uses possible, including studio-transmitter links (STLs) and conventional broadband in the 850MHz band. The TV white spaces concept opens up the possibility of increasing the utilisation of unused spectrum for broadband purposes, at no cost to the incumbents, either primary or secondary. This approach would expand the value of existing broadband infrastructure to provide additional connectivity within urban areas and to provide cheaper connectivity to underserved communities in rural areas. The lower (VHF and UHF) frequencies used by broadcasters have a longer propagation range than the existing IMT[3] frequencies, so that base stations may be further apart, thus reducing the cost of providing broadband services in sparsely populated rural areas. In addition, these frequencies have better penetration through walls, hence they are also valuable in dense urban areas for deep building penetration by operators, as well as being more useful for private, licence-exempt home use, supplementing existing home WiFi routers (sometimes called "Super WiFi"). Overall, the use of white space UHF frequencies has the potential to increase both the ubiquity and coverage of broadband services.

The research problem being investigated here is which of several possible regulatory regimes best suits the needs of the regulator, operators and consumers in South Africa. South Africa is a country characterised by good connectivity in urban areas, but relatively low coverage in large, poor, under-populated areas. These underserved areas are especially challenging, as the combination of a small population with low income over large distances means that the return on investment in such areas is particularly low. The VHF and UHF frequencies used by TVWS devices have good propagation characteristics over longer distances, and hence may be exploited to provide broadband coverage at a lower cost, provided that the chosen regulatory model is sufficiently flexible, and does not unduly increase costs. Further, the concepts of dynamic spectrum assignment may be extended to other IMT bands, and thereby reduce spectrum scarcity and achieve the objectives mentioned above. The emerging convention of making TVWS devices licence-exempt may not wholly satisfy the South African requirement of being able to provide commercial services with acceptable reliability and quality of service (QoS) in rural areas.

## SOUTH AFRICAN TVWS TRIALS

The first South African trial of TVWS technology[4] was concluded in Cape Town on 25 September 2013. It demonstrated, inter alia, that it was possible to achieve successful communication within a network of TV white-space devices without causing any interference to the incumbent broadcasters and their viewers. Three base stations on the roof of Tygerberg Hospital connected 10 schools via symmetrical UHF radio connections that allowed teachers and pupils high-speed access to the Internet. Google was the project sponsor, and built and operated the geo-location database. TENET[5] supplied the backhaul connectivity and was the project manager, with the CSIR[6] as the trial licence holder in terms of their MoU with ICASA to develop technology in this and other areas. E-Schools Network[7],WAPA[8] and Comsol Wireless Solutions[9] were also partners in the project, together with the 10 schools involved. Due to the uncertainty around the trial, schools that had existing ADSL Internet connections and computer labs were chosen. The equipment used was from Carlson Wireless[10] (US) with software from Nuel[11] (UK). The high-speed connectivity achieved facilitated research, website updating, email distribution and the use of online lessons for teaching purposes. This TVWS trial achieved several milestones not yet reached elsewhere in the world, including adjacent channel usage without interference, effectively tested against both analogue and digital transmissions, and provided the tightest spectrum mask achieved thus far.

The primary purposes of the trial were to demonstrate that:

1. TVWS can deliver improved broadband access to the Internet without interfering with licensed spectrum holders
2. Regulatory support for TVWS technology and its use for the delivery of broadband must be obtained.

It was successful in both of these aims. Additional trials in Limpopo and elsewhere are planned. These trials will address a number of issues, including broadening the current scope of knowledge in this field and refining our understanding of possible TVWS regulatory regimes. It is notable that the FCC is considering reducing the required channel separation between occupied TV channels and WSDs, and quotes the Cape Town trial as justification (FCC 14-144).

The South African regulator, ICASA, has recently licensed the CSIR to conduct a second TVWS trial, which will set up base stations at Limpopo University. The intention is to connect five rural schools using TVWS devices at a range of up to 10km. This trial will use different equipment from a different manufacturer (6Harmonics Inc., Canada), with Microsoft as the project sponsor. The CSIR will build and operate the dynamic spectrum management (DSM) geo-location database (GL-WSDB), working in collaboration with the same other parties, TENET, WAPA and e-Schools Network.

3 International Mobile Telecommunications, which for our purposes may be translated as "mobile broadband".
4 http://www.tenet.ac.za/tvws
5 The Tertiary Education NETwork: http://www.tenet.ac.za
6 Council for Scientific and Industrial Research. A division known as the Meraka Institute is primarily involved.
7 http://www.esn.org.za/
8 Wireless Access providers Association: http://wwwwapa.org.za
9 http://www.comsol.co.za/
10 http://www.carlsonwireless.com
11 http://www.neul.com/neul/.

The University of Limpopo is the host. This trial plans to test the capability of the technology in a challenging rural area, which is both hilly and wooded. In addition, it will carry out specific tests in relation to digital terrestrial television (DTT) signals. The initial equipment supplied by 6Harmonics was rejected by JSAG[12] as having excessive third and fifth harmonic outputs, as well as an unsatisfactory spectral mask. These issues were resolved before the trial commenced, but meant that adjacent channels could not be used throughout the frequency range.

Unlike the Cape Town schools, which had both existing connections and equipped computer facilities, the Limpopo schools have neither. Microsoft has supplied tablets and other equipment to all the schools.

The engineering issues that are intended to be addressed by these trials include a demonstration that successful communication between a network of WSDs can be achieved, at an acceptable data rate, without causing any detectable interference to television viewers, and that the radio frequency propagation modelling carried out by the database accurately depicts the situation in practice. In addition, the GL-WSDB implemented for this trial has the potential to record the characteristics of the WSDs, and prevent interference between them. (Mfupe, Mekuria & Mzyece, 2014) During the first trial, the modulation used was improved up to 16QAM. The current state of the art is 64QAM. The second trial addresses issues of non-line-of-sight propagation (TENET, 2013).

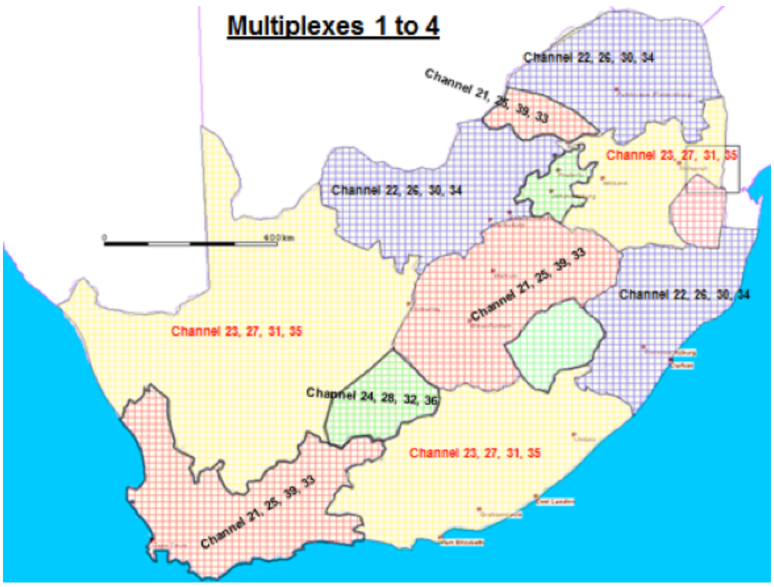
The primary regulatory issue that arises is the feasibility of changing the paradigm of spectrum licensing from the conventional "static, exclusive" regime to one of dynamic spectrum management (DSM).

## AVAILABLE SPECTRUM FOR TVWS

Let us consider two scenarios: the dual-illumination period (from April 2015[13]) and the digital period after the restacking process. The restacking process consists of moving all remaining digital UHF broadcast channels, after the analogue signals are switched off, from their current frequencies spread in the range 470MHz to 896MHz as per the GE06[14] based national radio frequency plan, down to the range 470MHz to 694MHz. Ideally, this needs to be achieved without causing an interruption of service to television viewers. Currently, 392MHz of UHF spectrum is reserved for analogue TV transmission. Of this, up to 93% is unused at any one place, largely due to onerous interference issues. Most of this is available for TVWS use.

After the digital migration, some 168MHz will be freed for "IMT" use for broadband communications services. Of this, a total of 2x63MHz is currently planned for frequency division multiplexing (FDD) broadband use giving a total of 126MHz (ICASA, 2014). The balance effectively constitutes guardbands, and much of this may be used for time division multiplexing (TDD) or white-space uses. The balance of the UHF TV band, consisting of some 224MHz, is reserved for broadcasting use. Of the 224MHz, up to 75% will be available at any one place for TVWS use, because of South Africa's intention, already coordinated via the ITU with all neighbouring countries, to implement 11 large single frequency networks (SFNs), up to several hundred kilometres across. Figure 2 below shows the channels planned to be used for the first four out of seven SFNs.

FIGURE 2: PLANNED LARGE REGIONAL SFNS AFTER FULL IMPLEMENTATION OF DTT




Acknowledgement for map to Koenie Schutte and Richard Makgotlo

12 CASA's Joint Spectrum Advisory Group, chaired by the author.

13 No official start of Dual illumination has been specified by either the Ministry of Communications or the Ministry of Telecommunications and Postal Services. Neither has any duration of dual illumination been declared. Note that the analogue switch off (ASO) date agreed by South Africa via the ITU remains 17 June 2015. This date is unlikely to be met.

14 ITU Regional Radiocommunications Conference held in Geneva in 2006 (RRC-06) adopted the GE06 Agreement for Region 1 (Europe and Africa).

## POSSIBLE REGULATORY REGIMES

A number of potential regulatory regimes exists for TV white spaces – and indeed dynamic spectrum management in other bands. In order to address this, it is necessary to understand key concepts involved in this area of spectrum licensing. In both the US (FCC 12-36, 2012) and the UK (Ofcom, 2013), a single, simple model has been used – Licence Exempt (ECC Report 132, 2009). The licence-exempt model has led to extraordinary innovation and growth in WiFi and has many benefits, such as delivering universal and affordable broadband access (Thanki, 2012). One of the reasons for its success is the widespread adoption of common, if rapidly evolving, standards. This results in WiFi equipment being manufactured in vast volumes, which brings the unit cost down. However, it does not lend itself well to commercial services with a defined quality of service (QoS), since the licence-exempt regime provides neither performance guarantees nor protection (ICT Regulators Toolkit, 5.1.3.1; Hayes & Lemstra, 2009). The potential therefore exists for a combination of models, including licence-exempt and managed spectrum.

In the case of pre-defined use, such as walkie-talkies and ski boat radios, no attempt is made by the regulator to coordinate usage (ICASA, 2012, p.70). No protection is provided to licensed users, other than from unlicensed ones. You talk when the channel is quiet. In the case of licence-exempt spectrum (such as the 2.4 GHz ISM band), the regulator provides no protection whatsoever. This is referred to in band plans as "no interference, no protection (NINP)". Users are obliged to adhere to certain standards, and their equipment is type approved to facilitate this (ibid: 69). Despite the anarchic nature of licence-exempt spectrum, the system works remarkably well. Originally, the 2.4GHz band was considered unusable – junk spectrum – because it matches the oxygen-hydrogen bond band gap in the free liquid water molecule, and is thus used by microwave ovens. However, the fact that no licence is required was an enormous spur to innovation (Hayes & Lemstra, 2009). Today, well over a billion WiFi devices are manufactured every year (ABIresearch, 2012).

The concept of "protection from interference" is an important one when considering spectrum licensing (TENET, 2013; Pahl, 2007). Briefly, it means that the licensee has recourse to the regulator for assistance when interference is experienced from the services offered by another party. The regulator has the skills and equipment to detect and identify the sources of interference, and in most cases, to deal with the problem rapidly by sealing, seizing or otherwise removing the source of interference. A primary user has protection from the regulator against all other users of the licensed spectrum. A secondary user has protection against all other users except the primary user. Indeed, it is the responsibility of the secondary user to ensure that his service causes no interference to the primary user. When spectrum is shared, then the users are obliged to coordinate and ensure that they cause no interference to each other (TENET, 2013; Pahl 2007). Dynamic spectrum management (DSM) is the emerging regulatory model that arises out of TVWS research (Mfupe, Mekuria & Mzyece, 2014), addressed further below.

## SELECTING AMONGST REGULATORY MODELS

The countries that are most advanced in regulating TVWS are the cUS and the UK (FCC 12-36, 2012; Ofcom, 2013). In both cases, they have focused on one model in their proposed rules, namely licence exempt. The license-exempt regime is epitomised by WiFi, where devices are required to conform to certain type approval specifications, but may otherwise be freely used in the RSA and other countries (Carter, Lahjouji & McNeil, 2003). This has proven to be a powerful spur to innovation, with some 1.5 billion WiFi devices shipped in 2012 (ABIresearch, 2012). Indeed, in many developed countries, almost 50% of mobile data is offloaded to WiFi networks, whether in the home, office or the local pub (Thanki, 2012; Cisco Networking Index 2013; Nitin, B., 2013).

The economic value of licence-exempt usage is considerable, with the potential of WiFi networks in South Africa estimated at USD143 million or approximately ZAR1,6 billion (Thanki, 2012). Furthermore, the rate of use of WiFi devices continues to increase (Cisco, 2014). However, a cursory calculation of the benefit derived from licensed usage of high demand spectrum also gives a value of well over ZAR1 billion, from published revenue figures of Vodacom and MTN alone. This leads the researcher to suppose that the licensed regime – as compared to the licence-exempt or "unlicensed" regime – bears closer examination.

Moreover, the licence-exempt regime is not without its problems. Chief of these is the limited spectrum available and more particularly, the inability of operators making use of WiFi and its associated standards (such as IEEE802.11a/b/g/n) to provide a quality of service (QoS) guarantee (Williamson, Punton & Hansell, 2013). While "best effort" is often good enough, there are circumstances where an operator needs to be able to offer a specified level of service. In this case, the TVWS paradigm may need to shift from a simple licence-exempt regime to a managed-access regime. On what basis should that access be managed? Should it be on a similar basis to the current licence-exempt regime, where no protection is provided to users, or a protected basis or some combination of the above?

### *LICENCE-EXEMPT REGIME*

In the licence-exempt regime (Pahl, 2007; Ofcom, 2013) for WSDs, all devices are registered in the geo-location database. They are lowest priority. They are assigned spectrum such that they cause no interference to other higher priority users, in the highest numbered available channels (up to one third of the channels available at that time and place). Once a device has been assigned licence-exempt usage of a channel, that channel is marked for licence-exempt use only. No protection is provided to the device from any other devices, whether coordinated or not. The device is obliged to renew its spectrum lease at regular intervals. If renewal is refused, transmission on that channel must cease immediately, but an alternative channel may be requested.

### *COORDINATED USAGE REGIME*

In the coordinated usage, or managed access regime (TENET, 2013; Pahl, 2007) for WSDs, all devices are again registered in the geo-location database. They are assigned spectrum such that they cause no interference to other higher priority (incumbent) users, in the lowest numbered available channels (up to two thirds of the channels available at that time and place). Once a device has been assigned coordinated usage of a channel, that channel is marked for coordinated usage only. Coordination is carried out with all other devices, in order to ensure that no interference is experienced by any registered device, including licence-exempt WSDs. The device is obliged to renew its spectrum lease at regular intervals. If renewal is refused, transmission on that channel must cease immediately, but an alternative channel may be requested.

### *DYNAMIC SPECTRUM MANAGEMENT*

Traditionally, national regulatory authorities (NRAs) have assigned spectrum in terms of what may be called "1960s technology". The assumption is that assignment of spectrum to a single entity "sterilises" that area for all similar uses (See Figure 1). In practice, tests show that broadband spectrum typically has a utilisation averaging 14% in dense urban areas, and rather less in rural areas (Pahl, 2007; Google and OTI, 2008; internal ICASA surveys 2012-2014). While broadcast spectrum may have a higher utilisation in terms of high-power broadcast transmitters on tall towers, there is considerable potential for low-power usage within a limited range. In either case, a new regime, dynamic spectrum management, has an important role to play. Dynamic spectrum management (DSM) entails carrying out calculations, as often as on a real-time basis, to determine if a candidate use can be accommodated without causing interference to other users (Mfupe, Mekuria & Mzyece, 2014).

In order to have effective DSM, full GPS position data is required, as well as an efficient and detailed radio propagation model (Korowajczuk, 2011). This is to ensure that an accurate radio frequency propagation pattern may be developed for each WSD, in order to calculate whether the WSDs will interfere with each other, or with television viewers. South Africa uses several radio propagation algorithms, with GIS and clutter data, also called a geo-location database (Mfupe et al, 2014). The position and characteristics of every licensed user of the spectrum in question must be accurately recorded in the database, and every white space device authorised to operate – whether licensed or licence-exempt – must similarly be recorded. When the situation changes, such as a primary user enabling a new transmitter, all calculations are rerun, and if necessary, TVWS devices are automatically instructed to shut down. They may request an alternative assignment, if this is available. Hence the TVWS devices need to incorporate significant intelligence as well as a software configurable radio (Lehr, 2014; Wu, 2014; Wyglinski et al., 2010).

## REGULATORY APPROACHES TO TVWS LICENSING FOR SOUTH AFRICA

An earlier concept paper on a possible regulatory approach to TVWS presented at the CSIR Workshop on Smart Radio Technology (Stucke, 2013) addressed the following issues from a South African perspective. The paper proposed a regulatory approach that would include a registration-based process with multiple stages. Spectrum is assigned on a protected basis as is the case with licensed spectrum, unlike WiFi. This is secondary to the primary use, namely broadcasting. There should be a limited time duration for a "lease" of spectrum, followed by a renewal process. GPS position identification is essential. The system should be simple to use and fast enough for "dynamic" assignment.

An outline of the process that was suggested is as follows:

1. A pre-registration process takes place, in which the characteristics of the devices are specified
2. The TVWS device is installed at a location
3. Candidate channels are found for the target location via a geo-location database
4. The TVWS device scans the spectrum and verifies that no signal transmitted by others is received on the candidate channel. The spectrum scan is provided to the database. The scan may be repeated at intervals, allowing the regulator to build up a comprehensive spectrum survey
5. The TVWS device is registered in the geo-location database, in order to avoid later TVWS devices causing interference with it
6. The TVWS device is automatically authorised to use the candidate channel, via the geo-location database, in terms of the rules specified by the Regulator
7. This master device then authorises other slave devices in its network to operate using the candidate channel.

Subsequently, the author has been persuaded that a combination of licence-exempt and managed access may be more appropriate. This is primarily because of recognition of the immense power of the licence-exempt regime, as noted above.

A standard for accessing such geo-location white spaces databases is in the process of being developed: Protocol for Accessing White Space (PAWS) (IETF 2012, 2013 & 2014). It should be noted that this standard does not specify the operation of the GL-WSDB, but merely the method of interacting with it by WSDs and others.

Generally, the "rules of operation" of the GL-WSDB are specified by the relevant regulator for the country concerned. WSDs from various manufacturers in various countries can be used in other countries, provided some minimum compatibility is maintained. The issues that need to be considered in this regard include: the frequency band used;

the channel width; the maximum allowed transmitted power, and whether the power output is controllable; the accuracy of the GPS location data provided by the device; and whether scanning of the frequency environment is required and should this be uploaded back to the GL-WSDB, at what intervals.

Emerging standards for WSDs include IEEE 802.22 and IEEE 802.11af, but these will not be discussed here.

## DESIGNING TVWS SPECTRUM LICENCE FEES

ICASA implemented an Administered Incentive Price (AIP) spectrum fee system in 2011 (ICASA, 2011). This has had a significant effect, reducing the cost of spectrum for most licensees, but considerably increasing it for "previously advantaged licensees" – those licensees who existed before January 2009 and had access to PtMP spectrum, prior to the Altech decision (Thornton, 2008) – who were the beneficiaries of spectrum for some of which they previously did not pay. The scheme has had the effect that those licensees with excessive assignments of spectrum have carefully considered which spectrum to return, thereby enabling other licensees to make more efficient use of the spectrum.

Calculation of the spectrum fee is based on a seven-part formula to calculate the fee due for either point-to-point (PtP) or point-to-multi-point (PtMP) uses. The formula assumes that spectrum will be used on a full-time basis, and provides a 50% discount for spectrum sharing. A spreadsheet (ICASA, 2012) is available to carry out these calculations. A possible approach to administered pricing for TVWS would be a further 50% discount (75% in total) for coordinated TVWS usage. This is in exchange for the undertaking to vacate spectrum when it is required by other licensed users, on a real-time basis.

What of the scenario where a licensee only uses spectrum for a month, or a day, or an hour? The AIP principle is capable of extension to this case, thereby facilitating a situation where a licensee will only pay for the TVWS spectrum assigned to it, for the period for which it is assigned. Thus charges would be based on time used as a proportion of the annual fee. This implies a charge of about ZAR39 per hour per MHz for national usage. Of course, the nature of TVWS is that use will be over relatively small areas at a time. Furthermore, since the geo-location database carries out careful calculations of the coverage area of the WSD network, it is easily possible to calculate all seven parameters of the AIP formula, as well as the time used, to determine the spectrum fee that ought to be due from each registered licensee for each usage.

## VALUE CONSIDERATIONS

There are a number of ways of measuring spectrum value, such as its economic, social and empowerment value. Each of these can, in turn, be considered as having several dimensions. For example, the economic value of TVWS spectrum will be considered very differently in the hands of a consumer, an operator, or the state. In addition, GDP multiplier effects can play a role.

The social value of TVWS spectrum may be considered in terms of the opportunities that it provides to content creators and consumers, and in terms of the ability to communicate with friends, family and business acquaintances. The social value of the communication that may be afforded by the use of spectrum includes building social cohesion, for example such that speakers of a particular language have an opportunity to use their language and grow its written record. From an empowerment point of view, the communications that make use of additional spectrum might bring opportunities to take advantage of e-government services, including online health advice and e-education.

### *ECONOMIC VALUE*

Considering only the economic value of TVWS, it will have vastly differing values to the various role players. Consumers value TVWS technologies and spectrum in terms of the increased communication abilities it brings them. The UHF (and even more so, the VHF) TV bands have good characteristics in terms of longer range than higher frequencies, and hence are likely to facilitate the provision of broadband in rural areas at lower cost (GSMA:5, 2014), many of which might currently be underserved. This will allow an increasing proportion of the population to become part of the digital economy.

Operators value TVWS spectrum as an opportunity to expand their service provision on a profitable basis. Together with their investment in equipment and networks, it provides an economic return. The state benefits from spectrum fees, where these are applicable, from taxes resulting from the increased economic activity that TVWS will facilitate, and from the GDP multiplier effect. The GDP multiplier effect operates in two ways. Firstly, work by the World Bank indicates that in a middle-income developing country, such as the South African economy, a 10% increase in broadband penetration brings a 1.38% increase in GDP (Kim, Kelly & Raja, 2010). Secondly, where spectrum is auctioned (unlikely in the case of TVWS), the effect on the GDP is some eight times the auction fees (USTTI, 2011).
Although the licence-exempt use of the 2.4GHz and other bands is carried out without any spectrum fees due to ICASA, this does not mean that it has no economic value. One estimate places the current economic value of WiFi usage in RSA at some USD143 million (Thanki, 2012). The availability of additional spectrum in the UHF TV broadcast band as well as in the 700 and 800MHz digital dividend bands will significantly increase the utility of the licence-exempt regime, and hence its economic value.

With up to 75% of the DTT spectrum available for white space use at any one place, the potential for broadband usage of this spectrum is considerable. Coordinated usage also has an important role to play. In another paper (Grootes & Stucke, 2013), the value of this spectrum is calculated as being at least ZAR1.8 million per MHz per annum. While the spectrum fees collected for this usage will be no more than a quarter of this value, the economic benefit from commercial usage should have a considerably higher impact on the economy, because of the increase in availability and ubiquity of broadband connectivity that will result.

## CONCLUSION

These case notes explore the potential for a dual-stream regulatory model for TVWS. There is room for a "spectrum commons" of licence exempt spectrum usage within the TVWS domain, with its concomitant potential for explosive growth of ad hoc usage and wireless offloading of mobile traffic (Geerdts, Langenhorst & Cull, 2014). At the same time, there is also room for a coordinated usage or managed access licensing regime, where registered users of TVWS spectrum are provided with protection against other users, such that they can achieve high quality connectivity to their customers for commercial broadband services. Such coordinated usage licensing would provide for a time-dependent spectrum fee.

A four-level regulatory regime is thus proposed: primary, secondary, managed spectrum and licence-exempt licensees. The location and characteristics of all devices in the four categories would be recorded in the database and lower-level devices only authorised to transmit such that they cause no interference to higher-level devices. No detailed consideration of master and slave, fixed and mobile WSDs is considered in these short notes. Furthermore, in all cases except licence exempt, coordination of usage between devices on the same level is required, in order to ensure that they do not interfere with each other. At present, primary and secondary uses are licensed under the existing static regime in the TV bands. In the future, it is expected that a gradual migration to dynamic spectrum management at all levels will be achieved in other bands. This holds the potential for significantly increasing the usage density of high-demand spectrum and hence, facilitating meeting South Africa's objectives in terms of ubiquitous high-speed broadband at an affordable cost to consumers (South Africa Connect, 2013).

It is apparent from the literature (Jun, Park & Lee, 2012) and from the initial Cape Town trial, that TVWS can have a significant economic value. The quantum of that value depends on from whose point of view it is measured: the consumer, the operator or the state. In addition, in implementing geo-location-based dynamic spectrum management in the relatively simple case of the TV bands, where the incumbent licences are mostly for large fixed transmitters, valuable lessons may be learnt for South Africa and for other regulators on the African continent and elsewhere. This experience will be a good foundation for South Africa to pursue engineering and regulatory innovation of dynamic spectrum management in the more challenging situation of other bands.

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