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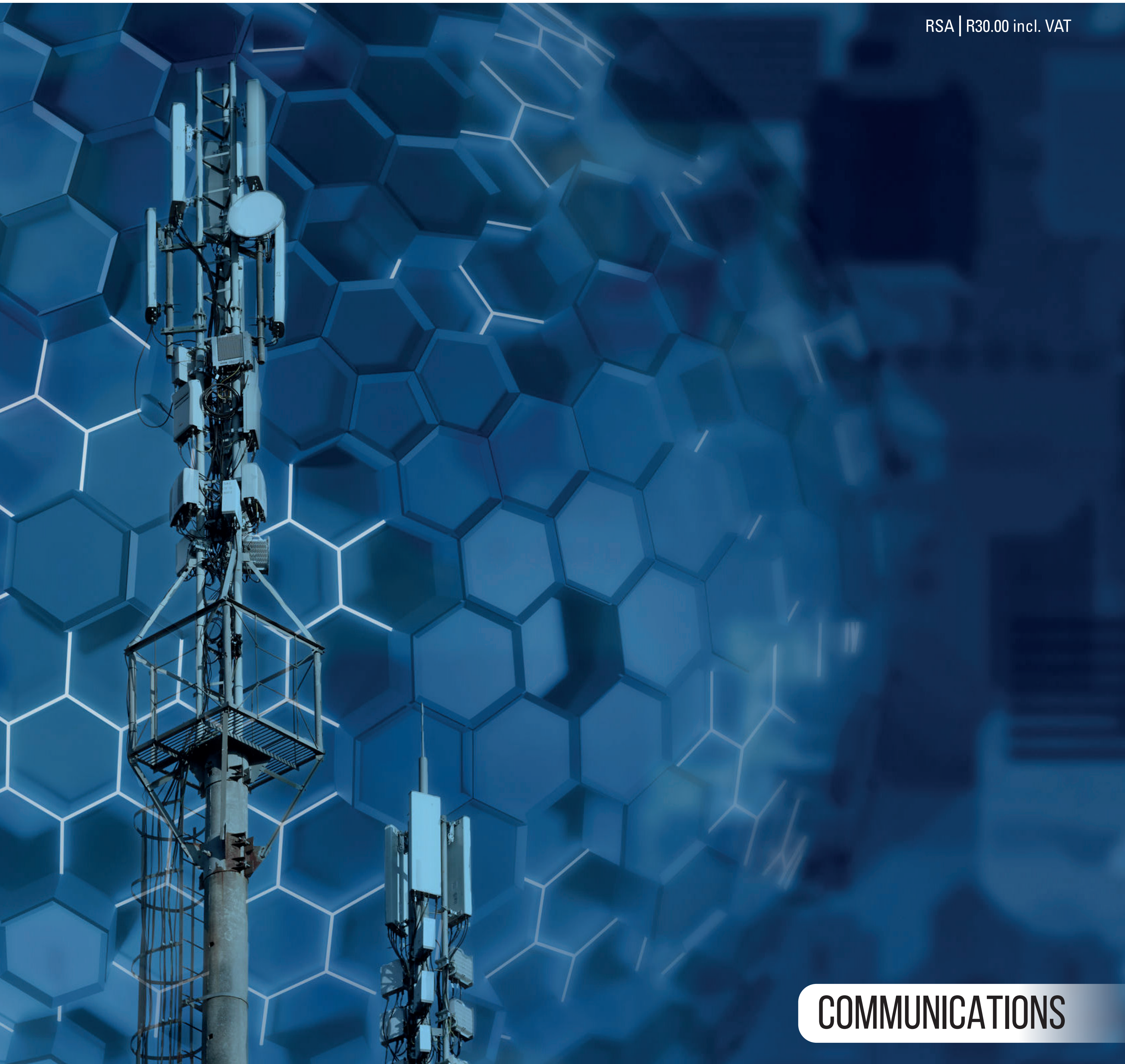

COMMUNICATIONS

SAIEE

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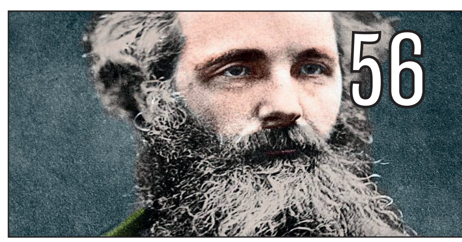

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We are nearing the end of July, which means we are in the midst of a South African winter - which to me feels colder than usual - it must be my mind playing tricks on me!

This issue focusses on Communication and our first feature article is on "Television Whitespace" (TVWS) which can be described merely as unused space found between channels that are used in the ultra-high frequency (UHF) spectrum. Read this article on page 24.

Page 32 features an article on AI and ML in Telecommunication Systems, which focusses on Globalisation, and the growing scale of industrialisation, which have led to the formation of complex nexus environments.

The SAIEE has been very busy with webinars in the past month, and I urge you to click here to see our upcoming events/webinars or go to page 71 to find a comprehensive calendar which includes our very successful online CPD Training Courses, powered by the SAIEE Academy.

The next **watt**now Tech Talk will take place on the 20th of August 2020 at 13h00. Watch out for the announcement.

This online version of **watt**now is interactive. So, on the contents page, click on the page number of the article you are interested in, you will be taken directly to the page. When you are done, select the endnote (wn) which will return you to the contents page.

Here's the July issue,
enjoy the read!

For information on locally manufactured electrical plug ranges, see page 13

Television Whitespace

SHARING CSIR'S EXPERIMENTAL RESEARCH EXPERIENCES ON A NEW WAY TO CONNECT PEOPLE AND BUSINESS

Television Whitespace (TVWS) can be described simply as unused space found between channels that are used in the ultra-high frequency (UHF) spectrum. TVWS frequencies span from 470 MHz - 694 MHz. With the TVWS, the Council for Scientific and Industrial Research (CSIR) and the Independent Communications Authority of South Africa (ICASA) have enabled a new way to do telecom in South Africa.

BY | DR ALBERT LYSKO
PROF FULUFHELO NELWAMONDO
DR LUZANGO MFUPE

This new exciting last-mile technology can offer 24 Mbps throughout, over 10 km range, handles propagation through vegetation and over obstacles better than traditional techniques, is cheaper than LTE and well suited for fixed links in traditionally challenging rural environments. This report includes some of the experiences from CSIR experimental work in TVWS.

INTRODUCTION

The digital transformation is happening, and the Covid-19 Pandemic has emphasised the need for this to be implemented quickly. The demand for connectivity has been growing exponentially[1,2], and the International Telecommunication Union (ITU) expects this trend to continue. Various operators indicate that Covid-19 has amplified the demand for broadband by around 50 per cent. Covid-19 has also highlighted a desperate need to connect schools and pupils and fulfil the targets of South Africa Connect, or broadband for all. What are the challenges in fulfilling this, and how to address them?

MOTIVATION FOR TVWS

ITU says[3] that, globally, an increase of 10 per cent in fixed broadband penetration yields an increase of 0.8 per cent in the gross domestic product (GDP), and an increase of 10 per cent in mobile broadband penetration produces a rise of 1.5 per cent. A study focusing specifically on the Africa region suggests that a 10 per cent increase in mobile broadband penetration in Africa would yield an increase of 2.5 per cent of GDP per capita[4].

In South Africa, ICASA reports[2] that the percentage of households with access to the Internet at home, or for which at least one member has access to or used the Internet, during 2018 was only 10.4% (although 64.7% of households had Internet access from somewhere). While the national 3G and 4G coverage are good, at 99.7% and 92.8%, respectively, the rural coverage for 4G/LTE is around 82%, and the cost of mobile data is still high.

Telecommunication services require investments in infrastructure. The most rapid and cost-efficient way to provide broadband is by using wireless[5] connectivity, which involves access to the radiofrequency spectrum and associated licensing. The investments are usually recovered by charging users for data. This works well in densely populated urban areas, but it is challenging to be profitable in sparsely populated rural areas.

Television WhiteSpaces (TVWS)

Television White Spaces (TVWS) is the term used to describe portions of unused radio spectrum; the gaps left between bands allocated for TV broadcasting in the **Ultra High Frequency (UHF) range (470 MHz to 694 MHz)**, excluding the **Radio Astronomy sub-band 606 MHz – 614 MHz**. The **Council for Scientific and Industrial Research (CSIR)** has been working on **Research, Development & Innovation (RD&I)** in the field of **Dynamic Spectrum Access** and **Spectrum Management (DSA/SM)** since 2009. This **RD&I** work has been taking place together with research addressing the cost to communicate and lack of broadband access in under-serviced and rural communities, hard-to-reach areas.

What are TVWS used for?

TVWS signals have the ability to **travel long distances** and penetrate both natural and man-made obstacles

DIGITAL TRANSFORMATION

Stronger societal use such as **studying at home or remote diagnosis**

Offer an approx. **24 Mbps broadband speed**, covering distances of more than **10 kilometres**

The various frequency bands offer multiple advantages. The frequencies used by television (TV) provide excellent coverage but limited bandwidth. The mm-wave-bands associated with frequencies between 10 300 GHz offer vast bandwidth but with minimal coverage. Access to the specific frequency band depends on the availability of the band and obtaining a license. Formally, most bands have already been allocated. Yet, most bands are usually only unavailable in a small percentage of locations. This is especially so for TV bands[6]. The traditional licensing process is very time-consuming, as a norm. Besides, the cost of spectrum licenses is often prohibitive for most entrepreneurs.

The ability of the signal to penetrate vegetation, walls and obstacles is another vital consideration. The peacefulness and beauty of trees, and other vegetation, often results in substantial and expensive-to-solve technical challenges when it comes to providing connectivity, especially at higher frequencies. Areas like this can be found in cities and particularly in rural areas.

Wireless entrepreneurs have also indicated[7] that there is an additional challenge arising from theft and vandalism, which place further constraints on the locations of and ability to set up wireless links.

VARIETY OF TELECOM SOLUTION OPTIONS

There are many traditional technologies used for wireless, varying in suitability. The urban areas are the most advantaged, benefitting from access to high-speed fibre and latest cellular, now also starting to include 5G in selected places. The options quickly reduce to somewhat cheaper, older and more common cellular technologies, like 3G and 4G, in less dense areas with lower economic activity. The low-cost and high-power 5.8 GHz version of Wi-Fi is often used for fixed wireless links. In the most remote locations, satellite connectivity is the only viable option.

A 2019 techno-economic analysis[8,9], tells that nationwide broadband coverage is best achieved using an optimal combination of different technologies. This is illustrated in Fig 1.

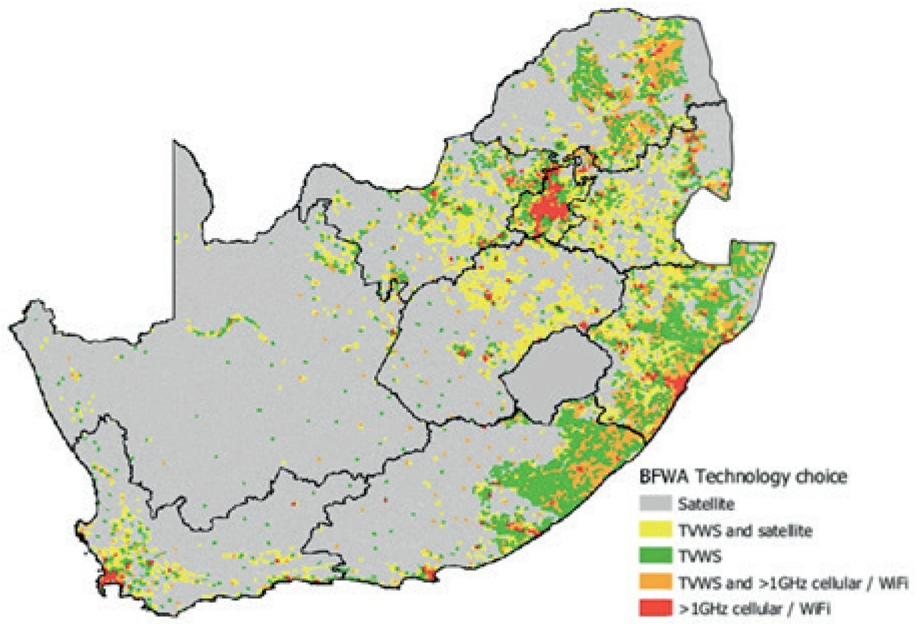

Fig 1: Matching population density to technology. Reproduced from "Assessment of current and future spectrum for WAPA, Report, Wireless Access Providers Association, 2019" with permission.

As per the same analysis, TVWS[i] might be the most suited technology to address the broadband connectivity needs of 12.5% of the South African population. Furthermore, if taken slightly further, TVWS can be used to provide coverage for around 42% of the population.

TVWS BAND AND ASSOCIATED ADVANTAGES AND CONSTRAINTS

The CSIR and ICASA have recently identified additional frequencies that can be used for telecom in South Africa, called television white spaces (TVWS), which involves the sharing of the 470 – 694 MHz band with the TV broadcasting on a secondary basis.

This new exciting development uses a significantly simplified and automated spectrum licensing regime borrowing unused TV spectrum (called *white spaces*, a term derived from the empty spaces on the hardcopy printouts showing graphs with occupancy of the spectrum), and keeping to the traditional TV channel width of 8 MHz.

The modern TVWS technologies can offer 24 Mbps and cover distances over 10 kilometres. However, the latest devices and optimised configurations may offer even higher speeds, with 54/9.8 Mbps achieved over 4 km distance in urban conditions[10].

There are several advantages and constraints associated purely with the specific frequencies used, i.e. 470 – 694 MHz.

The TVWS handles propagation through vegetation and over obstacles much better than traditional technologies like long-range 5.8 GHz Wi-Fi and is well suited for fixed links in traditionally challenging rural environments.

To quantify this advantage, it is possible to compare the specific attenuation due to woodland [ITU-R P.833] for different frequencies associated with different communication technologies. For example, the particular attenuation for TVWS band is below 0.15 dB/m, while 1800 MHz LTE experiences 0.37 dB/m and 5.8 GHz Wi-Fi has to concur 1.15 dB/m. This means the TVWS can typically penetrate about eight times thicker bush or trees than Wi-Fi. An overview plot is shown in Fig 2.

The higher robustness to vegetation and great flexibility afforded by TVWS also help to reduce the challenge of vandalism. For one, the TVWS equipment can handle much thicker vegetation than Wi-Fi or 4G and can even go over limited blockages. This gives planners and installers more flexibility in designing the networks and locating the network nodes, thus reducing costs and minimising the need

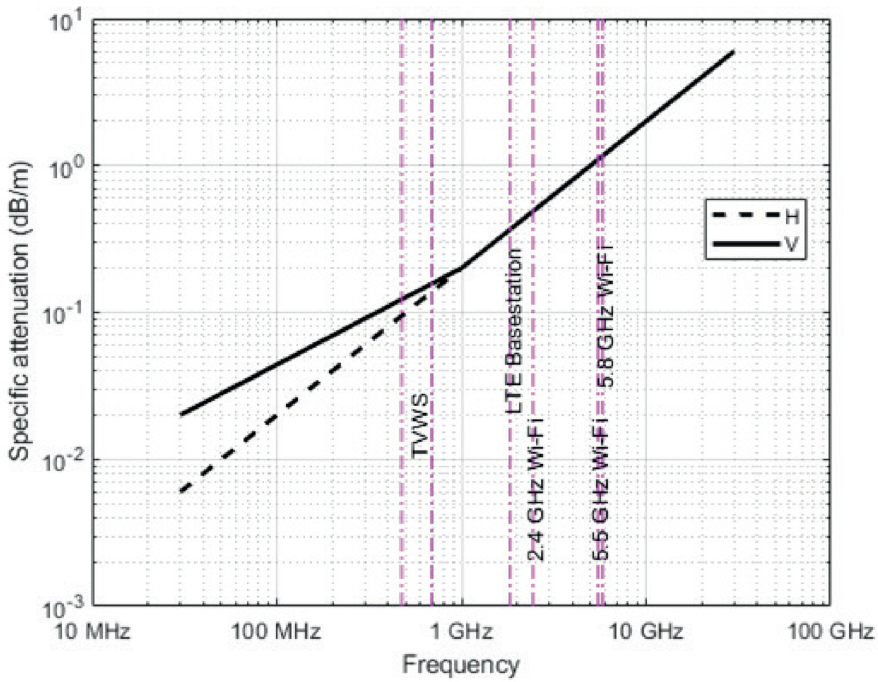

Fig 2: Specific attenuation due to woodland [Rec. ITU-R P.833-4]. "H" refers to the vertical polarisation and "V" refers to horizontal polarisation

to install in high-risk spots. Also, the devices themselves are more robust to theft, as they must identify themselves to a central database before the database allows them to transmit.

Usage of lower frequencies in the ultra-high frequency (UHF) TV band also brings a limitation. The gain for commercially available TVWS antennas is usually at most 14 dBi, limited by the practically acceptable size of antennas. Also, if one wishes to avoid ground losses, TVWS antennas need to be installed 2-3 times higher than 5.8 GHz Wi-Fi counterparts. Furthermore, the regulations limit the transmit power to 41.2 dBm for fixed rural, as compared to 53 dBm being permitted for 5.8 GHz Wi-Fi.

Nevertheless, these restrictions are usually compensated for by the much lower propagation loss, which is about 20 dB lower as compared to Wi-Fi. Overall, a typical TVWS installation could be expected to have about a half the range of a long-distance Wi-Fi point-to-point link while offering several times wider area coverage[12] in the point-to-multipoint scenario.

It should be noted that, as the close frequency bands, such as the 700 MHz and 450 MHz bands, are assigned and being considered for cellular communications in South Africa, the 4G (LTE) and 5G technologies will be able to offer similar frequency-related advantages. Utilising this advantage will likely be limited by the high cost of LTE and 5G.

BASIC PRINCIPLES OF OPERATING IN TVWS

The general principle is relatively simple. A white space device (WSD) informs a central database (which in South African TVWS terminology is called a geolocation spectrum database (GLSD)) about its location and operational parameters, such as antenna height and transmit power[13]. The GLSD also knows the location and parameters of the primary transmitters (here: TV broadcasting transmitters), criteria for protecting reception of the TV broadcasting as well as the topology of the landscape. Based on this information, the GLSD calculates the availability of the spectrum for the location of WSD and informs WSD, which enables WSD to start using the spectrum for communications.

As the WSD requires frequent communications with the GLSD, and this connection is made over the Internet, the TVWS cannot be used for links isolated from the Internet. Also, the availability of TVWS spectrum, i.e. availability of TV channels is not guaranteed.

The actual realisation is more involved, as it includes different types of WSDs (Master and Client), two levels of GLSD (Reference and Secondary), a set of regulations to be adhered to, and technology-specific compliance testing. The specifics of the automated spectrum allocation in South African TVWS works are described here.

TVWS IN SOUTH AFRICA

Active introduction of TVWS in South Africa started with field trials. International examples and several large field trials were used to convince the national regulator, ICASA, to begin drafting the TVWS regulations. South African trials were held in the Tygerberg district of Cape Town[14] and Polokwane, Limpopo[15]. Together, these two trials demonstrated providing TVWS-based broadband connectivity to over 16,000 students and teachers, without causing any interference to the reception of TV. This was followed by ICASA starting a public consultation process to produce the national TVWS regulations.

ICASA published South African TVWS regulations[16] in 2018. TVWS relies on the availability of unused TV spectrum. This availability is automatically determined by a geolocation spectrum database (GLSD) developed by the CSIR. According to the regulations, South Africa has two GLSD levels. The reference GLSD (R-GLSD) is the leading automated authority controlled by ICASA. The secondary GLSD (S-GLSD) is qualified[17] by ICASA and serves the WSDs (users) as depicted in Fig 3.

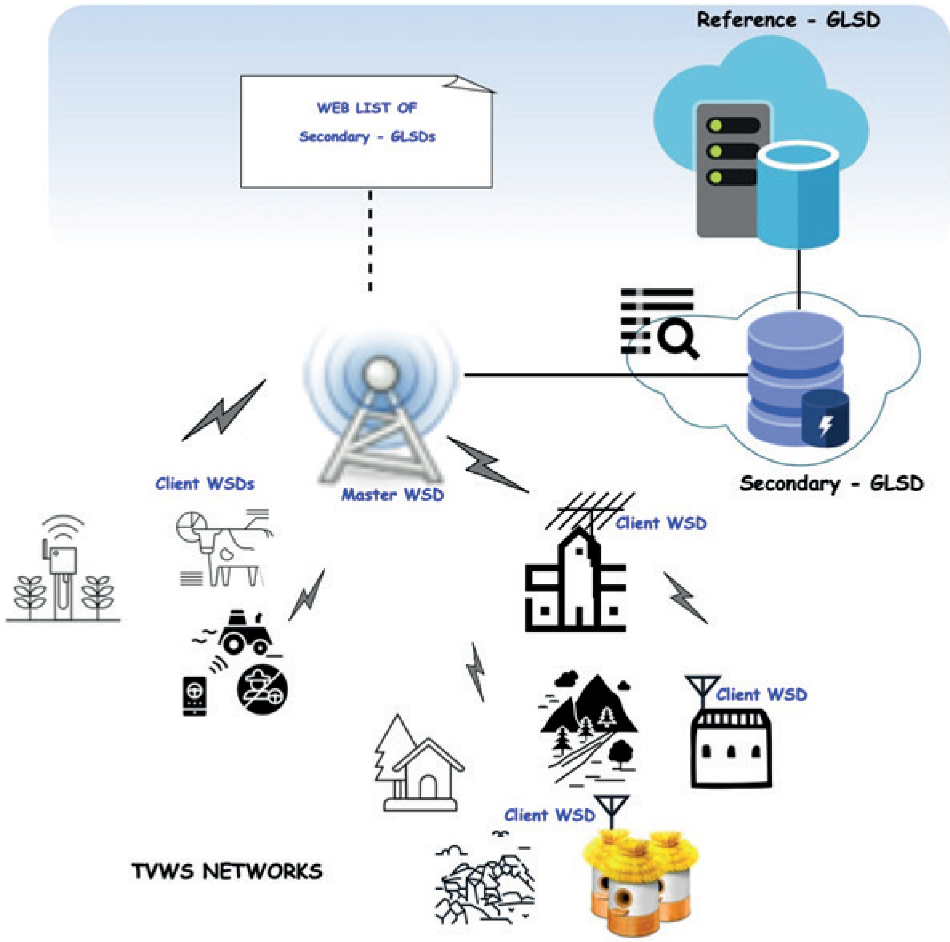

Fig 3: Illustration of TVWS network deployment under the South African regulatory framework

TVWS MANUFACTURERS AND PRACTICAL MATTERS

There are a host of manufacturers of TVWS equipment. When selecting TVWS equipment, it is essential to determine whether this equipment is compatible with ICASA's Reference GLSD. The CSIR currently offers such testing.

One Master WSD can usually serve 8 to 50 Client WSDs. Some brands and models use tighter radio frequency (RF) filters and can operate near TV transmitters. This permits them to be used even in cities with the highest occupied spectrum, such as Pretoria and Cape Town. Other models use less sophisticated filters and may require a substantial-frequency and distance spacing to the nearest TV broadcasting transmitter. However, considering that rural areas typically have an abundance of TVWS, most equipment can work well there.

The influence of filters may be demonstrated with the results showing the effects of 1) being near TV broadcasting signal, and 2) of the TVWS receiver's channel width on the "noise" level received by a TVWS card and its effect on the throughput, as shown in Fig 4.

The upper plot shows the measured levels of signals versus frequency, with TV broadcasting transmissions visible around the carrier frequencies of 530 MHz and 610 MHz. The "Noise 1" and "Noise 2" plots show the levels of noise measured by the TVWS card when it was configured at specific frequencies closer and further away from the TV-signals mentioned above. It is clear that the measured level of noise increases, as the card is configured to operate closer to the TV signal.

The last plot shows how the configuration affects the throughput achievable with the TVWS card. The best performance is achieved for the configuration corresponding to the lowest level of noise.

These explain the following practical observations applicable for some (not all) TVWS devices based on Wi Fi-like hardware:

1. drastic reduction of throughput from being too close to an operational TV channel;
2. when near an active TV broadcasting, lowering channel bandwidth may improve performance.

CHANNEL AGGREGATION AND MULTI-DEVICE OPERATION

Some TVWS equipment allows aggregating several TV channels, usually up to 24 MHz, to increase speed.

When one installs multiple WSDs on the same or a nearby mast, one needs

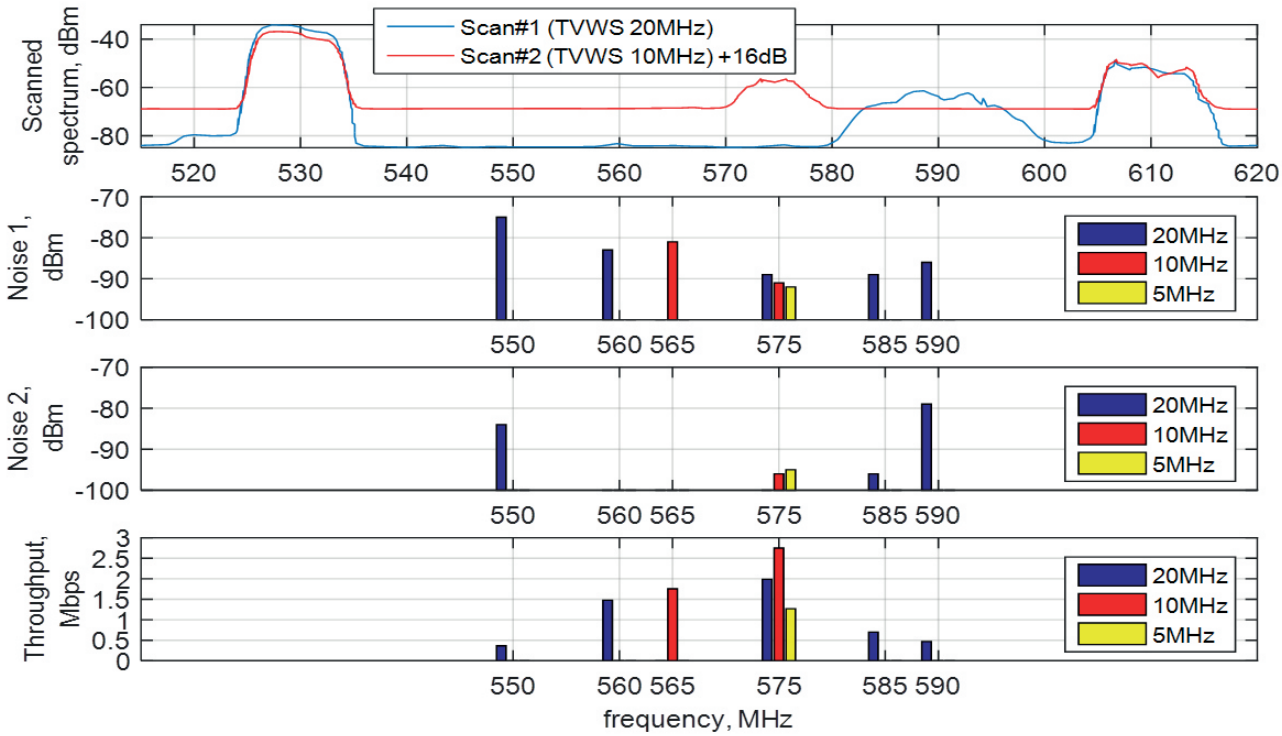

Fig 4: Effects of channel width and being near TV broadcasting channels. Based on CSIR/UCT research lead by Dr D. Johnson, 2016.

to consider the saturating effects of near-field coupling between antennas and devices. Many WSD units have dedicated connectors to allow for synchronising the transmissions between multiple devices and thus avoid losing sensitivity and range. Using such a synchronisation feature may lead to a minor, of the order of 10 per cent, loss in the throughput.

TVWS operates on a secondary basis avoiding interference to the primary users, i.e. TV receivers receiving TV broadcasting. The study *[A.A. Lysko and G. Dludla, Considerations for coexistence: DVB-T2 broadcasting and LTE base stations in 700/800 MHz bands in South Africa, IEEE GEMCON, 2018*] considered the mutual location of primary and secondary users of the spectrum (transmitters) and concluded that the optimum configuration involves co-locating primary (here: TV) and secondary (here: TVWS) equipment on the same tower. It should be noted that this optimal configuration may,

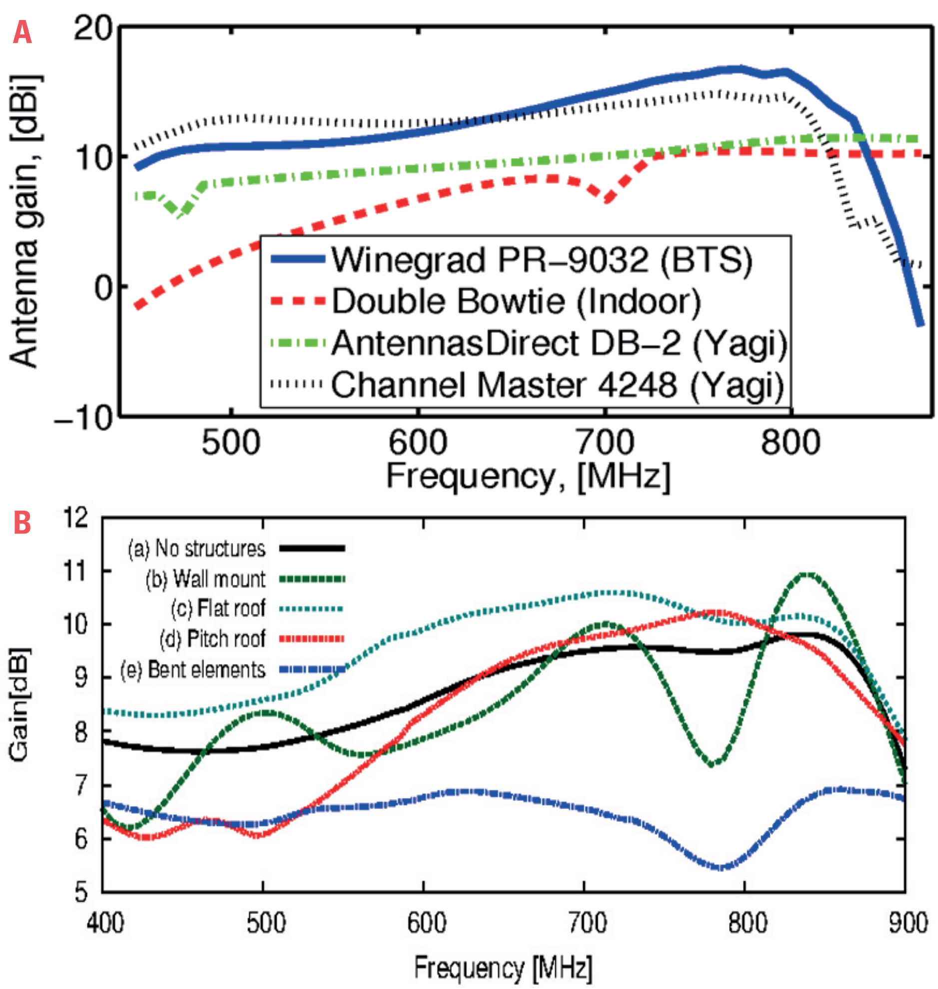

Fig 5: a) Influence of frequency dependence and b) influence of antenna mounting environment, simulated for several TV antennas.

however, not always be possible and that in rural areas with an abundance of the spectrum, not necessary.

SELECTION OF ANTENNAS

TVWS can use readily available TV antennas and cables. As a TVWS antenna must cover a comprehensive range of frequencies, its performance varies typically with frequency and may also depend on the nearby environment. These effects are illustrated with Fig 5 based on numerical simulations.

TVWS: PROS AND CONS

TVWS is an order of magnitude better in penetrating vegetation and trees than 5.8 GHz Wi-Fi, and somewhat better in handling obstacles, as well as having several times wider coverage area than Wi-Fi. The cost of TVWS equipment is between that of LTE and Wi-Fi equipment.

On the other hand, TVWS does have its limitations. TVWS installations require the Internet to access the database periodically. TVWS channels are not guaranteed in environments with significant usage of the TV spectrum. Some TVWS devices may be sensitive to TV broadcasting transmitters and require frequency or spatial separation from these transmitters. wn

For information regarding the CSIR secondary geolocation spectrum database (S-GLSD), please contact Dr Luzango Mfupe, CSIR (lmfupe@csir.co.za).

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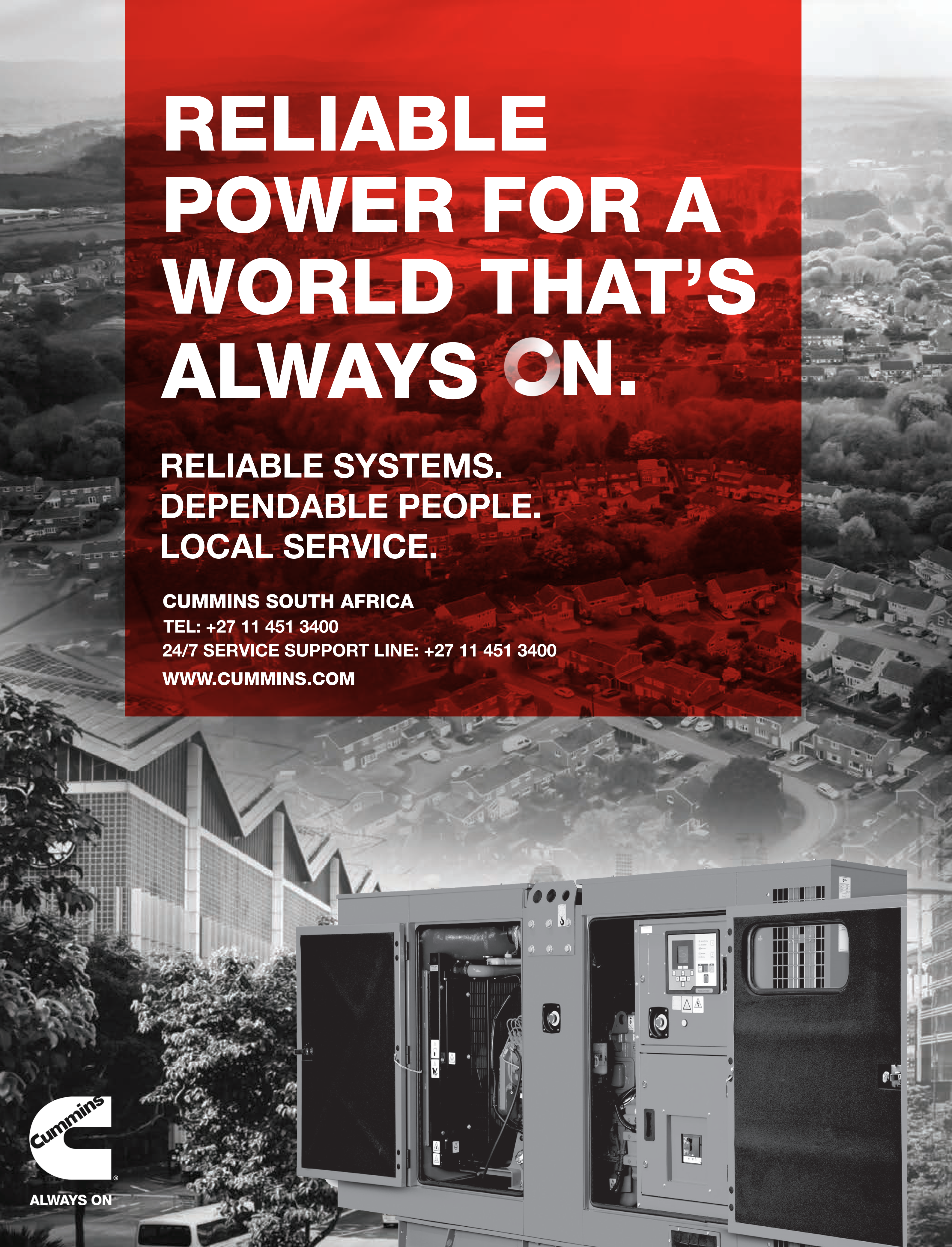
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