An Assessment Study on White Spaces in Malawi Using Affordable Tools

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***Abstract*—For rural areas, wireless is the only viable alternative for providing affordable telecommunications services. One limiting factor to the growth of wireless broadband penetration is the lack of available spectrum. White Spaces broadband uses gaps in spectrum bands that have been reserved for TV broadcasts. These frequencies offer significant capacity to help alleviate pressures on existing wireless networks and allow connectivity in remote areas due to their good propagation capabilities. This paper describes an assessment study on TV White Spaces availability in Malawi using affordable tools. The conclusion of the study is that 1) it is possible to assess the spectrum usage using low cost equipment 2) ample spectrum for TV White Spaces deployment is available in Malawi.**

I. Introduction

TV White Spaces have received a lot of attention in the last decade [1]. They offer a solution to the spectrum crunch that has resulted from the explosive growth of wireless technologies. While the focus of most researchers has been in protecting the incumbent user of the spectrum, the TV broadcasters, from the possible interference caused by the new entrants [2], we believe that rural areas in Developing Countries are ripe for the deployment of white spaces radios that can be used to provide Community Network services and Internet access. The reason is that TV broadcasters never had an economic incentive to serve sparsely populate areas with several concurrent TV channels as is the case in urbaspethe UHF TV speowrum is mostly fallen in these regions and ready to be put to good use. On the other hand, the recent decision of the FCC (Federal Communication Commission) in the US to allow the nationwide deployment of TV band devices [3], has provided the incentive for several manufactures [4] to invest in the production of equipment capable of providing two way digital communications at a reasonable throughput operating in the 470 MHz to 690 MHz band.

The remaining obstacle to make use of these frequencies for Internet connectivity is to persuade the regulators in Developing Countries of the benefits for rural populations. These frequencies have much better propagation characteristics and therefore offer better coverage with fewer base stations, in an economically viable way even in sparsely populated areas.

To this end, the measurement of the spectrum is a powerful albeit, up to now, expensive tool to convince the regulators.

We present the use of inexpensive spectrum analyzers coupled with laptops and the software required to perform spectrum measurement and visualize the data in a convenient way for highlighting the availability of spectrum holes, with examples of measurements taken in both urban and rural areas in Malawi.

II. Spectrum monitoring

Recently spectrum occupancy has become topical as the quest for efficient access to the spectrum continues. This is evidenced by empirical measurements of the radio environment in a bid to ascertain the spectrum usage by different wireless services [5]. A number of occupancy measurement campaigns efforts where initially carried out in USA using discone antennas, spectrum analyzers and a laptop [6-8]. These occupancy measurements showed information only about American spectrum regulation and utilization.

The efforts soon spread to Europe. A spectrum occupancy measurements was conducted in the frequency range from 75 MHz to 3 GHz in an outdoor environment in urban Barcelona, Spain [9]. Furthermore [10] takes a survey of Spectrum utilization in Europe and reports three major campaigns namely in the suburb of the city of Brno in the Czech Republic and in the suburb and the city of Paris in France during years 2008 and 2009 respectively.

In Asia, researchers in Singapore [11] measured a 24 hour spectrum usage in 12 weekdays in the band 80 MHz-5850 MHz. The authors conclude from their measurements that their work is preliminary in its nature and future long term studies need to be performed to determine any potential secondary usage on those channels that have low or no active utilization. The Malaysian efforts are reported in [12] with a focus on the 470-498 MHz band in an outdoor environment of a suburban area in Johor Bahru. In China, measurements have been focussed in the range 694-806 MHz [13] in the Chengdu area. In Vietnam [14], the frequency bands ranging from 20 MHz to 3000 MHz in Ho Chi Minh City and Long An province have been measured, while in Japan [15] three particular locations of Kanto area spanning the 90 Mhz-3 GHz band were monitored. There have been other efforts in Qatar [16].

In Africa, measurements have been carried out in South Africa [17] using the Meraka Cognitive Radio Platform

(MCRP) developed using the Universal Software Radio Peripheral hardware and the GNU Radio software. The authors present early results in rural and urban Southern Africa indicating that there are substantial white spaces available in both rural and urban areas for digital dividend.

The majority of these researches reach a common conclusion on the necessity for further occupancy measurements at different locations over varied times. This thus motivates the need for more occupancy measurement. On concluding their investigations, the authors in [14] affirm that the challenges of their campaign is not only cost (equipment) but also time (deployment) where multiple locations are to be measured to obtain local spectral pattern usage.

III. Affordable tools for Spectrum Monitoring

Monitoring the RF spectrum requires a spectrum analyzer. Commercial high-end spectrum analyzers are expensive (in the order of many thousand dollars) and bulky, and are not typically available in university labs in Developing Countries. Recently an affordable and easy to use device has become available, to analyze the frequency band between 240 MHz and 960 MHz, which encompasses the higher part of the TV band. This device is called RF Explorer [18] and sells for around 100$. The RF Explorer displays full frequency spectrum in the band, including carrier and modulated shape, and shows Spread Spectrum activity if that exist. There are some other devices of reasonable cost in the market which offers some of these features in an USB dongle, but they are restricted to the ISM bands and do not cover TV frequencies. RF Explorer is fully functional as an independent unit and does not require a PC to be used.

The software provided with the RF Explorer is not suited for the type of measurements we planned. There are both Windows and a Mac clients, free to use, but they are based on a GUI. We decided to automatize the measurement process by writing a script that sets the start and stop frequencies and then saves the measurement results as text files. In this way we can produce graphs and easily analyze the results. We included a GPS in the system so we know exactly where and when the measurements were carried out.

IV. Measurements in Malawi

Malawi is a landlocked country in southeast Africa. Malawi is over 118,000 km^2 with an estimated population of more than 14,900,000. It is among the world's least-developed countries. The economy is heavily based in agriculture, with a largely rural population. Internet access is limited by high cost and lack of infrastructure. According to International Telecommunications Union statistics for 2009, approximately 4.7 percent of the country's inhabitants used the Internet [19].

A. Measurement Sites

The measurements were first performed around Chancellor College Campus, and later in four selected rural areas of interest in Zomba and one urban area in Blantyre city. The locations of these sites are shown on Table 1 and Figure 1 shows the selected sites on a map.

Measurements were carried out in several spatially distributed locations with different population density, namely; urban, sub-urban and rural. For the urban location, a low density location called Namiwawa was chosen in Malawi's commercial city of Blantyre. For the sub-urban, Chancellor College Lecture Theatre 2 in the City of Zomba was chosen. For the rural, remote sites from Zomba city namely; Jali, Magomero, Makoka and Thondwe were selected. The selection criteria for the rural sites were based on the presence of nearby public infrastructure like hospitals, schools, market or police.

TABLE I. Sites in Malawi

Site Name	Location	Latitude	Longitude
Chanco LT	Sub-Urban	-15.38820114	35.3377872
Namiwawa	Urban	-15.77635384	34.97527684
Jali Trade Center	Rural	-15.482136	35.447648
Makoka	Rural	-15.5167	35.2167
Magomero Community College	Rural	-15.57694502	35.18616848
Thondwe	Rural	-15.5	35.235

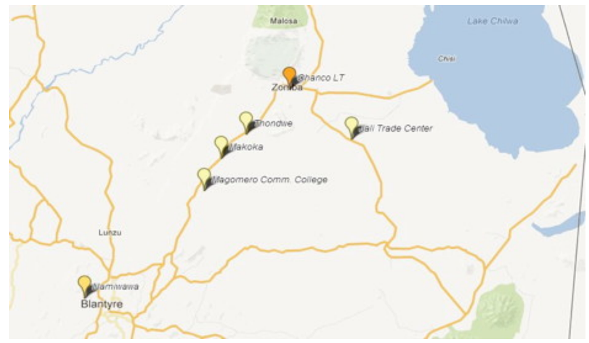

Fig. 1. Measured Sites in Blantyre and Zomba.

B. Methodology

The measurements were carried out from September 2012 to January 2013, using a car to drive to the different sites. The GPS was placed on the car's roof, while the laptop and the spectrum analyzer were in the car. In each location we carried out a series of measurements to cover the whole spectrum.

Bands of 100 MHz width were determined and categorized as follows: 400—499 (400 MHz band), 500—599 (500 MHz band), 600—699 (600 MHz band), 700—799 (700 MHz band), 800—899 (800 MHz band). For future measurements, the develop bash script will be will be modified to capture the spectrum in the 900 MHz band for GSM.

The design of the measurement setup is shown in Figure 2 while the actual devices are shown in Figure 3.

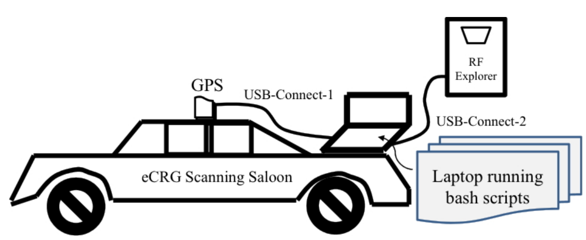

Fig. 2. Measurement setup.

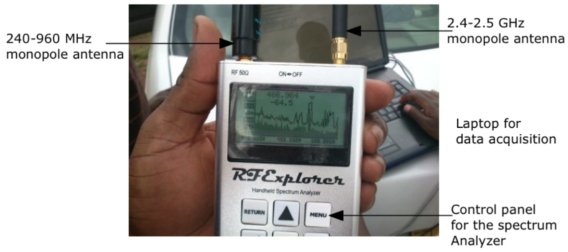

Fig. 3. The RF Explorer Spectrum Analyzer.

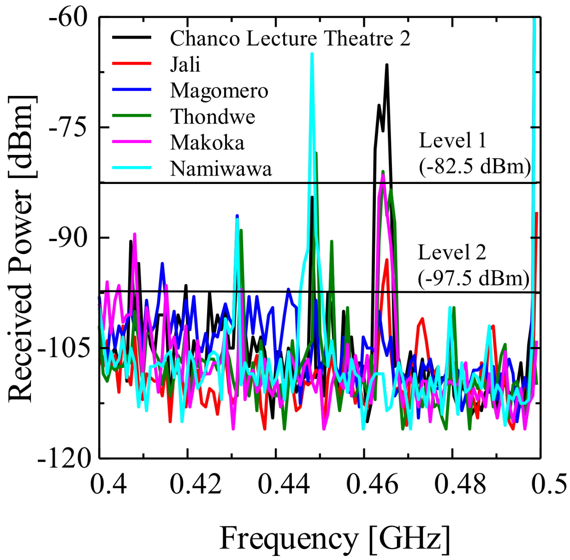

Fig. 4. Measurement from 400MHz to 499MHz.

C. Methodology

The results based on the methodology outlined earlier have been plotted and presented in graphs of Figures 4-8, followed by a discussion of the results.

The received signal strength was categorized as high, low and noise with threshold values of -82.7 dBm (Level 1 shown in the Figures) and -97.5 dBm (Level 2 shown in the Figures). For plots in Figures 4-8, the signal strength above Level 1 were considered high, those below Level 1 but above Level 2 were considered low, while those below Level 2 were considered noise. Values with strength below Level 2 are considered the noise floor they are below the receiver sensitivity of most radios and well beyond the level required for adequate decoding of a TV signal. The noise floor level will depend on the width of the filter used in performing the measurement. Therefore, we considered the signals below Level 2 as White Spaces. The signals above Level 1 were investigated further to precisely identify their sources and whether or not they were allocated by the regulator. The identification of the signal source would have been improved by using directive antennas (and this will be implemented in the future). For now, a National Band Plan guide book [20] was used to identify whether or not the signals were allocated the frequency spectrum they were captured in.

In Figure 4, the high signals are reported at 431 MHz, 448 MHz and 465 MHz. The National Band Plan guide book shows that the 430—432 MHz band is allocated for Amateur Radio Services, which explained the high level at 431 MHz. The 440—450 MHz band is allocated for Private Mobile Radios (PMRs) or PAMR/PPDR (pending studies and research), and fixed telemetry and dual frequency alarm systems. Thus the presence of a high signal at 448 MHz in Namiwawa which is a low density residential site can be explained as due to dual frequency alarm systems.

What was strange was the high signal level at 465 MHz. In the Malawi national Band Plan currently in use, the band 460—470 MHz is not allocated, however, a high signal was captured. Based on ITU regulations, this band is reserved for Fixed Mobile or Metereological-Satellite (Space-to-Earth). This is good information for the regulator to take it up for further investigation. It is an indication that probably a satellite is transmitting with a footprint that includes Malawi without the regulator being aware.

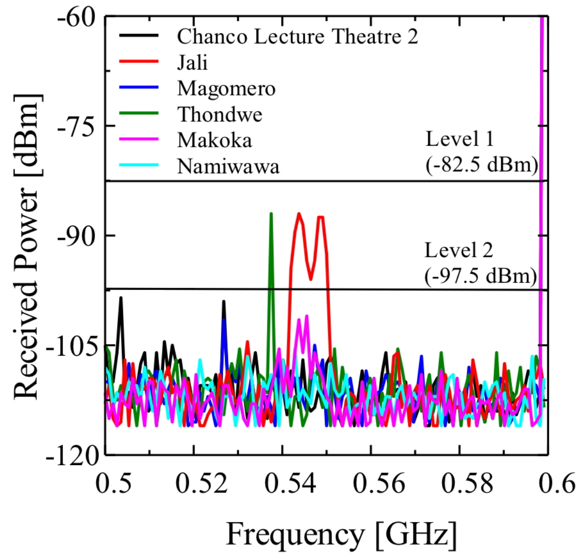

Fig. 5. Measurement from 500MHz to 599MHz.

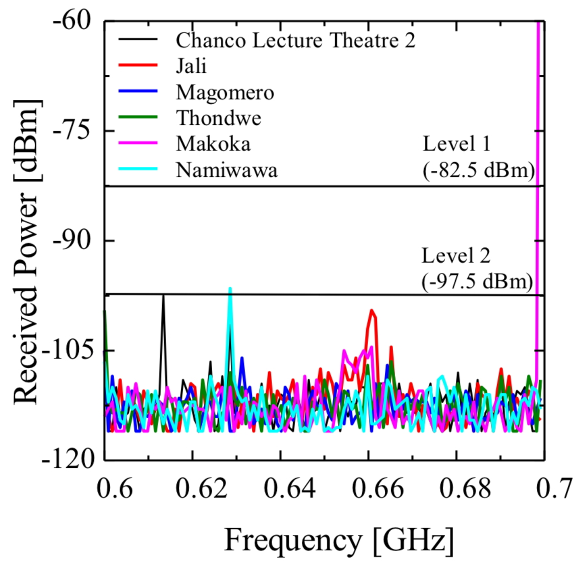

Fig. 6. Measurement from 600MHz to 699MHz.

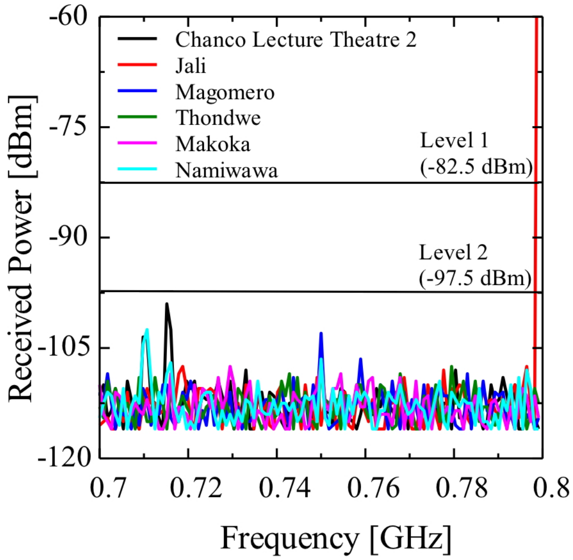

Fig. 7. Measurement from 700MHz to 799MHz.

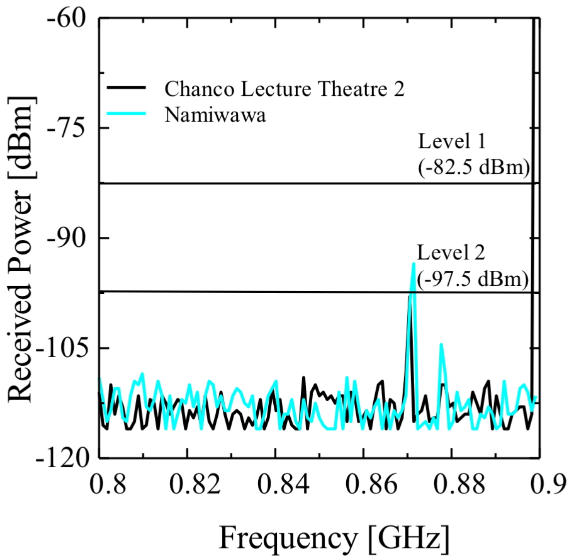

Fig. 8. Measurement from 800MHz to 899MHz.

Of particular interest to the researchers in this paper are the white spaces at 454 MHz, 470 MHz and 483 MHz in the 400 MHz band. If these frequencies were reserved for white spaces technology, each of them would be used as a specific radio channel. Depending on the type of radio developed for the white spaces technology, a single channel could be 1 MHz, 2 MHz or could even assume the conventional 6 MHz or 8 MHz channel bandwidth assigned to TV channels. One such radio developed specifically for the TV white space technology use is the Carlson Rural Broadband Radio. This radio is designed for the UHF TV spectrum (470 MHz to 786 MHz) and is claimed to be effective even in non-line of sight conditions. It is therefore a candidate for deployment in the studied areas and may be in Malawi as a whole.

Looking at Figures 6-8, we can affirm that the spectrum is completely unused and could therefore be used for Internet access.

V. Conclusions

We were able to measure spectrum usage in six sites in Malawi using affordable devices. The availability of low cost tools to assess spectrum usage can provide valuable data to pinpoint frequency bands that are not currently being exploited and make them known to the spectrum regulator agency in the country. Analyzing the measurement results, we claim that spectrum is available in rural Malawi and can be used for Internet access.

Developing low cost solution and making them available to researchers is a way to accelerate the adoption of the new White Spaces technology.

Acknowledgment

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