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Spectrum occupancy investigation: Measurements in South Africa

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A B S T R A C T

Regulatory bodies have predicted an impending shortage in commercial radio frequency spectrum in the near future. However, due to outdated regulatory practices, many of these bands are in fact inefficiently underutilised. Spectrum measurement campaigns have be carried out around the world to determine the extent to which this is true. However, there still seems to be a lack of knowledge regarding spectrum occupancy in South Africa. A spectrum measurement system was thus designed and employed to measure the spectrum occupancy of the ultra-high frequency (UHF), global system for mobile communications (GSM) 900 MHz and GSM 1800 MHz bands through a measurement campaign in the Hatfield area of Pretoria, South Africa. A method for determining spectrum occupancy, from raw spectrum measurements, has been described and used to calculate the average spectrum occupancy of these bands. Occupancy in the UHF band was found to be fairly constant at approximately only 20%. While the maximum occupancy of the GSM 900 MHz band was calculated to be much higher at approximately 92% and that of the GSM 1800 band to be approximately 40%. However, the GSM 900 MHz and 1800 MHz bands did exhibit fluctuations in occupancy of between 10% and 20% respectively according to the time of day. Slight variations in occupancy of between 1% and 3% were also evident over the days of the week. These results are placed into context by a comparison with the findings of various other measurement campaigns from around the world. When compared, occupancy was generally found to be lower in the UHF bands but higher in the mobile bands.

1. Introduction

The Federal Communications Commission (FCC) of the United States of America (USA) and various other regulatory bodies worldwide have found that in many frequency bands the radio frequency spectrum is currently underutilised. This is in spite of recent trends towards an increase in the demand for wireless connectivity [1]. With most of the useful radio spectrum already allocated, it is becoming difficult to find vacant bands to either deploy new services or enhance existing ones. Thus it seems that useful radio frequency spectrum is gradually becoming a more scarce resource [2]. This has led to the development of cognitive radio technologies, which rely heavily on understanding the spectrum occupancy dynamics of available radio resources [3,4].

Various measurement campaigns have been undertaken in other countries [5–15], but there is still a general lack of knowledge regarding spectrum occupancy in Africa, and more specifically in South Africa. This research project sought to fill this gap by developing a mobile autonomous system which can be used to gather spectrum occupancy information for a wide range of frequencies over long periods of time. A modular hardware system and software environment was developed to deliver detailed information about the occupancy of various commercially utilised South African frequency bands. These included the

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ultra-high frequency (UHF) and global system for mobile communications (GSM) bands. Measurements were thus taken from the following bands,

- UHF (470–854 MHz),
- GSM 900 downlink (935–960 MHz), and
- GSM 1800 downlink (1805–1880 MHz).

Data was collected from a six week long measurement campaign in the Hatfield area of Pretoria, South Africa [16]. The measurement site (GPS Co-ordinates: S25°45′11″ E28°13′42″) was situated on the Hatfield campus of the University of Pretoria, which is located in a typical urban area with a large student population density. The surrounding area is predominantly characterised by schools, office blocks, shops and student accommodation. The design and configuration of the measurement campaign is described in this article.

A technique for extracting the information bearing component from the noise component of a measured signal, described as the maximum normal fit (MNF) method, is described and used to calculate spectrum occupancy. Detailed information pertaining to the calculated occupancy of the measured bands is then presented and compared to the findings of various other measurement campaigns.

2. Measurement system

In this section the design and configuration of the measurement system is presented. The physical measurement configuration is illustrated in Fig. 1.

2.1. Hardware subsystem

The hardware configuration of the measurement system is illustrated in Fig. 2 in the form of a functional block diagram. Functional unit (FU) H1 is a wide-band Super-M Ultra base antenna with a frequency range of 25 MHz to 6 GHz capable of receiving both vertically and horizontally polarised signals. The main hardware components of the receiver system are housed within a metal cabinet, FU H2, located on the roof of the Engineering I building of the University of Pretoria. This cabinet houses FU H2.1, a low noise amplifier (LNA) with an operating range of 50 MHz to 3 GHz (operation at higher frequencies is possible, but at a lower gain), FU H2.2, a regulated 5V DC power supply for powering the LNA, FU H2.3, a custom built air conditioning unit and a spectrum analyser (SA), FU H2.4.

Although physically housed within the same enclosure, the SA FU H2.4, was split into two functional hardware units: a local PC that houses device controlling software, FU H2.4.1, and the radio frequency (RF) component of the device, FU H2.4.2. A temporary storage space is available on the local PC, FU2.4.1.1. FU H1 is connected to FU H2.1 via 10 m of rugged low loss LMR 600 coaxial cable. FU H2.1 is in turn connected to FU H2.4.2 via a Sucoflex 100 coaxial cable. An Ethernet connection provides the interface between FU H2.4 and two other functional hardware components: FU H3, a remote PC that runs the remote scheduling software and FU H4, a backup and storage server for remote storage and backup of the actual spectrum measurement data. FU H3 and FU H4 were located in an office in the Engineering II building of the University of Pretoria.

Fig. 1. Physical spectrum measurement system.

2.2. Software description

The software for the measurement campaign has been divided into three separate applications: interface and control software to locally control the SA, manage data files and report on operational status; remote control software to remotely schedule the scans to be performed and allow for easy access to the system configuration function from a remote location; and data backup software to securely store the result files on the backup server. Each component is illustrated in Fig. 3 as a functional block diagram.

The SA interface and control software package interprets the scan configuration command and configures the SA hardware for the appropriate operation. It then awaits the initiate scan commands from the remote control software. Upon receiving said commands, it begins scanning and saving measured data locally on the SA. The remote control software is responsible for reading a measurement schedule file (hosted on a secure data storage server, FU H4) and for sending relevant configuration commands and requests to the SA, FU H2.4. The file backup software sporadically checks the local storage location for new data and then moves them to the data storage server, FU H4.

2.3. System calibration and sensitivity

The major functional components of the measurement system have all been calibrated using an Agilent E5071C ENA series network analyser. Fig. 4 illustrates the complete system link budget and includes the calibrated gains for the antenna G_a, the coaxial cables (LMR 600, G_{cl}, and Sucoflex 100, G_{cs} and the LNA G_{lna}).