Spectrum Occupancy and Hidden Node Margins for Cognitive Radio Applications in the UHF Band

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Abstract. This paper presents the study of the spectrum occupancy in the UHF frequency band (470-870MHz) in Bilbao area, Spain. The study has been performed at three different sites and at different height to determinate the hidden node margin, the main problem of the cognitive radio. The objective of the paper is to determinate by signal power measuring if the cognitive device will be able to detect and distinguish the empty and occupied channel to carry out the communication. The results from the spectrum measurements taken in all the sites have been analyzed and compared to the official spectrum regulation. The study reveals that the spectrum occupancy is minimum, thus there are a lot of white spaces in this band.

Keywords: Cognitive Radio, White Space, Hidden Node Margin, Spectrum Measurement, Spectrum Occupancy.

1 Introduction

The feasibility of the idea of "cognitive radio" [6] for the UHF band is strongly dependent on the border conditions of the UHF band occupancy. Also, and not in a less relevant position, the potential propagation channel and attenuation of the signal radiated from cognitive devices are also key parameters to be analyzed before a sensible discussion on the feasibility of the technology is raised. This paper aims at providing field measurement data that could serve as a reference for the technical discussions around the possible use of White Spaces in the UHF band. This paper does not aim at providing an "a priori" opinion on the use of this spectrum management approach.

In principle, Cognitive Radio proposes that user devices perform a dynamic adaptation of their physical layer to the radio environment on a secondary use of the spectrum basis. The Cognitive Devices (CD) would use information gathering techniques to make intelligent choices for their radio resources: choosing the operating frequency, maximum ERP, modulation parameters etc. These techniques are based on Spectrum Sensing and on geolocation databases that will provide each

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device a reference of the use of the spectrum in the location where the device is operating. With this technology, unlicensed services could temporally use the white spaces of a certain broadcast service area.

Spectrum Sensing techniques are based on signal detection by different signal processing methods. In any of the techniques a problem called Hidden Node Margin (HNM) is a major issue. The HNM represents the difference of the channel usage estimation by the CD and the actual spectrum picture at the receiving antenna of the primary service (in our case Digital TV). Due to this HNM an occupied channel would be identified as free (White Space) by a CD and a potential interference to the primary (to be protected) service would occur.

Previous work on this topic can be found in [2][3][4][5][7]. A theoretical study from the BBC [1] has proposed a reference value of 40 dB for outdoor HNM (10 m to 1.5 m margin) and an additional 20 dB attenuation for the indoor case. Other studies have obtained values that range from 16.6 dB to 33 dB on channel 22. Additional work has based the results on the field strength simulated values provided by different algorithms, including results with 3D ray tracing and conventional UHF empirical and semi empirical methods (ITU-R P.1546). In this case, the values range from 4 to 46 dB.

This work tries to provide consistent values from a carefully planned measurement campaign.

This paper is organized as follows. Section 2 contains a description of the methodology and scenarios. Section 3 contains a discussion on the channel occupancy decision threshold. Section 4 presents a sample of the results that are expected at the end of the project and a discussion based on the first results. Finally, Section 5 contains the conclusions at this stage of the work.

2 Methodology and Scenarios

The first step of this survey was to elaborate an environment classification that would allow extrapolation of the measurement results and conclusions to a number of real cases as wide as possible.

Table 1 shows the features of the different scenarios that have been considered for the measurement campaign. The same table contains the first three measurement locations of the trial that have been used as the reference data for this paper. A higher number of locations have been already planned for a next phase of the research work.

Outdoor roof and indoor measurements were carried out in the three environments. Indoor measurements were performed in each floor of the building under tests, using a dipole antenna at 1.5 m. above the ground level.

At each location, the man-made-noise was evaluated in two frequencies, 408MHz (radioastronomy frequency) and 520MHz (free frequency) to determinate the channel occupancy decision threshold. After obtaining the reference noise value, 1MHz 100 power measures were taken starting from 470MHz up to 870MHz. A second measurement round was carried out at a selected list of channels using a 100KHz resolution bandwidth in order to obtain more accurate data at frequencies where potential doubts of occupancy could appear.

Table 1. Environment Description

	Urban	Suburban	Rural
Characteristics	Buildings with more than 3 floors Heavy traffic	Low-rice buildings and duplex Little traffic	Isolated houses. Usually surrounded by vegetation or in open areas
Place	Bilbao 43º15'40.46''N 2º56'54.80''O	Lezama 43º16'25.15''N 2º49'46.59''O	Maruri 43º23'02.78''N 2º52'19.50''O

The measurement system consisted of an ESPI test receiver (Rhode and Schwarz) connected to a PC and a set of antennas. A calibrated dipole was used for 1MHz measurements (ETS-LINDGREN 3121-D). A logperiodic antenna was used for taking measurements with a 100 kHz resolution. The system was controlled from a PC where data files were also recorded for further analysis. The Test Receiver was configured with a pre-amplifier for higher sensitivity.

Fig. 1. Measurement System. Examples of suburban and urban environments.

3 Decision Threshold

The choice of threshold is an important decision. Its value sets up the condition for channel occupancy decision. If the power measured is above the threshold, the device would decide that the channel is being used. In the same way, if the power is lower than the threshold, the device will decide that the channel is empty.

The election of this parameter has been a difficult choice. Low values lead to noise values higher than the threshold and may mislead the device. On the opposite case, if the threshold is too high, when a signal is extremely low, the device can decide that the channel is empty when it's not, and create interferences.

Based on other researches all the measurements were analyzed with a threshold 3 and 4dB above the power measures. A usual value for this threshold in the literature is

5 dB [4]. It was found that the Radio Noise in rural and suburban environments is below the receiver internal noise (-105 dBm/1MHz, -115 dBm/100kHz). In the case of urban spots, the Radio Noise was 3 dB higher than the equipment threshold.

4 Measurements

The power values measured along the frequency band from 470MHz to 870MHz were compared with the decision threshold. The results obtained are shown in Table 2, for band occupancy calculation. The figures represent the percentage of occupied channels as detected at each location.

Table 2. Spectrum Occupancy

	Rural	Suburban	Urban
Site	Mean percentage	Mean percentage	Mean percentage
Roof	%27.00	%32.25	%28.25
4rd floor			%21.50
3rd floor			%26.75
2nd floor	%18.00	%17.50	%25.00
1st floor	%20.00	%20.00	%25.00
Street		%22.25	
Basement		%3.00	%7.50

The spectral occupancy decision is higher at the roof of each building than the register. These channels present at the roof but not detected at lower locations are signals coming from transmitters outside the service area of the potential interfered transmitters. In any of the cases the spectral occupancy never exceeded the %32 of the band. If a higher threshold is assumed, 4dB above the measurements, the results are very similar and the percentage is reduced by %1.

The hidden node margin has been calculated as the difference of the signal power measured at the roof and all the floors. To show some results we have chosen the channel 22.

Table 3. Hidden node margin

	Rural	Suburban	Urban
Site	HNM(dB)	HNM(dB)	HNM(dB)
4rd floor			17.53
3rd floor			8.21
2nd floor	17.14	16.30	8.85
1st floor	23.50	15.76	12.35
Street		17.91	
Basement		28.86	38.34

The results obtained agree with the references available in the literature. Some theoretical estimations mention values close to 60 dB if indoor reception is considered [1] and in [2] HNM values were obtained in real measurements for different scenarios providing a 28.5 dB difference for outdoor measurements in a 90% of the locations. The values range from 18 dB for rural cases to 37 dB for dense urban spots. Considering that the trials of this paper are indoor, an average building penetration losses need to be added to our values. In that case, the value obtained in the trial ranges from 8 dB to 38 dB (rural and dense urban cases respectively).

5 Conclusion

The present paper investigated the spectral occupancy of the UHF band allocated for TV broadcasting trough real measurements performed in urban, sub urban and rural scenarios at roof, middle floor and basement. Results have shown that a top occupancy of 32% of the bandwidth is achieved in the roof and that the hidden node margin obtained range from 8 to 38 dB on channel 22 depending on the environment and lead to the conclusion that cognitive communications to be performed in the UHF TV band need the joint use of geolocation databases and spectrum sensing technique to avoid harmful interference to the primaries services of the broadcasters.

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