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| **Radiocommunication Study Groups** |  |
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| spectrum management proposAL for A cognitive radios application |
| “national spectrum management” |

1. Introduction

Considering the development stage of cognitive radios technology and the potential of this new segment to improve the spectrum efficiency, this document proposes a new management modality that can innovate the regulation on spectrum dynamic access, optimizing the use of radiofrequencies.

In addition, studies on WRC-12 Agenda item 1.19 and the recent meeting of ITU-R SG1/WP 1B Workshop: Spectrum management issues on the use of white spaces by cognitive radio systems had the recognition of potential benefits and applicability of CRS technologies to various radiocommunication services.

These discussions encourage the Administrations to explore the cognitive radios and highlight the following points;

1. the implementation of CRS will have to be in accordance with the Radio Regulations but also with national regulations;
2. it is noted that there are open issues and specific concerns related to several radiocommunication services that need further studies, especially in the bands shared between several services.

2. Spectrum occupation

In the available literature on cognitive radios there is unanimity opinion for low spectrum occupancy in several telecommunication services, as stated, for example in [1] and [2]. In many approaches it is reported that the radiofrequency use is less of 20%.

3. Evaluated frequencyband

This study evaluated and developed measurements on 450 MHz to 470MHz frequency band [3]. The mentioned frequency band isexplored by communication voice services, for cab groups,aviation support, transportation companies and downstreamindustry. All users are primary with licences and apply the frequency band tocarry out private services.

The equipment used to conduct themeasurements was the FSH8 - Rohde & Schwarz, connected toa J-Pole antenna. The site was in a building roof, located in thefollowing address: Barao de Paranapanema Street, 146, Bosque- Campinas - Sao Paulo - Brazil (urban environment) Latitude:22º 54' 33.25" South / Longitude: 47º 02' 43.61" West -Altitude: 667m.

The data collecting periodwas from 08:00 AM to 18:00 PM hours, in July, 2011, withindustrial and commerce activities running on the whole. Onerepresentative example of the acquired samples (channeloccupation) is presented on figure 1, thatcorresponds to thetime segment (about 40 minutes) of an occupied frequency:457.530 MHz, monitored from 14:19:00 PM to 15:00:20 PMhour. The respective time occupation percentage of frequencywas 34.3 %.



Figure 1: Spectrum occupancy 457.530 MHz: 34.3%.

The criterion to select the channels to be investigated was the frequency monitoring, focus on those that were presenting the major spectrum occupation time. This criterion was selected to check the hypothetic cognitive radio system robustness when the density of primary and the secondary users are high. On average was observed that the channels tested had a relatively low occupation, as can be seen in the graph of figure 2.

In a survey in the range of 450 to 470 MHz, there is 20 MHz bandwidth available, in which there are about 1,600 channels with bandwidth of 12.5 KHz, as standardization of the local telecommunication regulator. Around the measuring point of Campinas, in a radius of 20 km, there are 1,563 authorized (allocated) frequencies. Some mentioned frequencies have irradiation at 100% of the time, which would prevent the use of cognitive radios in these channels in the same region. However, many of the allocated channels (in fact the great majority) have a low occupancy in time domain, so there is a real opportunity to use the spectral spaces for cognitive radios in secondary mode.



Figure 2: Channels occupation in Campinas.

4. Cognitive technology

This document does not have the intention to provide an explanation about cognitive technology, but it is clear that there is a good opportunity to increase the number of users in the same frequencies, allocated to primary users. It will increase the spectrum efficiency use.

Independently of applying properly statistics models, if the average of spectrum occupation is about 26 %, there is 70.4 % free, that can be used by cognitive radios as secondary users. Considering that secondary user will have the same behaviour of primary users, it is possible to insert at least 2 new users in the same frequency.

The secondary users (cognitive radio) have to monitoring the primary user frequency and exploit the same channel when it is free. The cognitive radio also needs to stop periodically the transmission and check if the primary user come back to occupy the channel. It will guaranty the minimal interference in the primary services.

This is a simple spectrum share explanation, but there are numerous studies about the spectrum monitoring techniques and the modeling of radiofrequency use as [3]. The application of properly technology will guaranty that the levels of interference in the primary user communication be so low that it can be imperceptible.

5. Spectrum management proposal

The primary users located in Campinas - Sao Paulo - Brazil have the licences and pay for all the taxes accordingly with Brazilian law. The channel used by this users blocked the others candidates to explore the radiofrequency in the same area. But as mentioned, the occupation is low in terms of time percentage. Therefore, if the cognitive radio be implemented it is possible to increase the spectrum efficiency.

**Method 1**

If the local regulator is very conservator, it is possible to allocate the primary user frequency to secondary users that have the same spectrum occupation model (≤ 30 % of time). In this case it is suggested more two users in the same frequency. The cognitive technology applied needs to guaranty levels of interference in primary users lower than 1 % of time.

In this case, the primary users will not detect any operational degradation in their communications. It is recommended to the local regulator do a properly frequency sharing (number of secondary users) to assure that the services maintain a good quality. The secondary users need to transmit a label code periodically to be identified by the local regulator if it is necessary.

The primary user taxes remain the same, the secondary taxes needs to be lower than the primary ones.

**Method 2**

If the local regulator wants to be more modern and sophisticated in terms of regulation, it is possible to increase more the spectrum occupancy. In this second method, more secondary users (cognitive radios) can be allocated in the same channel. The number of users will depend on the occupation modeling and the degradation that will be accepted by users, or by determination of local regulator, in order to meet more users in the same area.

In this case, the primary users need to know that the frequencies will be shared. Maybe some minimal operational degradation could be detected in their communications. It is recommended to the local regulator do a properly frequency sharing to assure that the services maintain a necessary quality.

The primary user taxes needs to be reduced, the secondary taxes needs to be lower than the primary ones. The number of users includes the primary one is suggested as a preliminary approach in the graphic of figure 3 in a very conservative standard. Statistics studies on spectrum occupation modeling,in the local of operation, can provide a better number of secondary users (cognitive radios).



Figure 3: Suggestion number of users in cognitive system.

Each Administration have to analyse the specific conditions of users operation and study the spectrum occupation modeling, in order to achieve more successes in the scenario. Some operational services could run with 2 or 3% of time degradation without any disturbance on the service. It will permit to increase the number of cognitive users in a safety way.

The table 1 provides a good comparison of the advantages of the methods presented in this document.

Table 1: Proposal methods comparison.



\* Depends on the amount of users.

\* \*Depends on the amount of users and the cognitive technology applied.

6. Conclusion

The currently cognitive radio technology offers many opportunities forthe implementation of new management modality that can innovate the regulation on spectrum dynamic access, optimizing the use of radiofrequencies.

The presented methods are conservative, however, they can be preliminarily implemented and improved in a near future, so the Administrations meet suppressed communication demands and increase the efficiency of use of the radio spectrum.

Nevertheless, each local communications peculiarity needs to be analysed to understand the spectrum occupation modeling of primary and secondary users, and the level of degradation that can be accepted for the services.

7. References

[1] Jaeweon Kim, & Jeffrey G. - Andrews Sensitive White Space Detection with Spectral Covariance Sensing. IEEE Transactions on Wireless Communications, Vol. 9, No. 9, September, 2010.

[2] Simon Haykin. - Cognitive Radio: Brain-Empowered Wireless Communications. - IEEE Journal on Selected Areas in Communications, Vol. 23, No. 2, February, 2005.

[3]7th European Conference on Antennas and Propagation 2013 - EUCAP 2013 - Gothemburg Sweden - 08 - 12 April 2013 - Spectrum Occupation Modeling on the 450 MHz Band for Cognitive Radios Aplication - A. Canavitsas, L.A.R. Silva Mello, M. Grivet - Pontificia Universidade Catolica do Rio de Janeiro – PUC-RJ - CETUC

[4] ITU-R SG 1/WP 1B WORKSHOP: SPECTRUM MANAGEMENT ISSUES ON THE USE OF WHITE SPACES BY COGNITIVE RADIO SYSTEMS - Spectrum management studies, incl. RA-12 & WRC-12 related outcomes

[5]Report ITU-R SM.2152 (09/2009) Definitions of Software Defined Radio (SDR) and Cognitive Radio System (CRS)

[6]Resolution ITU-R58 - Cognitive Radio Systems