White Space Devices - Compatibility with FWA in the 3.4 to 3.8 GHz Band

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Abstract — This paper is oriented to the study of the necessary conditions required, for the implementation of White Space Devices (WSD) in the 3.4 to 3.8GHz band. The study was based on the Fixed Wireless Access (FWA) technology as there were no implementation studies, for WSDs.

It was considered different types of interference, from different interfering-victim relationships situations, as the assigned values differ, either from service to service, but also if it is a terminal or a Base Stations. It must also be noted that in the adjacent channel are considered extra interference phenomena such as blocking and out of band emissions are considered. Therefore, it was necessary to consider measurements in order to mitigate this risk.

The findings of this study suggest that it is possible to implement the use of WSDs for the various scenarios considered, depending on some constraints in terms of distance which also differ from service to service but also from the interfering-victim relationship.

Key Words: WSD, FWA, Fixed service, Nomadic, Offloading, FSI, ITU P.526-2, ERCEG model

I. INTRODUCTION

A cognitive radio system - known as CRS - is a radio employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained [1].

On the other hand a ‘White Space’ is a label indicating a part of the spectrum, which is available for a radiocommunication application (service, system) at a given time in a given geographical area on a non-interfering / non-protected basis with regard to other services with a higher priority on a national basis, and even though a white space device is a cognitive device, White Space Devices (WSDs) are devices that can use White Space spectrum without causing harmful interference to protected services by employing required cognitive capabilities [2].

Although the present technology was only studied, tested and implemented in the TV white spaces on the UHF Band, or TV Broadcasting band, the concept can be implemented in any band, which is the aim of this paper: to study the possible implementation of WSDs in 3.4 to 3.8 GHz bands, given that they do not interfere with the existing services.

The motivation and goals for this paper were to study the availability of implementing WSDs in order to find a solution for the lack of available spectrum assigned to the data mobile services.

II. Background

WSDs are devices that can use white spaces of the spectrum, without causing harmful interference to protected services by employing required cognitive capabilities.

According to CEPT Report 24 [3] a white space is defined as a part of the spectrum, which is available for a radiocommunication application (service, system) at a given time in a given geographical area on a non-interfering / non-protected basis with regard to other services.

It is also important to take notice that the usage of WSDs relies on certain technologies: Spectrum Sensing, Beacon Signals and Geolocation Databases, from which only the Geolocation or a combination of the previous technologies are reliable.

For the implementation study of WSDs three main applications were considered: Backhauling, Nomadic Wireless Access and Traffic Offloading. For each type of application different representative scenarios were considered. Relatively to the chosen band, the 3.4 to 3.8 GHz Band: The Fixed Wireless Access (FWA) was preferred allocated to the 3.4-3.6 GHz band, amongst others, in 1998, through the approval of the CEPT/ERC/REC 13-04, for P-P and P-MP links. At the moment the 3.4-3.8 GHz band has been partly used for FWA regional licences, being therefore eligible accordingly with the study criteria.

Additionally, European Commission has adopted the Decision 2014/276/UE [4] amending Decision 2008/411/EC, adopting the duplex modes proposed by ECC Decision ECC/DEC/(11)06 as well a total new BEM. The power limits from the base station and terminal station within range of 3400- 3800 MHz, adopted by 2014/276/UE will be considered.

III. SCENARIOS AND CONSIDERATIONS

In this paper it was assumed that the WSD will operate under the channelization presented in the new EC Decision, i.e., channels with 5 MHz of bandwidth. Also, the scenarios were established only taking into account the existing spectrum licenses for FWA (where channels of 1 MHz are being used). It is shown on Figure 1 and in the following figures, the different scenarios considered along the 3.4 to 3.6 GHz band for the FDD mode. However, when considering the TDD operation, only one extra scenario had to be studied, as will be explained. Also, it is to be noted that the adjacent channel situation will provide a minimum guard band of 2 MHz.
Fixed Service

As known, the fixed service works with a line of sight condition (respecting the Fresnel zones).

Table 1 – Fixed WSD Characteristics

<table>
<thead>
<tr>
<th>Fixed WSD Terminal TS</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>F(MHz)</td>
<td>3437.5</td>
</tr>
<tr>
<td>Pt (dBm)</td>
<td>28</td>
</tr>
<tr>
<td>G(dBi)</td>
<td>8</td>
</tr>
<tr>
<td>e.i.r.p (dBm)</td>
<td>29</td>
</tr>
<tr>
<td>Effective height (km)</td>
<td>0.03</td>
</tr>
<tr>
<td>B(MHz)</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2 – FWA Base Station Characteristics

<table>
<thead>
<tr>
<th>BTS FWA</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise (dBm)</td>
<td>-106</td>
</tr>
<tr>
<td>G(dBi)</td>
<td>10</td>
</tr>
<tr>
<td>Effective height (km)*</td>
<td>0.1, 0.2, 0.5, 1</td>
</tr>
<tr>
<td>F (MHz)</td>
<td>3437.5</td>
</tr>
<tr>
<td>NF (dB)</td>
<td>8</td>
</tr>
<tr>
<td>B(MHz)</td>
<td>1</td>
</tr>
<tr>
<td>S/N (dB)=</td>
<td>23</td>
</tr>
<tr>
<td>Sensitivity (dBm)</td>
<td>-83</td>
</tr>
<tr>
<td>C/I (dB)</td>
<td>45**</td>
</tr>
<tr>
<td>I/N (dB)</td>
<td>-6</td>
</tr>
<tr>
<td>Imax (C/I)</td>
<td>-128</td>
</tr>
<tr>
<td>Imax (I/N)</td>
<td>-112</td>
</tr>
</tbody>
</table>

*The height of the FWA antenna was derived from the median heights of all the existing Fixed Service antennas.

Note: the range of parameters used on the Base Stations and Terminal Stations are equal, and therefore will not be further repeated.

Also, due to very similar characteristics of both Terminal and Base Stations of FWA, when considered different scenarios over the band, the results achieved won’t change significantly the final result and because of that, it will be only simulated a global scenario for the Fixed Service, i.e., WSD Fixed Station interfering to the FWA BS (as being the worst case).

A. FDD Scenarios

In this first set of scenarios the WSD will be operating in FDD mode. The considered antenna height is 30 m as it is a realistic height for nomadic and offloading scenarios.

1) Scenario 1

In this first scenario it will be considered that the uplink of the WSD will interfere with the FWA service, i.e., the WSD Terminal station will interfere with the FWA Base Station.

Considering the FWA spectrum licence, and the assumed channel arrangement of 5 MHz channels, in this scenario the considered frequency for WSD operation was 3437.5 MHz, which considers the co-channel situation with the last FWA channel – see figure 2 below. As referred above, the frequency of WSD for adjacent channel was 3432.5 MHz.

2) Scenario 2

Scenario 2 considers the interference of a WSD Base station in a FWA Terminal Station. Considering the FWA spectrum licence, and the 5 MHz channels, in this scenario the considered frequency for WSD operation is 3537.5 MHz. The remaining considerations about the co-channel and adjacent channel remain. As it is being also considered the last FWA channel for the co-channel situation, the frequency at the first adjacent channel is 3532.5 MHz.

3) Scenario 3

Scenario 3 considers the interference from WSD in the same FWA frequency block as scenario 2, but in the other edge of the band, i.e., WSD terminal station (UL) is interfering with FWA terminal station. As it can be easily concluded, this scenario is very similar to scenario 2, however, amongst these two scenarios, we concluded that the worst case will be the scenario 2, i.e., it is considered that the it most probable that FWA terminal station (usually located outdoor above rooftop) will suffer interference from the WSD Base Stations (Nomadic and Offloading) because these stations share the same environment. Moreover, as it can be seen in the next figures, this
scenario will occur in adjacent channel only at the duplex gap of 3400-3600 MHz, where a minimum of 10 MHz of guard band is considered.

Figure 3: Detail of the adjacent channel situation for the Scenario 3

B. TDD Scenarios

Similarly to the previous set of scenarios, those as indicated below will only consider the situations where the WSD works on TDD, in the same range of blocks as before, i.e., the channel arrangement adopted in near future will follow a TDD mode. However, it should be noted that the FWA operation will maintain the FDD mode.

1) Scenario 4

In the above scenarios it is considered a WSD FDD mode operation, i.e., the 3410 to 3500 MHz range of frequencies could be used for the WSD uplink. Similarly to scenario 1 the frequency chosen as the worst scenario for FWA is the 3437.5 MHz, although in this case the interference occurs from a WSD Base Station to the FWA Base Station.

Below in tables 3 and 4 is presented the sum of characteristics that will be used along the nomadic and offloading scenarios.

### Nomadic WSD Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS e.i.r.p. (dBm)</td>
<td>29</td>
</tr>
<tr>
<td>TS e.i.r.p. (dBm)</td>
<td>19</td>
</tr>
<tr>
<td>BS Gain (dBi)</td>
<td>8</td>
</tr>
<tr>
<td>TS Gain (dBi)</td>
<td>0</td>
</tr>
<tr>
<td>Effective height (km) BS</td>
<td>0.03</td>
</tr>
<tr>
<td>Effective height (km) TS</td>
<td>0.0015</td>
</tr>
<tr>
<td>B(MHz)</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3– Nomadic WSD Characteristics

### Offloading WSD Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS e.i.r.p. (dBm)</td>
<td>11</td>
</tr>
<tr>
<td>TS e.i.r.p. (dBm)</td>
<td>-2.2</td>
</tr>
<tr>
<td>G (dBi)</td>
<td>0</td>
</tr>
<tr>
<td>Effective height (km) BS</td>
<td>0.01</td>
</tr>
<tr>
<td>Effective height (km) TS</td>
<td>0.0015</td>
</tr>
<tr>
<td>B(MHz)</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 4– Offloading WSD Characteristics

C. Co-Channel vs Adjacent Channel

Considering the frequency arrangements presented in EC Decision (2014/276/UE), i.e., multiples of 5 MHz, the WSD will operate at adjacent channel with a minimum guard band, in relation to the FWA spectrum, of 2 MHz (special case is when WSD UL operates near the duplex gap of the 3400-3500 MHz band, where a minimum guard band of 10 MHz is achieved).

In terms of frequency, the adjacent channel only differs from the co-channel in a range of 5 MHz, as seen before, since the frequency centre for WSD in co-channel case is the same as the FWA channel.

D. Interference Phenomena studied: Blocking and Out-of-Band emissions

The radio spectrum is a limited resource and can only be used optimally if compatibility is assured between radiocommunications systems located in the same or adjacent frequency bands. For example, an important criterion for radio compatibility is the difference between the wanted and unwanted signal levels in the victim receiver input. This parameter is used to derive a separation between the victim and interfering systems or services in geographical space or frequency domain. Considering that the interferer operates only at the adjacent bands of a victim, the most significant interference mechanisms are the unwanted emissions from the transmitters as well as blocking in the victim receiver [5].

In this paper, it is understood that the interference due to unwanted emissions are related to the imperfections of the transmitter which operates in adjacent spectrum that the receiver, i.e., the energy that the transmitter is not able to filter is ‘collected’ by the receiver. In the other side, the imperfections of the receiver will cause interference by blocking, since the filter of the receiver will ‘collect’ energy from adjacent spectrum emissions.

For a typical receiver, the normal operational condition is established by planning the network taking into account its characteristics, namely: the bandwidth (B|MHz), noise figure (NF|dB) and signal-to-noise ratio (S/N|dB). With such it can be derived the minimum level of the received signal that the receiver is able to discriminate from the noise floor – sensitivity. Specific planning considerations, to be adopted by operators, are not taken into account in this paper.

\[
S_{\text{dBm}} = \text{Thermal Noise}_{\text{dBm}} + 10 \log(\text{Bandwidth}_{\text{MHz}}) + NF_{\text{dBm}} + \frac{S}{N_{\text{dB}}}
\]

Moreover, any unwanted signal ‘collected’ by the receiver, coming from other sources, will be summed in power to the noise and will cause a so called ‘desensitization’ of the receiver. This will require an increase of the signal level in order to maintain the S/N relation.

Other way to obtain the maximum interference level, from unwanted emissions, is considering a value for the relation I/N. Generally, I/N=−6 dB protects the receiver against interference, allowing a maximum “desensitization” of 1 dB, which is being considered acceptable. Another method was also used, assuming: C/I=45 dB (ITU-R REC. F. 755-2.) and C/I=28 dB (value from manufacturer).
Therefore, it is calculated the Minimum Coupling Loss (MCL), which is defined as the minimum distance loss including antenna gain measured between antenna connectors [6].

\[
MCL_{db} = -\text{Imax}_{db} + GR_{dbi} + GTx_{dbi} + PITx_{dbm} - \text{PropLoss}_{db}
\]

(2)

where:
- \( Ptx \): power feed to the WSD Tx;
- \( GTx \): Gain, in dBi, of the WSD Tx antenna;
- \( \text{PropLoss} \): propagation loss, in dB;
- \( GRx \): Gain, in dBi, of the Rx antenna;
- \( IMAX \): maximum value of the interference, considering the assumed protection criteria, for both co-channel and adjacent channel.

In order to make such calculations it also needs to be taken into account: the following expressions for the calculation of the maximum interference \( Imax \), for the \( I/N \) and \( C/I \) parameters, Noise Floor and Power Transmission:

\[
P_{eirp_{dbm}} = P_{TX_{dbm}} + G_{DBL}
\]

(3)

\[
P_{TX_{dbm}} = P_{T_{dbm}} + 10 \log\left(\frac{B_{1MHz}}{B_{2MHz}}\right)
\]

(4)

The second part of this equation (4) is only considered when there is the need to convert the power transmission in scenarios where the bandwidths are different [7].

\[
\text{Imax}(\frac{C}{I})_{db} = \text{Sens}_{dbm} - \frac{C}{I_{db}}
\]

(5)

\[
\text{Imax}(\frac{1}{N})_{db} = \text{Noise floor}_{dbm} - \frac{C}{I_{db}}
\]

(6)

\[
\text{Noise floor}_{dbm} = Nth_{dbm/MHz} + 10 \log_{10}(B_{MHz}) + NF_{dbm}
\]

(7)

where \( Nth = -174 \text{ dBm/MHz} \)

If we consider a WSD adjacent channel operation, two different calculations must be performed: protection against blocking and unwanted emissions. For the protection of blocking, and according to [UIT-R REC. F.755-2], \( C/I=0 \text{ dB} \) was considered.

In relation to the unwanted emissions, this paper considered two different spectrum masks: the SEM (spectrum emission mask) defined in the standards, for the WSD Terminal Station, and the Block Edge Mask (BEM) defined in relevant EC Decisions for the implementation of BWA (2008/411/EC) and ECS/LTE (2014/276/UE). The protection criteria used in these calculations was \( C/I=28 \text{ dB} \), as unwanted emissions are considered within the receiver bandwidth (similar calculations for the co-channel scenario, but using the signal level derived from the mask).

It is also needed to be taken into account the antenna radiation pattern, as the interference between antennas might occur from main lobe to main lobe or when the antennas are not aligned, i.e. antenna discrimination.

If antenna discrimination is being considered, it is necessary to consult the UIT-R F.699, 2.1+3 recommendation in order to choose the right value for the antennas alignment.

In extreme situations the antennas are not align by a factor of 39º to 90º in absolute values, translating into an off-axis gain of -6.28 dB.

IV. PATH LOSS PROPAGATION MODELS

A. Free Space Propagation Model

The considered model does not consider any type of attenuation due to buildings, nor line of sight or even vegetation, as such it will be used mainly in the Fixed Service, where is mandatory to have line of sight between the Transmitter and receiver antenna in order for the service to work and for Nomadic and Offloading scenarios when such conditions exist.

Although the present model is considered in most of the previous reports about the current subject, it was considered not to be the worst case scenario (equation 9) and therefore, there will be the need to use a different Path Loss Propagation model, in order to evaluate all the possible interferences.

\[
P_{R_{dbm}} = P_{T_{dbm}} + G_{R_{dbi}} + G_{T_{dbi}} - L_{P_{db}}
\]

(8)

\[
LP_{db} = 32.4 + 20 \log{(f_{MHz})} + 20 \log(d_{km})
\]

(9)

B. P.526-2 Propagation Model

ITU-R P.526 evaluates the effect of diffraction (by terrain irregularities) on the received field strength, applicable to different obstacle types and to various path geometries. It will be mainly used in the fixed scenario, due to the clutter loss obtained from FWA as the working distances might go until 90 km, the occurrence of obstacles interference is vast.

This model was implemented by using the formulae used in SEAMCAT® developed by CEPT.

C. ERCEG Model

Other propagation model used was the ERCEG, also known as 802.16 model, for NLOS environment and nomadic/mobile applications. This propagation model was used in ECC Report 100, for the compatibility between BWA and Electronic News Gathering/Outside broadcasting (ENG/OB), and it was chosen for the compatibility scenarios either in Nomadic and Offloading, from which was implemented option C of this model for Flat/ light Tree density.

Finally, in order to calculate the maximum Transmission Power permitted, for a certain distance, it's only necessary to reorder equation 8 as a reverse engineering calculation, using the value of LP accordingly with the respective propagation model, which varies among scenarios

\[
P_{T_{dbm}} = P_{R_{dbm}} - G_{R_{dbi}} - G_{T_{dbi}} + L_{P_{db}}
\]

(10)
V. CROSS-BORDER REQUIREMENTS

The 3.4-3.8 GHz band has been addressed by European Union. The technical conditions established in these decisions have being drafted based on CEPT Report 15 (based on ECC Report 100) and 49, respectively. In both reports it is clear that cross border issues were not fully analysed. This paper considers some preliminary analysis of border requirements for coordination of operations between Portugal and Spain, as well between the geographical areas, defined at the FWA and BWA structure. With such, it can be compared the results obtained from the above scenarios and the cross border limitations.

Also, during WRC-07 the 3.4-3.6 GHz band was allocated for International Mobile Telecommunications (IMT), providing that the requirement for border coordination is fulfilled. Such provision identifies that the power flux-density (pfd) produced at 3 m above ground shall not exceed - 154.5 dB (W/(m² * 4 kHz)) for more than 20% of time at the border of the territory of any other administration.

It was also recalled that the border requirement for the geographic areas established for FWA and BWA is -122 dBW/MHz/m².

Therefore, in order to compare the results first it will be needed to convert the established power flux density into a maximum value of the Electric Field at the border, which can be derived from equation (12):

\[ E_{\text{Max}}(\text{dB} \mu V/m) \Rightarrow E(dBm.W/m^2) \]

\[ = E(dBmW/m) - 115.8 \]

\[ \Leftrightarrow E(dBmW/m) = E(dBm.W/m^2) + 115.8 \]

Once, the maximum Electric Field is determined, one can calculate the maximum distance considering both the co-channel and adjacent channel, using the equation (13) from UIT – R P. 525

\[ E_{dBm/\mu V/m} = P_{dBm} - 20 \log d_{km} + 74.8 \]

VI. RESULTS AND CONCLUSIONS

Due to the nature of this paper, it only will be presented in the following a summary of the achieved conclusions for all scenarios will be presented.

A. Fixed Scenario Results

From the results obtained it is concluded that in order to be possible the implementation of WSDs in the considered band it is necessary to respect a minimum distance of 25 km or 3.50 km for C/I=28 dB, with a 100 m height antenna (most used), without and with antenna discrimination for the co-channel situation and considering the P.526-2 model. Considering the FSL model there are never reached working conditions.

For the adjacent channel it is noted that the implementation is possible if it is being considered the P.562-2 model. The usage of this model allowed to establish that for Blocking is necessary to maintain a minimum distance of 0.50 km for most used antennas and 1 km for out of band emissions. With antenna discrimination the WSDs can be used freely.

B. Nomadic Scenario Results

For the Nomadic Scenarios it is concluded that in order to such devices to operate without causing harmful interference it is necessary a minimum distance required from the FWA antenna station around:

For Terminal Stations, and co-channel, it is necessary to maintain a minimum distance of 1 km for the manufacturer C/I relationship value, for the most used antennas (30 m), without antenna discrimination and 2.5 km for C/I=45 dB, taking into account the same conditions. It is also important to take notice that those results were achieved while using the ERCEG Model, as the FSL model never meets the operation requirements.

For the Base Station it is necessary to maintain a minimum distance of 1.5 km for the manufacturer value and 3.5 km for the C/I=45 dB, while using the ERCEG model and without antenna discrimination. These values are reduced to 1 km and 1.5 km with antenna discrimination.

Considering the adjacent channel, it isn’t necessary to maintain a minimum distance for the Nomadic Stations as the MCL calculated, demonstrates that no restrictions for the WSD operation will need to be imposed. Nevertheless, it is also possible to operate in Terminal and Base Stations, considering the FSL model, as they retrieve minimum operating distances of 2.5 km for Blocking and SEM LTE and 1 km and 2.5 km for Blocking and BEM LTE.

C. Offloading Scenario Results

For the Offloading Scenarios it is concluded that in order to such devices operate without causing harmful interference it is necessary a minimum distance required from the FWA antenna station around:

Considering Terminal Stations, and co-channel, it is necessary to maintain a minimum distance of 0.5 km and 1 km for the manufacturer value and C/I=45 dB respectively, for the most used antenna (30 m).

If a Offloading Base Station it is being considered it is needed to impose a minimum distance from the antenna around 1 km and 2 km for C/I=28 dB and 45 dB, for the most used antennas.

Considering the adjacent channel, it isn’t necessary to maintain a minimum distance for the Offloading Stations as the MCL calculated, demonstrates that no restrictions for the WSD operation will needed to be imposed. Nevertheless, it is also possible to operate in Terminal Stations and Base Stations considering the FSL model, as they retrieve minimum operating distances of 2.5 km for SEM BWA and 1 km and 4.5 km for Blocking and BEM LTE. This last value reduces drastically if antenna discrimination it is being considered.

It is also concluded that in most cases, except for the fixed service, there is power operating margins, i.e. the considered power can be increased, in order to be able to operate in smaller distances from the antenna station.
The reverse engineering calculation demonstrated that the results obtained from WRC-07 in Table 5 were more restrictive, for both considered channels.

Comparing the results retrieved from the usage of the BEM masks, it is concluded that it should be used the BEM LTE mask in adjacent-channel situation as they retrieved smaller working distances.

As a final conclusion it is seen that even though it was calculated the restrictions distances in the cross border coordination, those are not our worst case, as some of the tested scenarios, never reached or reached higher operating distances.

It is therefore concluded the possibility of WSD implementation along the 3.4 to 3.8 GHz band, for the studied scenarios, if the minimum required operating distances are applied.

For future works, the effects of WSD implementation in aggregated antennas, as well the implementation study of adjacent Adjacent-Channels, who might retrieve less restrictive operating distances. Other implementation studies might be the implementation study of WSDs in other considered bands.

Table 5: Distance at which a WSD can operate, WRC-07 reference

<table>
<thead>
<tr>
<th>TX (dBm)</th>
<th>Gain</th>
<th>e.i.r.p (dBm)</th>
<th>d_h (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Channel</td>
<td>28</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>0</td>
<td>18</td>
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<tr>
<td></td>
<td>26</td>
<td>0</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>4.8</td>
<td>0</td>
<td>4.8</td>
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<tr>
<td>Adjacent Channel, with BWA mask</td>
<td>28</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>8</td>
<td>-40</td>
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<td></td>
<td>-7</td>
<td>5.98</td>
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<tr>
<td></td>
<td>-34</td>
<td>0.27</td>
<td></td>
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</tbody>
</table>

References

[2] ECC report 159 on technical and operational requirements for the possible operation of Cognitive Radio Systems in the ‘white spaces’ of the frequency band 470-790 MHz