Field Trial on Coexistence between IMT and ISDB-T Systems

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Abstract— In Brazil the 698-806 MHz frequency band was reformed and it will be used by mobile operators for the deployment of fourth generation IMT systems after the analog switch-off. That brings the possibility of interference on TV receivers introduced by the incoming system. Therefore, it is important to study the coexistence between both systems. In this paper we show the result of a field trial on the effect of the downlink of an LTE system with 10 MHz bandwidth (763-773 MHz) in an ISDB-T receivers on channel 51 (692-698 MHz). The results show that, for the trial scenario, interference can be identified only in critical cases and can be easily mitigated using filters between the antenna and the ISDB-T receiver.

Index Terms— Field trial, IMT, ISDB-T, interference, coexistence.

I. INTRODUCTION

Terrestrial television (TV) broadcasting uses a valuable spectrum range below 1 GHz. The transition from analog TV to digital releases some frequency bands. These frequencies are known as digital dividend [1], for instance, 698-806 MHz in Brazil and 790-862 MHz in Europe. In Brazil, the frequency band from 470 MHz to 806 MHz was allocated to broadcasting service (analog and digital TV) until November, 2013 [2]. In 2014, the 698-806 MHz frequency band was reformed. Currently, it is allocated for mobile and fixed service, and in the future it will be used for the deployment of IMT (International Mobile Telecommunications) networks, like LTE (Long Term Evolution) systems. After the total transition from analog to digital, which will be accomplished in 2018, the spectrum in Brazil will be designated as shown in Fig. 1.

Broadcasting companies were worried about the fact that LTE systems might cause harmful interference in reception of the channels still allocated to digital TV. This is primarily due to Rec. ITU-R BT.1895, which recommends “that the total interference at the receiver arising from all sources of radio-frequency emissions from radiocommunication services with a corresponding co-primary frequency allocation should not exceed 10% of the total receiving system noise power” [3]. This restriction implies that the interference-to-noise ratio (I/N) should not exceed -10 dB.

Considering the power emission level of an LTE eNodeB, a large percentage of houses with TV could be affected by Rec. ITU-R BT.1895 restriction. Using this recommendation, Vita et al, for example, simulated some scenarios in Italy, and concluded that, in some cases, mitigation techniques
would be necessary in more than 50% of the houses [4].

Although Rec. ITU-R BT.1895 states that there is no harmful interference on TV if the unwanted signal (in this case LTE) doesn’t exceed 10% of the total receiving system noise power of the TV, it is not possible to infer that there will be harmful interference if that restriction is not satisfied. In some countries, field trials were conducted to assess the real conditions of coexistence between IMT and broadcasting systems for some systems and channel arrangements [5]. An interesting fact occurred in England, where estimates of houses that would require a filter to mitigate the interference were constantly revised downwards [6].

To assess the real conditions in which the coexistence between the two systems in Brazil is still possible, field tests were conducted. The purpose of this paper is to show the effect of the downlink of an LTE system with 10 MHz bandwidth (763-773 MHz) in ISDB-T receivers on channel 51 (692-698 MHz). The results show that: (i) the coexistence between the two systems in such scenario is possible; (ii) the interference occurs only in critical cases where the distance between the ISDB-T (Integrated Services Digital Broadcasting Terrestrial) receiver and the eNodeB is very small; and (iii) the interference can be easily mitigated with filters between the antenna and the ISDB-T receiver.

Fig. 1. Spectrum before and after the transition from analog to digital in Brazil. Values in MHz.

II. METHODOLOGY

A. Environment

The field trial took place in Pirenópolis, Goiás, Brazil. Pirenópolis was chosen because: i) there are no TV channels at 700 MHz frequency band; ii) it is surrounded by mountains (interference isolation from other broadcasting transmitters in other cities); and iii) there are no high buildings in the city (the TV and LTE signal is not obstructed). For propagation models, Pirenópolis can be considered a suburban environment.

We used an ISDB-T transmitter (Tx TV), three commercial TV receivers connected to an external passive antenna, an LTE eNodeB and an LTE terminal (a CPE, used to generate traffic). Measurements were done at four points. The location of these points and the transmitters are shown in Table I and Fig. 2.

Measurement point (MP) 1 is the most critical. Fig. 3 shows the propagation environment between the TV receiver (Rx TV) and the eNodeB LTE. The distance between them is about 10 m, and the azimuth angle between both antennas is about 0°. These conditions allow the reception of the highest possible level of LTE signal and still meets the radiated near field condition, in which the point-source
propagation model is acceptable [7].

The purpose of MP2 is test TV reception when the receiver antenna is pointed backwards the eNodeB. At MP3, the receiver antenna points to about 90° of the eNodeB. MP4 shows an intermediate case between MP2 and MP3. At all measurement points, the TV receiving antenna azimuth was adjusted to point toward the TV transmission station.

Transmission of TV signal was as follows: an ISDB-T signal from an existing Digital TV station was received over the air, demodulated and the transport stream was sent to an ISDB-T transmitter tuned at channel 51. It was possible to adjust the transmitter power between 32 dBm and 50 dBm. The signal was filtered (3.6 dB insertion loss) to meet the out of band emission mask [8]. Finally, it was sent to the antenna through a transmission line of 43 m (5.99 dB/100 m loss at channel 51).

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The LTE system had a maximum output power of 40 W per MIMO (multiple input, multiple output) layer. Only one layer was used (1T2R mode). Transmitter antenna had 16.7 dBi gain, 32 dB front to back ratio and 65°H/9°V beamwidth. The CPE was placed far enough from the TV receiving antenna to not interfere in the TV reception, but in a place where it was still possible to establish the LTE connection and load 100% of the resources blocks. The LTE eNodeB had two sectors, but during the tests only one was operating at a time, accordingly to the receivers’ position.

Brazil has adopted the APT (Asia-Pacific Telecommunity) arrangement at 700 MHz (LTE band 28). The uplink and downlink use 703-748 MHz and 758-803 MHz frequencies bands, divided in 9 blocks of 5+5 MHz [2]. In the auction, which happened in 2014, Brazil allowed competitors to bid for the rights of using blocks of 10+10 MHz, starting at block number 2. Therefore, the tests described here used blocks 2 and 3 (uplink: 708-718 MHz, and downlink 763-773 MHz), which is the closest frequency band that will be used by a mobile operator in relation to the last DTV channel (channel 51).

<table>
<thead>
<tr>
<th>Point of interest</th>
<th>Latitude (South)</th>
<th>Longitude (West)</th>
<th>Terrain height (m)</th>
<th>Antenna height antenna (m)</th>
<th>Distance from Tx TV (m)</th>
<th>Distance from eNodeB (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tx TV</td>
<td>15º 50’ 01.70”</td>
<td>48º 57’ 50.08”</td>
<td>1019</td>
<td>36.5</td>
<td>0</td>
<td>2443</td>
</tr>
<tr>
<td>eNodeB LTE</td>
<td>15º 51’ 18.80”</td>
<td>48º 57’ 33.90”</td>
<td>787</td>
<td>12.4</td>
<td>2443</td>
<td>0</td>
</tr>
<tr>
<td>MP1</td>
<td>15º 51’ 19.00”</td>
<td>48º 57’ 33.60”</td>
<td>787</td>
<td>12.0</td>
<td>2450</td>
<td>10</td>
</tr>
<tr>
<td>MP2</td>
<td>15º 51’ 17.10”</td>
<td>48º 57’ 34.30”</td>
<td>788</td>
<td>12.0</td>
<td>2389</td>
<td>53</td>
</tr>
<tr>
<td>MP3</td>
<td>15º 51’ 17.40”</td>
<td>48º 57’ 29.50”</td>
<td>786</td>
<td>12.0</td>
<td>2430</td>
<td>137</td>
</tr>
<tr>
<td>MP4</td>
<td>15º 51’ 25.80”</td>
<td>48º 57’ 35.30”</td>
<td>790</td>
<td>12.0</td>
<td>2646</td>
<td>220</td>
</tr>
</tbody>
</table>
Fig. 2. Pirenópolis: The antenna icon shows the position of the eNodeB LTE. White circles show the measurement points. The black line connects the eNodeB and the ISDB-T transmitter.

Fig. 3. Environment of the measurement point 1.
B. Procedures to test the interference of the downlink of LTE system in the ISDB-T receivers.

The purpose of the downlink test is to check if an LTE eNodeB interferes in an ISDB-T receiver. The interference was assessed by visual observation of the TVs. If harmful interference occurs, ways to mitigate it should be evaluated. The test was based on Rep. ITU-R BT.2215 [9] and consisted of the following procedure:

1) The ISDB-T transmitter was set up to channel 51, which is the nearest channel in relation to the LTE system. The signal was modulated using 64-QAM and the power adjusted so that the TV reception occurred at approximately -74 dBm. This value was chosen because it is 3 dB higher than the minimum receiver level defined at ABNT NBR 15604 [10]. Attenuators can be used to reach the -74 dBm level.

2) The image should be displayed without any loss of quality (artifacts) in all tested TV receivers.

3) The LTE eNodeB was set up to transmit a 10 MHz bandwidth signal with maximum transmitter power (46 dBm). Two cases are verified: with 0% (idle state) and with 100% of the resources blocks loaded.

3.1) It should be noted if there was any loss of quality in TV reception. If not, the test was finished, because in this case the highest possible power of the eNodeB was used.

3.2) If interference occurred, the LTE signal level was decreased until the point that some identified image could be seen at the display. From that point on, the LTE signal level was adjusted, reducing it 1 dB by 1 dB until no harmful interference occurred for 5 minutes. This point is the threshold of visibility (TOV), the point at which picture degradation becomes perceptible [11].

4) When TOV was identified, the power level was measured at channel 51 (Rx TV: 692-698 MHz) and blocks 2-3 (Rx LTE: 763-773 MHz).

5) Steps 2) to 4) were repeated using the maximum power of the ISDB-T transmitter (100 W) and for an intermediate power. If the eNodeB was set up with its maximum power and the power of the ISDB-T receiver was higher than -74 dBm, the ISDB-T transmitter power was reduced to find the TOV.

Fig. 4 shows a simplified workflow of the steps 1 to 4 of the test procedure. The workflow must be repeated according to step 5.

At step 1, the frequency response of the attenuator is constant within the Rx TV and Rx LTE frequency bands.

The LTE system in step 3 was loaded using iperf [12]. When 0% load is set up using iperf, the nominal power is approximately 10 dB higher than the effective transmitted power. This paper shows the nominal values.

Steps 3 and 4 were repeated for each ISDB-T receiver. Initially, the TOV was found for one receiver. Then, the cable was disconnected from the TV and connected to the spectrum analyzer.

After these steps, it is possible to show the cases where interference can be seen at the display of the tested receivers in that scenario. With the three measurements of receiving power Rx TV and Rx LTE,
it is possible to trace the carrier-to-interference (C/I) curve of the receivers.

The TOV was chosen to measure the interference because it reflects the perspective of the viewer. Considering that our aim is check possible interferences between the two systems that might disturb reception of the user TV, we believe that in this case the TOV is more important than the BER (bit error rate).

![Diagram](image)

Fig. 4. Simplified workflow of the steps 1-4 of the test procedure.

### III. RESULTS

After executing the procedure described in the previous section, no harmful interference was found in the three TV receivers at MP2, MP3 and MP4 with LTE transmitting at maximum power and full load. Therefore, the results shown in this section refer only to measures made at MP1. It is worth noting that, at MP1 the distance between the eNodeB and the ISDB-T receiver was only 10 m, and the antennas were aligned – this represents a critical case. That was the only assessed case that allowed us to observe the TOV of the TV receivers.

Table II shows, for each receiver (Rx1, Rx2 and Rx3), the transmitted and receiver power and the load of the eNodeB when TOV was identified. Measurements were made in different days. Fig. 5-7 show, for each receiver, the Rx LTE power versus Rx TV power for idle state and for 100% load. These curves are characteristic of each receiver. In Rx1 is possible to observe a linear trend. For Rx2 and Rx3, the last points indicate that the receivers reach the overload threshold [9].
### Table II. TOV for LTE Transmission Using Blocks 2-3.

<table>
<thead>
<tr>
<th>Load of LTE</th>
<th>Receiver</th>
<th>Tx TV [dBm]</th>
<th>Tx LTE [dBm]</th>
<th>Attenuator [Rx [dB]]</th>
<th>Rx TV (692-698 MHz) [dBm]</th>
<th>Rx LTE (763-773 MHz) [dBm]</th>
<th>Rx TV – Rx LTE [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>Rx1</td>
<td>35</td>
<td>43</td>
<td>10</td>
<td>-74.3</td>
<td>-16.2</td>
<td>-58.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>34</td>
<td>43</td>
<td>0</td>
<td>-64.5</td>
<td>-6.6</td>
<td>-57.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36</td>
<td>46</td>
<td>0</td>
<td>-62.3</td>
<td>-3.4</td>
<td>-58.9</td>
</tr>
<tr>
<td>Idle</td>
<td>Rx2</td>
<td>32</td>
<td>42</td>
<td>0</td>
<td>-67.2</td>
<td>-7.8</td>
<td>-59.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>34</td>
<td>43</td>
<td>0</td>
<td>-64.5</td>
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<td>-57.9</td>
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<td></td>
<td></td>
<td>43</td>
<td>46</td>
<td>0</td>
<td>-56.0</td>
<td>-3.5</td>
<td>-52.5</td>
</tr>
<tr>
<td>Idle</td>
<td>Rx3</td>
<td>32</td>
<td>39</td>
<td>6</td>
<td>-73.9</td>
<td>-16.4</td>
<td>-57.5</td>
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<td></td>
<td></td>
<td>34</td>
<td>42</td>
<td>0</td>
<td>-64.5</td>
<td>-7.6</td>
<td>-56.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40</td>
<td>46</td>
<td>0</td>
<td>-56.0</td>
<td>-3.5</td>
<td>-52.5</td>
</tr>
<tr>
<td>100%</td>
<td>Rx1</td>
<td>35</td>
<td>38</td>
<td>10</td>
<td>-74.0</td>
<td>-12.0</td>
<td>-62.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36</td>
<td>41</td>
<td>0</td>
<td>-63.0</td>
<td>0.5</td>
<td>-63.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41</td>
<td>46</td>
<td>0</td>
<td>-58.5</td>
<td>5.6</td>
<td>-64.1</td>
</tr>
<tr>
<td>100%</td>
<td>Rx2</td>
<td>32</td>
<td>44</td>
<td>0</td>
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<td>-5.9</td>
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<tr>
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<td></td>
<td>50</td>
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<td>-49.4</td>
<td>3.6</td>
<td>-53.0</td>
</tr>
<tr>
<td>100%</td>
<td>Rx3</td>
<td>35</td>
<td>36</td>
<td>10</td>
<td>-74.0</td>
<td>-14.1</td>
<td>-59.9</td>
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<tr>
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<tr>
<td></td>
<td></td>
<td>50</td>
<td>41</td>
<td>0</td>
<td>-49.4</td>
<td>0.4</td>
<td>-49.8</td>
</tr>
</tbody>
</table>

Fig. 5. Rx TV versus Rx LTE for Rx1.
Overloading starts when the interference power is very high. The normative adjacent channel leakage ratio (ACLR) of an LTE eNodeB is -64 dB for 10 MHz. The eNodeB under test has an ACLR much better than the normative – Fig. 8. Thus, this indicates that the interference at the receiver is due to its low selectivity (ACS – adjacent channel selectivity), which allows the ISDB-T receiver to receive the LTE signal at blocks 2-3. In this case, the out-of-band emission of the eNodeB can be neglected.
The low selectivity of the filter of the receivers can be compensated using external filters connected between the antenna and the ISDB-T receiver. To validate this mitigation technique, two prototype filters were tested. Their frequency responses are shown in Fig. 9. Table III shows the effect of the filters in TV reception at MP1 for an LTE system with 100% of load. The main difference between the filters is that the slope of filter 1 is higher than the slope of filter 2 in the LTE uplink region (703-748 MHz) as well as the interference rejection in the LTE downlink region (758-803 MHz). Despite the differences, both filters solve the harmful interference.

![Fig. 8. ACLR of eNodeB.](image)

![Fig. 9. Frequency response of the filters 1 and 2.](image)
IV. CONCLUSIONS

This paper shows the effect of the downlink of an LTE system with 10 MHz bandwidth (763-773 MHz) in ISDB-T digital TV receiver on channel 51 (692-698 MHz). Harmful interference was identified only in critical cases, in which the TV receiving antenna was very close and aligned to the transmitter eNodeB. In this case, harmful interference can be easily solved using filters between the antenna and the ISDB-T receiver.

With the data presented in this paper it is possible to understand the effect of the LTE downlink interference under the field trial conditions, but in order to establish a TV receiver protection ratio from LTE downlink, studies in controlled environment (laboratories), with additional TV receivers that better represent the quality variance of the receivers installed in houses are needed. Trials and laboratory tests are complementary evaluations.

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