Experimental Analysis of 3.5 GHz WiMAX 802.16e Interference in WiMedia-defined UWB Radio Transmissions

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Abstract - The interference produced by WiMAX mobile wireless transmissions operating in the 3.5 GHz band on a WiMedia-defined ultra-wideband (UWB) wireless link is experimentally analyzed in this paper. The investigation includes standard IEEE 802.16e WiMAX, and ECMA-368 UWB equipment as defined by the WiMedia alliance. A conventional meeting room scenario has been considered for the measurements. The experimental results indicate that WiMAX transmitters must be located at distances larger than 5 m from the UWB receiver to guarantee successful UWB communication.

Keywords - Ultra-wideband, WiMAX, radio interference, wireless coexistence, communication systems regulation

I. INTRODUCTION

Ultra-wideband (UWB) wireless technology is receiving a large amount of interest for the deployment in a very broad range of applications, from computer peripheral integration over wireless USB to home multimedia streaming. UWB is a short-range high-bit rate radio communication technology potentially exceeding 1 Gbit/s bit rate [1]. This technology exhibits unique characteristics, such as very low power transmission and consumption, high tolerance to multi-path fading, low probability of interception and low cost [2]. Successful market introduction of UWB requires an adequate worldwide regulatory framework in order to guarantee smooth coexistence with existing incumbent and future services sharing the same frequency bands.

UWB applications operate in the same bands as microwave access (WiMAX) wireless transmission technology, which targets medium to large range communications. WiMAX is expected to support future wireless local area networks. UWB radio can operate in the 3.1-10.6 GHz band in current North America regulation [3]. First generation UWB systems in the market operate in the 3.1 to 4.9 GHz band, thus overlapping with WiMAX IEEE 802.16d/e systems in the 3.5 GHz band [4-5]. These systems are employed in indoor broadband wireless access (BWA).

Coexistence of UWB with narrowband wireless systems such as UMTS, GSM, GPS and satellite DTV have been investigated in [6]-[9]. The impact of UWB interference on WiMAX in the 3.1 to 4.2 GHz band has been recently studied analytically in [10,11]. In this paper, the interference produced by WiMAX transmitters operating in the 3.5 GHz band on UWB is experimentally investigated to assist related European spectrum policy development.

Interference of WiMAX transmissions on UWB wireless links in a real user scenario, i.e., a meeting room with human activity, is investigated in this paper. The impact of WiMAX transmissions with channel bandwidths (BW) of 5, 10 and 20 MHz on a WiMedia-compliant UWB wireless link is measured at different separation distances and the relevant protection margins are identified for the scenarios analyzed.

This paper is divided into five sections. Section II describes the UWB radio environment analyzed in this radiated experiment. Section III presents the experimental set-up including the radio configurations. In Section IV, the experimental results are described and discussed. Finally, the main conclusions of the experiment are presented in Section V.
II. SCENARIO UNDER ANALYSIS

The scenario considered in this analysis is a complex radio office environment (e.g., a meeting room) where UWB and WiMAX are operating in the presence of other wireless technologies, such as Wi-Fi and Bluetooth. The potential interference in this scenario comes from transmitters located inside the area under analysis at close distances.

UWB wireless operation is expected for short-range applications like audio transmission (e.g., smartphone wireless headsets), file sharing and printing (e.g., wireless USB hard discs and portable printers) and high definition video streaming (e.g., UWB-enabled projectors). WiMAX transmissions are also expected from WiMAX-enabled electronic devices, such as laptops, smartphones and other business devices. WiMAX connectivity is intended for wireless local area networking and Internet access. This scenario is depicted in Figure 1(a).

Figure 1(b) is a picture of the office environment used for this experiment. This office scenario is located in the Universidad Politécnica de Valencia, building 8G, fourth floor. Within this environment there are typical office materials and furniture made of wood, plastic and metal. There is also a Wi-Fi network operating at 2.4 GHz in the area.

Figure 1(c) shows the precise location of the measurement equipment in the room. This figure shows an UWB transmitter and receiver (UWB Tx and Rx blocks in Figure 1(c)) located along the longitudinal direction of the room. An interfering WiMAX transmitter (WiMAX Tx block in Figure 1(c)) is located at a 30 degree angle from the UWB link line-of-sight direction. The point marked <A> is shown in Figures 1(b) and 1(c) for future reference.

III. MEASUREMENT SET-UP

Figure 2 shows the experimental setup. This setup consists of a point-to-point WiMedia-defined MB-OFDM UWB link following the ECMA-368 standard [3]. The link distance is fixed at $d_{UWB}=1$ m. An IEEE 802.16e WiMAX interferer is located 30º from the UWB link line-of-sight direction. UWB performance is measured for different WiMAX configurations at different interferer distances, $d_{WiMAX}$. The UWB link degradation is evaluated by measuring the error-vector magnitude (EVM) parameter from the received UWB constellation.

The WiMAX interference distances are selected in compliance with the ECC report for future UWB detect-and-avoid (DAA) techniques [12]. This report defines three zones according to the licensed service signal level detected by the UWB transceiver. WiMAX distances are precisely selected to fit those zones: 0.36 m, 1 m and 1.7 m for zone #1, 3 m and 5 m are selected for zone #2, and 8 m and further is selected for zone #3.

A. UWB victim link

The UWB signal is generated following the WiMedia-defined UWB specification, as described in the ECMA-368 standard [3]. The transmitted signal, generated by a Wisair DV9110 module, comprises three channels with 528 MHz bandwidth. Each channel bears one orthogonal frequency-division multiplexed (OFDM) signal comprising 128 carriers modulated in quadrature phase shift keying (QPSK), 6 null carriers, and 12 pilot tones. Achievable bit rates range from 53.3 – 480 Mbit/s. The DV9110 transmits a signal that hops among three adjacent bands according to the specified time-frequency code (TFC). The bands are centered at 3.432 GHz (band #1), 3.96 GHz (band #2), and 4.508 GHz (band #3).
Table I describes the four UWB operational configurations considered in this analysis. The two hopping sequences are TFC 1 = \{1, 2, 3, …\} and TFC 5 \{1, 1, 1, …\}, and the two bit rates are 53.3 Mbit/s and 200 Mbit/s. Note that TFC 5 employs only band #1; hence, no hopping is employed.

<table>
<thead>
<tr>
<th>Table I. UWB LINK PARAMETERS</th>
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<tr>
<td>Time frequency coding</td>
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<td>Hopping sequence</td>
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<tr>
<td>Band group #1</td>
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<td>Center frequency</td>
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<td>Bit rate</td>
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<td>EIRP</td>
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Two UWB omnidirectional patch antennas (In4Tel-omni, 0 dBi gain) are employed in the UWB link. The antennas are located at 1 m height and separated by \(d_{\text{UWB}}=1\) m. The set-up shown in Figure 2 includes a low noise amplifier/attenuator pair (Amp 1, Att 1) to adjust the maximum transmitted power to equivalent isotropic radiated power (EIRP) limit at ECMA. In this case, power spectral density (PSD) is adjusted to \(-41.3\) dBm/MHz following current regulation [6].

The UWB receiver consists of a digital signal analyzer (Agilent Tech. DSA 80000B). A low-noise amplifier (Amp 2 in Figure 2) is used to adjust the received UWB signal to the DSA dynamic range. The EVM of the received UWB signal is measured to evaluate the link distortion due to the presence of the WiMAX interferer.

B. WiMAX interferer

The WiMAX interferer in the set-up shown in Figure 2 corresponds to a BWA indoor terminal following the IEEE 802.16e standard. WiMAX utilizes scalable orthogonal frequency-division multiple access (SOFDMA) QPSK modulation. The signal is centered at 3.5 GHz following the European regulation [13].

The main WiMAX signal parameters are summarized in Table II. This signal is synthesized by software (Agilent N7615B signal studio) and generated by a vector signal generator (Agilent ESG 4483C) with 15 dBm power level measured at its output port. This level is translated to 23 dBm EIRP after the WiMAX antenna (9 dBi gain indoor planar antenna HUBER+SUHNER SPA 3500/65/9/0V). This transmission level is in accordance with IEEE Std. 802.16 Part 3: Radio Conformance Tests [14] and meets ECC/DEC/(07)02 (BWA services operating at 3.4 - 3.8 GHz) [13].

<table>
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<th>Table II. WiMAX INTERFERER PARAMETERS</th>
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<tr>
<td>Center frequency</td>
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<tr>
<td>Bandwidth</td>
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<td>FFT-points</td>
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<td>Subchannel spacing</td>
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<td>Oversampling rate</td>
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<td>Guard period</td>
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<td>Symbol duration</td>
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<td>Modulation</td>
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<td>Downlink data rate</td>
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Three possible bandwidths (5, 10 and 20 MHz) are considered in the measurements. Figure 4 illustrates WiMAX spectra measured at the transmit antenna (reference point 4 in Figure 2) for the three bandwidths with 10 dB attenuation.

Figure 4. WiMAX spectra for bandwidths of (a) 5 MHz, (b) 10 MHz, and (c) 20 MHz measured in RBW=1 MHz at the transmit antenna

IV. MEASUREMENT RESULTS

Figure 5 shows an example of the UWB received spectrum (53.3 Mbit/s bit rate) in the presence of WiMAX (5 MHz BW) with \(d_{\text{WiMAX}}=1\) m measured at reference point 3 in Figure 2.

Figure 5. UWB signals (53.3 Mbit/s) for (a) TFC 1 and (b) TFC 5 in presence of a WiMAX signal (BW=5 MHz) at \(d_{\text{WiMAX}}=1\) m separation measured in RBW = 1 MHz
In Figure 5 it can be observed that there is frequency overlap between WiMAX and the UWB band #1. Figures 6 and 7 illustrate the impact of WiMAX on the UWB link for TFC 1 and TFC 5, respectively. Error vector magnitude (EVM) of the UWB constellation is plotted versus separation distances ranging from 36 cm to 8 m. Data points are given for UWB bit rates of 53.3 Mbps and 200 Mbps and WiMAX bandwidths of 5, 10, and 20 MHz. The 18.8% EVM threshold for successful UWB link operation [3] is also shown.

Figure 6. EVM of UWB link (TFC 1) versus separation with interfering WiMAX transmitter

Figure 6 indicates that for the TFC 1 UWB configuration, EVM is under the 18.8 % threshold only when the WiMAX interferer is located at 5 m or further from the UWB link. In Figure 7 for the TFC 5 UWB configuration, the UWB EVM threshold is still not achieved even when the separation of the interfering WiMAX transmitter is greater than 8 m (the maximum distance in the measurement room). This implies than special protection techniques, like detection-and-avoid [12] should be included in this case. These rules hold for any WiMAX bandwidth measured, as shown in the figures.

Figure 7. EVM of UWB link (TFC 5) versus separation with interfering WiMAX transmitter

Comparing Figures 6 and 7, it can be seen that EVM results in the TFC 5 case, with WiMAX is in operation, are worse than the TFC 1 case. For example, at TFC 5 53.3 Mbit/s UWB link, EVM changes from 7.10 % without WiMAX to 41.31 % at 3 m distance, and to 23.33 % at 8 m distance (WiMAX BW 5 MHz). When TFC 1 is used, which implies frequency hopping, the WiMAX interference is not so harmful for the transmission. For example, at TFC 5 53.3 Mbit/s, the EVM shifts from 7.53 % to 26.12 % at 3 m interference distance and to 12.86 % at 8 m (WiMAX BW 5 MHz).

WiMAX bandwidth has an impact on the UWB transmission. The experimental results show that a UWB TFC 1, 200 Mbit/s configuration interfered by WiMAX at 10 MHz (5 m distance) permits UWB operation. However, if a WiMAX 20 MHz configuration (5 m distance) is present, the UWB link cannot be established.

In general, a UWB link using TFC 5 is more susceptible to WiMAX interference than one using TFC 1. This is due to the fact that information is transmitted on a single band (band #1 of 528 MHz BW) always exposed to the WiMAX signal. However, TFC 1 includes a frequency hopping over three bands and the UWB signal is interfered by WiMAX only a third of the UWB transmission time.

Figure 8 represents EVM for each UWB sub-carrier when WiMAX (5 MHz BW) is present at d_{WiMAX}=1 m measured over 23 UWB symbols. In addition, the error vector magnitude rms (EVM) in terms of relative constellation error (RCE) is plotted as a continuous line, in order to analyze UWB link degradation. Again, the UWB system exhibits more performance degradation when the TFC5 configuration is used compared to the TCF1 case, due to the transmission over just one channel.

Figure 8. UWB EVM for each sub-carrier. UWB links (53.3 Mbit/s) for a)TFC 1 and b)TFC 5 in presence of interfering WiMAX transmitter (BW= 5 MHz) at d_{WiMAX}=1 m

V. CONCLUSIONS

The impact of an IEEE 802.16e WiMAX interferer on a WiMedia-defined (ECMA-368) UWB link (1 m distance, 53.3 Mbit/s and 200 Mbit/s bit rate) has been analyzed. The experimental results indicate that the WiMAX interferer should be located further than 5 m (UWB TFC 1 configuration from the UWB link to meet the 18.8% EVM threshold required in UWB communications. In the case of UWB TFC 5, the WiMAX interference strongly degrades EVM even at 8 m (distance of the large meeting room scenario considered). This indicates that detection-and-avoid or other mitigation techniques should be included in this specific situation.

DISCLAIMER

Certain commercial equipment, software, and materials are identified in this article to specify technical aspects of the reported results. In no case does such identification imply
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