Rajesh Thakare, Kishor Kulat / IOSR Journal of Engineering *(IOSRJEN)*
www.iosrjen.org
Vol. 1, Issue 1, pp. 037-040

Evaluation of UWB Interference on WiMAX

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Abstract— This paper describes the analysis of UWB interference on WiMax systems. Co-existence between these two systems is important due to unlicensed use of 3.1 to 10.6 GHz frequency band by UWB. The interference impact of UWB devices entirely depends on the victim receiver characteristics. From the knowledge of noise density and allowable maximum noise raise in WiMax receiver, maximum permissible interference due to UWB devices is calculated. For the co-existence between UWB Transmitter & WiMax Receiver for the given parameters distance and Probability of interference is calculated.

Keywords-UWB; WiMAX; Co-existence.

I. INTRODUCTION

UWB was originally a term used to describe impulse-based technologies whose use was restricted to the U.S. military for national security reasons. With advances in communications and semiconductor technology in the late 20th century, however, commercial applications for UWB-based communications emerged. In early 2002, the U.S. Federal Communications Commission (FCC) approved UWB for commercial communications applications. At that time, the FCC defined UWB as any radio technology with a spectrum occupying greater than 20 percent of the center frequency or a minimum of 500MHz bandwidth, and allocated unlicensed spectrum between 3.1 GHz and 10.6 GHz for enterprise and consumer applications [2].

Ultra Wideband (UWB) technology, due to its large bandwidth, is capable of supporting high data rate applications. The Federal Communications Commission (FCC) agreed in February 2002 [14] to allocate 7.5 GHz of spectrum for unlicensed use of UWB devices for communication applications in the 3.1 GHz to 10.6 GHz frequency band . UWB came to be known for the operation of sending and receiving extremely short burst of Radio Frequency (RF) energy. The UWB communication devices are a very good choice for indoor high data rate wireless applications. Potentially a large number of UWB devices may operate in close proximity of an indoor wireless application such as Wireless Local Area Network (WLAN). The UWB signal is a very low power signal and therefore the power of any single UWB device can be compared to that of a noise floor.

Worldwide Interoperability for Microwave Access (WiMAX) forum promise to offer high data rate over large areas to a large number of users where broadband is unavailable. This is the first industry wide standard that can be used for fixed wireless access with substantially higher bandwidth than most cellular networks [2]. The first version of the IEEE 802.16 standard operates in the 10–66GHz frequency band and requires line of sight(LOS) towers. Later the standard extended its operation through different PHY specification to 2-11GHz frequency band enabling non line of sight (NLOS) connections, which require techniques that efficiently mitigate the impairment of fading and multipath [1].

Considering the UWB (Ultra Wide Band) permitted region of operation from 3.1 GHz to 10.6 GHz, 802.16a technology is particularly affected as it lies in the main UWB transmission band. One of the systems whose operation could be harmed by UWB interference is Wi-Max IEEE 802.16a based Fixed Broadband Wireless Access (FBWA) system and IEEE 802.16e based mobile broadband wireless access (MBWA) in NLOS operation

Ultra Wideband (UWB) is a term used to describe the nature of an RF signal which occupies a large bandwidth and which is intended for very-high-speed data transmission. Because of its wide spectrum occupancy, UWB signals coexist with other wireless communication systems. Regulators have defined emissions masks for UWB transmission to avoid harmful interference to existing or planned wireless communication services.

These constraints are in line with the planned commercial use of UWB for short range, high data rate communication in Wireless Personal Area Networks (WPAN).One significant example of coexistence is with the WiMAX (Worldwide Inter-operability for Microwave Access) communication systems, which are or will be operating in a number of bands in the 2.3 GHz, 2.5 GHz, 3.5 GHz or 5.8 GHz frequency ranges.

WiMAX provides medium to long range communications for a number of applications with the primary objective to provide broadband wireless access (BWA). WiMAX specifications were developed by the IEEE and WiMAX standards are currently maintained and promoted by the WiMAX forum [3]. There are currently two main sets of standards: IEEE 802.16-2004 (also called IEEE 802.16d) for fixed applications and IEEE 802.16e-2005 to support mobility [3].

The organization of the paper is as follows : Section 2 presents the background on UWB and WiMax system. Section 3 gives the result of interference between these two systems and paper conclusion is given in section 4.

II. Related Work Of Coexistence Of UWB With Other Communication System

In this section, we will present works related to the coexistence between UWB systems and other communications systems. Hamalainen et al. studied the coexistence of a UWB system with GSM900, UMTS/WCDMA, and GPS [5]. They gave the bit error rate (BER) of the above mentioned systems for different pulse lengths. Hamalainen et al. investigated the coexistence of the UWB system with IEEE802.11a and UMTS in modified Saleh-Valenzuela channel [6]. They gave the BER of a UWB system for different types of modulation (direct sequence and time hopping). Guiliano et al. studied the interference between UMTS and a UWB system [7]. In [8], Hamalainen et al. investigated the effect of the in band interference power caused by different kinds of UWB signals at the UMTS wide band CDMA (WCDMA) frequency bands. The UWB interference was given for the UMTS/WCDMA uplink and downlink. In [9], Hamalainen et al. studied the effect of the in band interference power caused by three different kinds of UWB signals on GPS L1 and GSM-900 uplink bands. None of the above mentioned works studied the effect of the UWB interference on the urban macrocell range or capacity. In [10], the bit error rate of the WiMAX system is given when it is affected by UWB interference caused by multiple UWB transmitters. In [11], the BER of the WiMAX system affected by multiple pulsed UWB transmitters is given. Neither[10] nor [11] have studied the effect of the UWB interference on the WiMAX range. In [12], the impact of the WiMAX interference on MB-OFDM UWB systems has been given. The bit error rate of the MB-OFDM system has been given for different values of SINR and different scenarios. In [13], the performance of bit-interleaved coded OFDM systems impaired by ultra-wideband (UWB).

III. Analysis Of UWB Interference On Wimax System

A Interference Effects on IEEE 802.16d WLANs

WiMax is an acronym that stands for "Worldwide Interoperability for Microwave Access"

- Fixed WiMax
  - This is called as IEEE 802.16d-2004.
  - Frequency band: 2 GHz - 11GHz.
  - Data rate: upto75 Mbps.
  - Distance covered: Approximate 30 miles (50 km).
  - Single-carrier PHY.
- Mobile WiMax
  - This is called as IEEE 802.16e-2005.
  - Frequency band: 2GHz-6GHz.
  - Data rate: 1 Mbps-75 Mbps.
  - Distance covered: Approximate 10 miles (15 km).
  - Multi-carrier PHY.

In this section, we consider the specific performance degradations to IEEE 802.16d systems resulting from UWB interference. The IEEE 802.16d and 802.16e standards are specifications for wireless local area networks.

Consider the situation where a WiMax node is surrounded by several UWB transmitters in a two-dimensional setting. Fig. 1 shows the model scenario, where the victim receiver is placed at the center of two concentric circles.

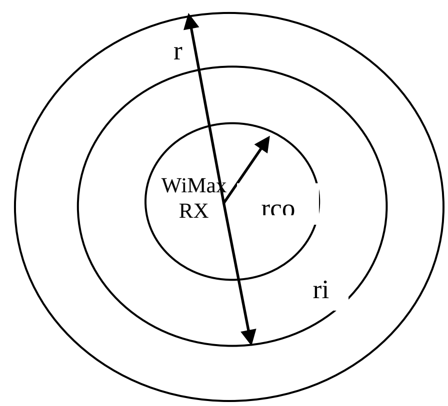

Fig.1: The interference scenario of a WiMax receiver along with UWB transmitters.

The victim WiMax receiver is shown in Fig 1 is in the center of the circles. The inner circle defines the boundary of a UWB-free zone; that is, no UWB transmitters are closer to the victim than with rco $_{min}$. In between the inner and outer circles (given by r_{max}), the UWB transmitters are distributed uniformly over the surface. All the interfering UWB devices are assumed to be transmitting with equal power. This power is given by the maximum PSD defined in the relevant frequency band by the FCC emission mask, as well as the actually employed bandwidth of the victim system.

The interference impact from incumbent UWB devices entirely depends on the victim receiver characteristics such as noise floor, receiver sensitivity, bandwidth, acceptable interference criteria, etc. So WiMAX must design with low cost, small size and low power consumption. Noise Floor (NoF) is the integration of noises, losses & errors present over the effective operating bandwidth at the WiMAX receiver. It includes thermal noise, mixer noise, synthesizer noise & several errors such as estimation error, tracking error. ImL is the implementation loss, including the non-ideal receiver effects such as channel estimation errors, tracking errors, quantization errors & phase noise. The increase of NF or ImL reduces the receiver activities which results in a higher level of received signal requirement. We define the Noise Density (ND) when the NoF is normalized with 1 MHz of channel bandwidth and is given by

$$ND = TN + NF + ImL \quad (1)$$

NF and ImL are the critical parameters for analyzing receiver sensitivity, since TN will remain more or less constant at room temperature.

The receiver sensitivity (R) is the summation of ND and the minimum acceptable signal to noise to ratio (SNR). SNR is determined usually by the type of modulation & coding used in the system if the standard Bit Error Rate (BER) is met. The receiver sensitivity R is given by,

$$R = ND + SNR + 10log_{10}(BW) \quad (2)$$

BW is effective bandwidth in MHz.

For WiMax receiver, the maximum permissible interference due to UWB can be given by

$$I_{UWB} = ND + 10\log_{10}\left(10^{N_r/10} - 1\right) \quad (3)$$

Where, N_r is maximum allowable noise raise in WiMax receiver in dB.

The minimum coupling loss gives the minimum protection distance between UWB Transmitter & WiMax Receiver.MCL is given by

$$MCL = P_{t(UWB)} + G_{t(UWB)} + LRF_{(UWB)} - G_{t(WiMax)} - I_{(UWB)} \quad (4)$$

The victim receiver has certain noise figure and is within LOS of UWB transmitter such that free space loss equation applies, then we calculate the distance at which received power will equal to permissible input of incumbent receiver, for a given UWB transmitter power.

$$Path\ Loss = 20log_{10}\left(\frac{4\pi}{c}\right) + 20log_{10}(f) + 20log_{10}(ri) \quad (5)$$

Where ,f is center frequency MHZ, c is velocity of light m/s and ri is radius in meter.

The probability of interference is given by

$$\int_{rco}^{ri} \frac{2ri}{r^2 - rco^2}\ dri \quad (6)$$

Where, ri is interference zone radius and receiver inner radius is rco.

IV. RESULT

Fig 2 shows maximum allowable interference input power corresponding to the permissible noise at WiMax client for NF and IL of 5 and 0 dB respectively

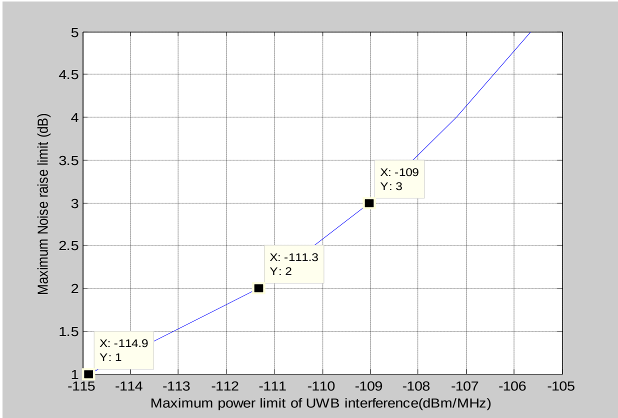

Fig.2Maximum Interference power with respect to Noise Raise

For UWB Transmit Power -65 & -70 dBm/MHz , Gain 0dB, RF Loss1dB,WiMax Frequency 3.5GHz and receiver gain 0dBm the distance between UWB Transmitter & WiMax Receiver is shown in Fig.3 for different value of noise raise

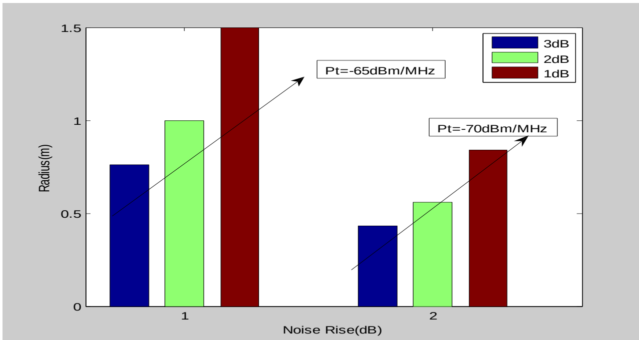

Fig. 3 Effect of Noise Raise on Distance

Probability of interference and distance between UWB Transmitter & WiMax for different value of noise raise is shown in Fig.4

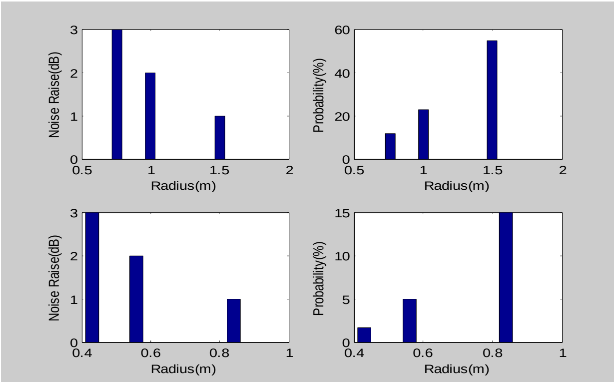

Fig. 4 Probability of Interference with respect to Distance

V. Conclusion

From the result it Shows that as permissible noise raise at WiMax receiver increases the maximum UWB interference power increases. From the bar chart, for Nr=2 dB and Nf=5dB, interference effect of UWB on WiMax is negligible if interferer is located beyond 1m for -65dBm/MHz transmit power and 0.56m for -70dBm/MHz transmit .Hence if transmit power of UWB is increases then distance between UWB Tx & WiMax Rx is increases .So as the value of Nr increases the distance is decreases and Probability of interference also decreases.

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