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Performance Analysis of WiMax Receiver in presence of Ultra-Wideband System

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Abstract— Ultra-wideband (UWB) signal with a large bandwidth has some advantages for instance multipath immunity, low transmission power, good resolution for ranging and detecting geo locations as well as restricting narrow-band interference. However, the main disadvantage is overlapping with existing narrowband-wideband cellular communication system operating simultaneously in the same area. WiMax is one of the 4G wideband cellular systems which are affected by narrowband UWB interference. Hence in this paper, path loss model and WiMax receiver characteristics have been determined to examine the coexistence issue between these two systems. Again, receiver sensitivity of different coding schemes and different antenna heights are considered to obtain the maximum cell radius with minimal interference.

Keywords- *UWB, WiMax, Receiver Sensitivity, Path Loss, CER.*

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I. INTRODUCTION

Ultra wideband technology is capable of transmitting enormous digital data over a wide spectrum of frequency bands with very low power in a short distance. The low-power, huge spatial capacity, and high precision ranging of ultra-wide-band (UWB) communications promise to address the needs of the quickly growing home networking market that are not currently being met by the existing communication techniques [1]. According to the Federal Communications Commission (FCC), the UWB operating bands is restricted to 3.1-10.6 GHz with maximum transmission power of -41.3 dBm/MHz. Hence, the usage model of both UWB and WiMax will be in very close proximity to personal computer, Laptop, mobile handset etc [2]. However, the main disadvantage of UWB is overlapping with different narrow band systems for its very large bandwidth. To minimize this problem, the WiMax receivers can reveal the presence of a victim terminal by measuring the power in its transmitting or receiving operative bands. When the presence of the victim is asserted, the UWB modifies its transmission parameters in order to avoid overlap [3].

In this paper, the coexistence issue between an UWB-based system and a 4G WiMax cellular system has been studied. As the coexistence of UWB system with WiMax has been investigated thoroughly in the literature [4] where the maximum allowable noise raise parameter has been fixed up to 3 dB to solve the interference problem, but the cell radius reduction is the prime concern to obtain the better performance for WiMax system. The reduction of cell radius due to UWB interferer can be estimated in two steps: a) Firstly, the tolerable noise raise limits are analyzed which will present a given level of UWB signal at the WiMax receiver. b) Secondly, the reduction of cell range is computed with introducing a fixed CER and antenna heights of the WiMax system. Also different parameters of WiMax receiver have been analyzed such as noise density, receiver sensitivity and height of different antennas effect to get the maximum interference limit from UWB to WiMax receiver. Afterwards, the cell radius is premeditated according to the change of different antenna heights to acquire the better performance for WiMax system.

The calculation of cell radius has been obtained for the different heights of base station with a fixed height of SSR. By considering the proposed height of base and subscriber station antenna from analytical result, the cell range has been increased a lot compared to all previous results.

II. WIMAX RECEIVER CHARACTERISTICS

WiMax base stations are known as WiMax tower or Booster which operate as wireless mobile network. The connectivity between two base stations is done by using high speed microwave link known as backhaul. The subscriber station receiver (SSR) receives the radio frequency signal from the WiMax base station receiver (BSR) and provides connectivity to the WiMax network. WiMax subscriber can be indoor or outdoor depending on the available distance to the nearest WiMax base station tower.

The BSR uses large size high gain directional antenna for power consumption that gives better performance than SSR. The performance of SSR may also be improved by selecting an antenna that has high gain and good omni directional radiation pattern. Therefore, the selection of SSR is one of the important issues to avoid interference [4].

Subsequently, the interference of WiMax antenna from UWB devices may depend on the characteristics of different receiver parameters such as Noise Density, Noise Floor, WiMax Receiver Sensitivity, the maximum allowable noise raise limit etc. In this paper, these parameters have been calculated to understand the victim WiMax receiver characteristics for further investigations.

A. *Noise Density*

Noise Figure measures the degradation of the signal-to-noise ratio, caused by the components of a radio frequency signal by which the performance of a radio receiver can be specified. Also the Noise Density is the ratio of the output noise power to the portion of thermal noise in the input terminal at 290 K standard noise temperature. Therefore,
Noise Floor = kTB + Additional Part
$= 10 * \log_{10} (1.38 \times 10^{-23} \times 293 \times 1 \text{ Hz}) + 30\text{dB}$
= -174 dBm/Hz
So Noise Density, ND = TN + NF + ImL (1)

After calculating the above equation, the Noise Density of WiMax Receiver is 101 dBm considering the worst case value of NF and ImL which are 8 dB and 5 dB respectively.

B. *Receiver Sensitivity:*

Receiver sensitivity or RF sensitivity is one of the key specifications of any radio receiver whether it is used for Wi-Fi, cellular telecommunications broadcast or any other form of wireless communications. The ability of the radio receiver to pick up the required level of radio signals will enable to operate more effectively within its application. The receiver sensitivity R_{SS} is the summation of ND and the minimum acceptable signal to noise ratio (SNR) which is determined by different types of modulation & coding schemes used in the system when the standard Bit Error Rate (BER) is met.
The minimum receiver sensitivity:

$$R_{SS} = -114 + SNR + 10 \log_{10}(R) + 10 \log_{10}(BW) + ImL + NF \quad (2)$$

Here R is the repetition factor, BW is the bandwidth and NF is the number of used FET size. Noise Figure (NF) generates from Low Noise Amplifier and ImL is the implementation loss which includes phase noise, quantization error, tracking errors and channel estimation errors etc.

TABLE I. RECEIVER SENSITIVITY

Coding	Coding rate	SNR(dB)	F_S	N_U	NF	R_{SS}(dB)
QPSK	½ QPSK	5 dB	128	5	8	-96.2
	¾ QPSK	8 dB				-93.3
16 QAM	½ QAM	10.5 dB				-90.8
	¾ QAM	14 dB				-87.3
64 QAM	½ QAM	16 dB				-85.3
	2/3 QAM	18 dB				-83.3
	¾ QAM	20 dB				-81.3

The Table I demonstrates the WiMax receiver sensitivity of different coding schemes with fixed sampling frequency. The analytical calculation shows that, QPSK coding gives better sensitivity as it has the lower power level among other coding schemes.

C. *Maximum Allowable Noise Raise Limit*

WiMax has strong primary signal while the UWB system consists of weak secondary signal. As a result, the WiMax system affects the capacity loss, cell coverage reduction and poor connectivity by UWB signal. For the WiMax victim receiver, the maximum permissible noise due to UWB transmitter is given by

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

Where Nr is the maximum allowable noise raise in SSR. During the investigation, it has been considered that the UWB transmitter is placed inside a building or indoor and interferences with the victim receiver that can be inside or outside the building.

TABLE II. ALLOWABLE NOISE RAISE CALCULATION

N_r(dB)	TN(dBm)	ND(dBm)	I_{UWB}	I_{UWB}/ND
0	-114	-101	-101	0
1			-106.8	-5.86
2			-103.3	-2.32
3			-101	-0.02
4			-99.2	1.79

To overcome the interference problem, we choose the value of N_r as 3 dB for further cell radius calculations. This loss may also be reduced if proper heights of base and subscriber station antenna have been selected.

III. CELL RADIUS CALCULATION

The proposed model for estimating the cell radius of WiMax is Erceg model which provides the best result compared to other propagation model. This model [Erceg1999] is based on extensive experimental data collected by AT&T Wireless Services across the United States in 95 existing macro cells at 1.9 GHz. Therefore, the cell radius calculations are based on three terrain categories where Category A is hilly terrain with moderate-to-heavy tree density and has a high path loss. Category C is mostly flat terrain with light tree density and low path loss while Category B is hilly. For all three categories, the median path loss with two correction factors X_f and X_h at distance $d > d_0$ is given by

$$\text{Path Loss, } PL = A + 10 \gamma \log_{10} (d/d0) + X_f + X_h + S \quad (4)$$

and

Path Loss= $P_t + G_{BS} - FM - L_{wall} + G_{SS} - R_{ss}$ (5)

Where P_t is the base station power referenced to 36 dBm; G_{BS} and G_{SS} are referred to as base station antenna gain and subscriber station antenna gain respectively which value are considered as 15 dB and 0 dB respectively.

The Correction Factor, $X_f = 6 \log_{10}(\frac{f}{2000})$ (6)

For A and B type terrain, $X_h = -10.8 \log_{10}(\frac{hr}{2000})$ (7)

For C type terrain, $X_h = -20 \log_{10}(\frac{hr}{2000})$ (8)

Therefore, the intercept A is a fixed quantity is given by the free space path loss formula [5]

$A = 20\log_{10}(4\pi d_0/\lambda)$ (9)

Moreover, the fade margin FM = xσ, based on the actual signal variation within each cell is calculated to ensure the desired cell edge reliability [6]. Therefore, it is necessary to derive the distance to the cell radius d at any desired signal strength with CER. It is to be noted that, while considering CER the lognormal shadow fading known as scaling factor has been ignored from the path loss formula.

$$CER(x) = \frac{1}{\sqrt{2\pi}} \int_{-\alpha}^{z} e^{t2/2}\, dt \quad (10)$$

As well as the path loss exponent γ is a Gaussian random variable over the population of microcells within each terrain category is given by

$\gamma = a - bh_b + (c/h_b)$ (11)

TABLE III. PARAMETERS FOR ERCEG MODEL

Model Parameter	Terrain A	Terrain B	Terrain C
a	4.6	4	3.6
b(m-1)	0.0075	0.0065	0.0050
c(m)	12.6	17.1	20.0
S	10.6	9.6	8.2

In the above table a, b and c constants depend on three terrain categories for calculation of path loss exponent. These parameters for different base station antenna heights are listed in the table below:

TABLE IV. PATH LOSS EXPONENT CALCULATION

h_b	γ_A	γ_B	γ_C
30m	4.795	4.375	4.11
40m	4.615	4.16	3.9
50m	4.477	4.01	3.75
60m	4.36	3.89	3.63

Hence, based on the above findings, the path loss has been calculated to find out the cell radius in three terrain environments. The model is derived from data taken at 3.5 GHz with a fixed antenna height h_r which has been considered from 3m to 12m. In this paper, firstly the cell radius has been estimated for various types of coding schemes depending on different CER values.

Cell Radius, $d = [\log^{-1}\{(PL - A - X_f - X_h)/ 10\, \gamma\}]^* d_0$ (12)

TABLE V. CELL RADIUS IN KM FOR 30M BSR AND 3M SSR

CER	QPSK		16-QAM		64-QAM	
	½ QPSK	¾ QPSK	½ QAM	¾ QAM	½ QAM	¾ QAM
75%	2.49	2.2	1.91	1.61	1.46	1.21
80%	2.3	2.02	1.79	1.51	1.37	1.13
90%	1.96	1.69	1.5	1.27	1.15	0.95

From the table it has been observed that 75% CER and ½ QPSK provide the best cell range compared to other parameters. Therefore for further calculation, 75% CER and ½ QPSK coding have been considered to get the maximum distance, d.

The results of cell radius have been obtained by varying the base station height with fixed SSR. Having the distance of each device from the victim receiver, the received power and path loss have also been calculated with a constant CER. Thus, table VI shows aggregate cell radius for different values of BSR and SSR for 75% CER and ½ QPSK coding technique. The final results demonstrate that, 6 meter height of Subscriber Station Receiver antenna and 40 meter height of Base Station Receiver antenna provide better cell coverage area for three terrain categories with minimal interference.

TABLE VI. CALCULATION OF CELL RADIUS IN KM

h_b(meter)	Cell Radius (km)											
	Terrain A				Terrain B				Terrain C			
	h_r = 3m	h_r = 4m	h_r = 5m	h_r = 6m	h_r = 3m	h_r = 4m	h_r = 5m	h_r = 6m	h_r = 3m	h_r = 4m	h_r = 5m	h_r =6m
30m	2.49	2.61	2.73	2.84	2.66	2.86	3	3.14	0.65	0.75	0.84	0.91
40 m	2.52	2.71	2.83	2.95	2.79	3	3.17	3.33	0.64	0.74	0.83	0.91
50 m	2.6	2.79	2.92	3	2.9	3.15	3.32	3.48	0.63	0.73	0.82	0.91
60 m	2.67	2.87	3	3.15	3	3.26	3.44	3.62	0.62	0.73	0.82	0.90

IV. CONCLUSION

In this paper, the performances of WiMax receiver characteristics with different parameter such as allowable noise limit and CER have been analyzed to get the maximum cell radius. Again, comparing the performance of receiver sensitivity of different coding schemes, ½ QPSK gives the best sensitivity with 75% CER. Moreover, the cell area according to the change of base station and subscriber station antenna heights have been examined and the analytical results prove that, BSR of 40 meter and SSR of 6 meter give better coverage than all other earlier result.

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