UWB 시스템에 의한 WiBro 시스템에서의 간섭영향에 관한 연구

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Analysis of Interference Impact of UWB System on WiBro System

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요 약

본 논문에서는 3.1 GHz에서 10.6 GHz 주파수 대역을 사용하면서 실내 및 실외 통신에 적용되는 초 광대역(UWB) 시스템이 OFDM(Orthogonal Frequency Division Multiplexing)을 근간으로 한 2.3 GHz 대 WiBro(Wireless Broad-band)시스템에 미치는 간섭 영향에 대해 분석하였다. 최악의 상황을 고려하여 단일 UWB 간섭의 경우는 최소결합손실(MCL) 방법으로 간섭분석을 수행하였고, 다중 UWB 간섭인 경우는 실제 상황을 고려한 간섭 시나리오를 바탕으로 몬테칼로(MC) 방법으로 간섭 시뮬레이션을 수행하였다. 분석 및 시뮬레이션 결과 두 시스템의 양립성을 보장하기 위해 단일 간섭 원 과 희생(victim) 수신기 사이의 이격 거리는 34.4m 이상이 요구되었다. 또한, 다중 UWB 간섭 원 인 경우에 WiBro 단말기의 최소 throughput 손실을 보장하기 위해 허용할 수 있는 UWB 송신전력 레벨은 약 - 81 dBm / MHz 이하로 요구되었다.

Key words : UWB, Interference, WiBro, OFDM

ABSTRACT

This paper presents the impacts of Ultra Wide-Band(UWB) system applied in Indoor and Handheld communications using frequency band from 3.1 GHz to 10.6 GHz on Wireless Broad-band(WiBro) system based on Orthogonal Frequency Division Multiplexing(OFDM) using frequency of 2.3 GHz. The Minimum Coupling Loss(MCL) method for the case of single interference and Monte Carlo(MC) simulation for multiple interference considering practical scenario were used to evaluate the interference effects of UWB system on WiBro system. As a result, the minimum separation distance between single interferer and the victim receiver required 34.4 m and above to guarantee the co-existence. Also, the UWB transmitting PSD of around - 81 dBm / MHz below should be required to meet the minimum throughput loss of WiBro mobile station in case of multiple UWB interference.

Ⅰ. Introduction

The importance of Ultra Wideband(UWB) technology has been increased with the advent of communication services including low-cost, high speed and wireless network in these days. In addition, as the frequency

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resources become limit, the technology has been highly attracted in order to share the frequencies between UWB system and other existing services such as mobile communication, satellite communication and broadcasting system.

As the UWB spreads from DC to several GHz, it is appropriate for short-range communication networks requiring high rate and large capacity of data transmission. The UWB technology has been developed mainly for the distance measurement, communications devices for the military purpose and object measurement in basement[1]. The Federal Communications Commission(FCC) defined the UWB system as 20% above Fractional Bandwidth of center frequency or the system with 500MHz above RF bandwidth[2].

In the past, the impulse method has been suggested to get wide-band frequency characteristics as an implementation method. However, Multiband Orthogonal Frequency Division Multiplexing(MB-OFDM) and Direct Sequence-CDMA(DS-CDMA) have been discussed actively in IEEE because they have advantages of implementation feasibility and flexible frequency bandwidth[3].

There have been many contribution reports containing the protection requirement of existing services from UWB interferences in ITU-R TG/18[4]. However, few of them explained how to get the protection requirement of victim services from UWB interferences in detail.

In specific, this paper presents the impacts of UWB Indoor and Handheld communications using frequency band from 3.1 GHz to 10.6 GHz on Wireless Broad-band(WiBro) system based on Orthogonal Frequency Division Multiplexing(OFDM) which is one of next mobile communication services in Korea using frequency of 2.3GHz. The Minimum Coupling Loss(MCL) and Monte Carlo(MC) were used as an interference analysis method to evaluate the interference effects of UWB system on WiBro system.

The results of analysis and simulation showed the minimum separation distance between UWB system and WiBro system and also, the allowable transmitting power spectral density of UWB system for the compatibility.

Ⅱ. Interference Analysis of the impact of single UWB on single WiBro Mobile station in Indoor environment

The impact of single UWB on single WiBro mobile station in Indoor environment was analyzed in terms of MCL method. The system parameters for MCL method and analysis scenario for the worst case were considered. The minimum separation distance between UWB interferer and victim system was obtained.

The scenario for the interference analysis was established as follows. Service environment: Indoor environment, Interferer: single UWB device, Victim system: single WiBro mobile station, UWB transmitting power spectral density(PSD): -51.3 dBm/MHz @ 2.3 GHz(FCC Indoor), In Bands: 3.1-10.6 GHz, Antenna characteristics: omni directional, Reference Distance: 36cm or 1m, Reference Bandwidth: 1MHz.

The specifications of WiBro Mobile were defined as follows. Operating frequency: 2385.5MHz, Channel bandwidth: 9MHz, Noise Figure: 7dB, Noise Floor: -107dBm/MHz, Antenna characteristic: Omni directional Antenna, Implementation loss: 5dB, Path loss model ($I_{UWB \rightarrow Wibro}$): Indoor path loss and free space path loss.

When the protection criteria which is the ratio of Interference signal power over Noise Floor(I/N) was defined as - 6 dB by considering the worst case scenario, the allowable maximum UWB PSD and the minimum separation distance were analyzed. The analysis results using MCL method were summarized in table 1.

As a result, the minimum separation distance should be 34.4 m in order to meet protection criteria of -6 dB I/N.

Reference distance between interferer and victim receiver is considered by ITU-R TG 1/8 as 36cm and 1m. Therefore, the UWB transmitting PSD depending upon I/N value was acquired according to each reference distance as in table 2. In this case, line of site(LOS) was taken for the worst case[5]. If reference distance of 36 cm and protection criteria (I/N) of -6 dB were fixed taking into consideration of practical situation, the allowable maximum UWB transmission PSD would be -76.9 dBm/MHz.

Table 1. The summary of interference analysis results using system parameters and MCL method

Parameters	Value	Units
Frequency	2385.5	MHz
Thermal Noise Power Density	-174	dBm/Hz
Reference Bandwidth	1	MHz
Victim Channel Bandwidth	9	MHz
Victim Noise Figure	7	dB
Victim Noise Floor, N	-97.3	dBm
Protection Criteria	-6	dB
Allowable max. UWB Interferer Power Level	-127	dBm/MHz
UWB PSD(FCC Indoor Limit)	-51.3	dBm/MHz
Victim Receiver Antenna Gain	0	dBi
Required Isolation	70.7	dB
Path Loss Model	Free Space Loss (ITU-R P.525)	
Minimum Separation Distance	34.4	m
Path Loss Model	Indoor Path Loss (ITU-R P.1238) plus 29 dB power loss coefficient	
Minimum Separation Distance	11.45	m

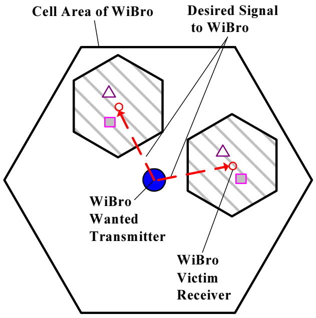
Table 2. UWB Transmission Limit according to reference distance and I/N

Reference Distance	I/N[dB]	UWB Transmission PSD[dBm/MHz]
36 cm	-6	-76.9
	-10	-80.9
	-13	-83.9
	-20	-90.9
1 m	-6	-68.0
	-10	-72.0
	-13	-75.0
	-20	-82.0

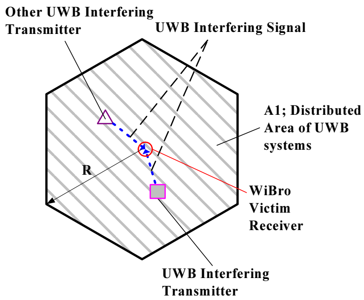
Ⅲ. The analysis of the impact of multiple UWB devices on WiBro mobile station in Outdoor environment

The MC method was used for the analysis of the impact of multiple devices on WiBro mobile station in Outdoor environment. System parameters and scenario were defined for the MC analysis. The maximum UWB transmitting PSD was considered so as to keep maximum throughput and minimum outage in WiBro mobile station.

Fig.1 is the geometric model considered the proposed idea. The WiBro wanted transmitter, so called base station(BS) is communicating with multiple WiBro victim receivers(VRs) with uniformly distribution within the cell area of WiBro in Fig. 1 (a). Each WiBro VR just receives the desired signal



(a) WiBro Link Model



(b) Interference Model

Fig. 1. Geometric proposed model

power from the WiBro BS without UWB interfering signals. As shown in Fig. 1 (b), multiple UWB interfering transmitters operate close to each WiBro VR. WiBro VRs will receive not only the desired signal power from the WiBro BS but also interfering signal powers from multiple UWB interfering transmitters with the maximum UWB PSD.

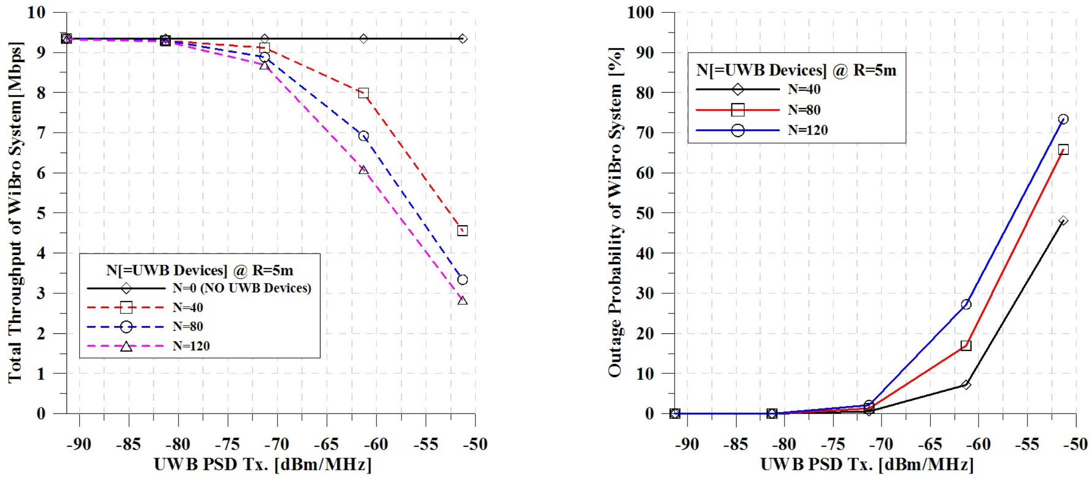
Here, the received interfering signal powers($iRSS_{m,VR}$) from multiple UWB interfering transmitters with the maximum UWB PSD $P_{UWBm,VR}$ can also be given by

$$iRSS_{m,\,VR} = P_{UWB_{m,\,VR}} - \Gamma_{m,\,VR} \tag{1}$$

where $\Gamma_{m,\,VR}$ is the free space propagation path loss at multiple UWB interfering transmitters. Under the environment of multiple WiBro VRs and multiple UWB interfering transmitters, the total received interfering signal power($I_{UWB,VRs}$) at multiple WiBro VRs is given by

$$I_{UWB,\,VRs} = \sum_{k=1}^{K}\sum_{j=1}^{J} iRSS_{k,\,j} \tag{2}$$

where, the constant j depicts the index of WiBro



(a) Total throughput loss for UWB PSD (b) Probability of outage at UWB PSD

Fig. 2. Performance of WiBro system over maximum UWB PSD

Table 3. Parameters for the evaluation of UWB interference impact

Parameters	Value
Frequency bands	2.3 GHz bands
Occupied channel bandwidth	9 MHz
Protection Criteria(I/N)	- 6 dB
UWB density over unit area(km^2)	40, 80, 120
Path loss - UWB interference transmitter to Wibro victim receiver - WiBro wanted transmitter to WiBro victim receiver	 Free Space(LOS) Modified Hata model

VR. The constant J is the total numbers of WiBro VRs uniformly distributed in cell area of WiBro. The constant k means the index of each UWB interfering transmitter around and close to each WiBro VR. The constant K is the total number of UWB interfering transmitters over unit area of km^2.

The major parameters for the evaluation of UWB interference impacts are summarized in Table 3.

Evaluation of the performance for WiBro system with multi-rate support is obtained from two factors; the total throughput and the probability of outage at multi-rate. Each factor is evaluated for maximum UWB PSD as well as density N devices/km^2 as shown in Table 3. Here, the total throughput depicts the total mean throughput for WiBro system with as well as without the interference due to multiple interfering signal powers by multiple UWB interfering transmitters.

The probability of outage at multi-rate explains the total mean outage in WiBro VRs. The outage at multi-rate happens under less than the minimum sensitivity in WiBro VR. The minimum sensitivity is also derived from the minimum modulation mode corresponding to QPSK modulation and 1/2 coding rate. Finally, the maximum UWB PSD P_{UWB} of UWB interfering transmitter to protect WiBro system is estimated. The emission PSD of UWB system is limited from them. Also, it is assumed that multiple UWB interfering transmitters in cell area of WiBro transmit the same maximum UWB PSD P_{UWB}, which is called UWB PSD Tx., and all of them are active state.

If multiple UWB interfering transmitters closing to WiBro VRs don't exist and then the received interfering signal powers $iRSS$ to WiBro VR is less than the tolerable UWB interfering signal powers I_{UWB}, the outage in WiBro VRs may not be regarded as the performance degradation for WiBro system and this means zero as shown in Fig.2.

Fig.2 shows the performance of WiBro system according to the impacts by multiple UWB interfering transmitters at UWB density, which is calculated by both numbers of UWB devices N and cell radius R for distributed area of UWB systems A1. Firstly, Fig.2 (a) shows that the total throughput for WiBro system in the protection criteria of UWB

I/N, which is -6 dB, tends to decrease according to increasing numbers of the multiple UWB interfering transmitters(N devices in related to the total interfering signal powers to WiBro VRs). Secondly, Fig.2 (b) shows that the outage at multi-rate happens due to interference by multiple UWB interfering transmitters.

As shown in Fig.2 (b), the outage at multi-rate grows drastically according to the maximum PSD of UWB interfering transmitter. However, if the maximum UWB PSD of UWB interfering transmitter decrease by -80 dBm/MHz at the cell radius R of 5 m as shown in Fig.2 (b), the probability of outage at multi-rate of WiBro system is nearly becomes zero. This means that WiBro system is not affected by the multiple UWB interfering transmitters with maximum UWB PSD.

Ⅳ. Conclusions

The impact of single and multiple UWB devices on WiBro mobile station were analyzed through MCL method and MC method. In the case of Indoor environment, the minimum separation distance between UWB interferer and the victim system and the allowable maximum UWB transmitting PSD were defined to meet UWB I/N of - 6 dB. For the Outdoor environment, the interference effect of multiple UWB devices to WiBro mobile station was analyzed through MC method to meet the total throughput loss and outage of Wibro mobile station.

As a result, the maximum UWB PSD to WiBro system must be restricted by approximately - 80 dBm/MHz according to UWB densities and should be rigidly limited by less 30 dB than FCC provision of -51.3 dBm/MHz to guarantee conflict-free coexistence between UWB and WiBro system in the assumed scenarios for the evaluation of UWB interference impacts. Also, the maximum UWB PSD may be dependent on the different services of UWB communication application. In addition, if multiple UWB interfering transmitters close to WiBro victim receivers don't exist, the total throughput loss and the outage at multi-rate are not regarded as the performance degradation for WiBro system.

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