Analysis on the Effects of Interference Mitigation for Ultra-wideband Coexistence with BWA

Young-Keun Yoon[1] · Hong-Heon Jin[1] · Ik-Guen Choi[2]

Abstract

This paper presents the impacts of Ultra-wideband(UWB) applied in the communication applications using frequency band from 3.1 GHz to 10.6 GHz on Broadband Wireless Access(BWA) based on orthogonal frequency division multiplexing(OFDM) using frequency band of 3.5 GHz. It proposes low duty cycle(LDC) for enabling UWB to mitigate strong interference to BWA. The effects of interference mitigation are evaluated and analyzed in the environment of UWB coexistence with BWA. UWB with LDC scheme will be given to bring higher transmit power level corresponding to Federal Communications Commission(FCC) provisional limit for enabling UWB operation at 3.5 GHz bands.

Key words : UWB, BWA, LDC.

Ⅰ. Introduction

The importance of UWB techniques is rapidly increasing due to the many desirable features such as high bit rates support and low power consumption[1]. The UWB technology is one of the viable candidates for short-range radio communication systems supporting very high bit rates services and applications. But, due to the very large bandwidth occupied by the UWB signals, the spectrum for UWB cannot be allocated exclusively so that UWB signal band overlaps with those of existing systems. Therefore, to protect existing services against potential UWB interference, the federal communications commission(FCC) restricted the UWB operating bands and UWB transmissions power for each UWB application/device[2]. However, although UWB PSD limits has been provided by FCC in [2], the potential interference due to the very large bandwidth occupied by the UWB signals have been reevaluated for the successful operation of the existing systems[3],[4]. The impacts for interference of UWB systems to the existing communication systems have also been considered in the worst case. These results in worst case have been derived so pessimistic conclusions considering UWB emission mask at in-band of below 6 GHz proposed by European Conference of Postal and Telecommunications(CEPT) as in Fig. 1. Therefore, this paper proposes low duty cycle (LDC) in order to mitigate strong interference to a Broadband Wireless Access(BWA) victim. In this paper, an analysis for the effects of UWB interference to the target system, which is BWA using frequency band of 3.5 GHz, was performed.

Also, the effects of interference mitigation are evaluated in the environment of aggregated UWB coexistence with BWA.

Ⅱ. Broadband System Features

In this paper, BWA system is considered as victim service from UWB for the interference analysis. The basic parameters based on orthogonal frequency division

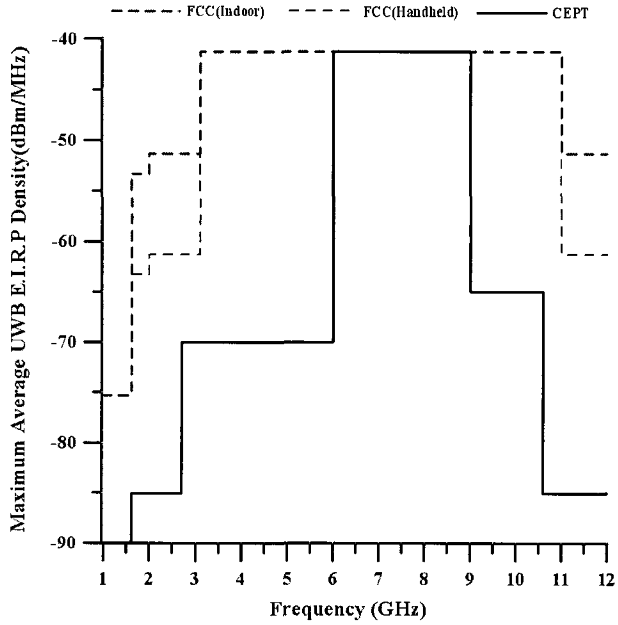

Fig. 1. Provisional masks for UWB emissions.

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Table 1. Parameters of BWA.

Parameters	Values
Channel Bandwidth	3.7 or 7 MHz
Dimension of FFT	256
Number of Subcarriers	200
TDD Frame length	5 ms
Subcarrier Modulation (Coding Rate)	64 QAM(Rate=3/4, 2/3) 16 QAM(Rate=3/4, 1/2) QPSK(Rate=1/2)

multiplexing(OFDM) and time division multiplexing (TDD) schemes for broadband system are summarized in Table 1[5]. BWA system, which is called WiMAX based on IEEE 802.16d-2004, is considered at 3.5 GHz frequency bands. The target broadband system provides the multi modulation modes.

Ⅲ. Interference Modeling Approach

3-1 Scenario for UWB Coexistence with BWA

Fig. 2 shows that the whole considered area around the victim BWA would be populated by multiple UWB devices. It was assumed that more than one UWB device were transmitting at a given time. Also, the given simulation area of 1 km^2 is considered. Therefore, area is limited by circle of 0.6 km radius around a victim BWA.

3-2 Modelling Duty Cycle of UWB Transmitter

The duty cycle is modelled by "on-off" keying of the transmit power, which is set through uniform distribution function, prob=U(0,1), applied to the result of a uniform sample between 0 and 1 for transmit power of the interfering transmitter. Therefore, the duty cycle of UWB devices, considered to be less than 5 % (<0.05) in worst case, was modelled by setting the output power distribution of interfering transmitter as shown in Fig. 3.

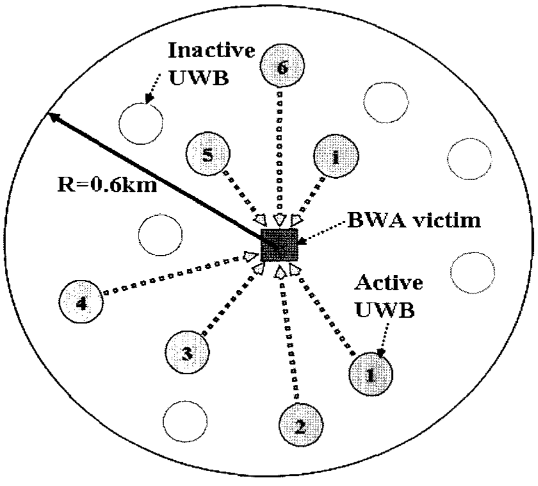


Fig. 2. Placing multiple UWB around a victim BWA.

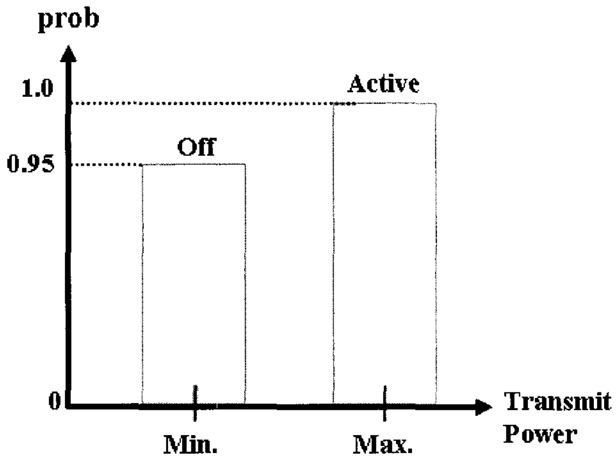


Fig. 3. Modelling UWB duty cycle.
(c.f. duty cycle=5 %)

3-3 Modelling of Permissible Interference to Victim

In the environment of coexistence among multiple UWB devices with a BWA victim as shown in Fig. 2, permissible interfering signal power to a victim BWA in dBm/MHz, iR is described in equation (1).

$$iR = 10 \log_{10} \sum_{i=1}^{I} 10^{\frac{p_i}{10}} \tag{1}$$

where, p_i is the received UWB interfering signal power to a victim BWA from i-th active UWB transmitter. It is defined by equation (2).

$$p_i = P_{Tx} - \Gamma_{i \to vr} + G_i + G_{vr} \tag{2}$$

Here, P_{Tx} depicts that the emission power signals of an active UWB interfering transmitter in dBm/MHz, which is called for UWB power spectrum density(PSD) Tx. in this paper, and also is set "on-off" through uniform distribution function, prob=U(0, 1), applied to the result of a uniform sample between 0 and 1 for transmit power of the interfering transmitter as shown in Fig. 3. G_i in dBi and G_{vr} in dBi mean antenna gain of UWB transmitter and antenna gain of BWA victim receiver, respectively. $\Gamma_{i \to vr}$ in dB depicts the median path loss between UWB transmitter and BWA victim receiver. Path loss is considered for the worst case. Therefore, the path loss model defined in equation (3) is used for the analysis of UWB interference impacts on a BWA victim receiver[6].

$$\Gamma_{i\to vr} = 20\log_{10}\left(\frac{4\pi d_0}{\lambda}\right) + 10n\log_{10}\left(\frac{d_{i\to vr}}{d_0}\right) \tag{3}$$

where, d_0 means the reference distance in meter, λ is wavelength, n means the attenuation coefficient, for example, $n=2$ in case of free space. $d_{i\to vr}$ depicts the separaton distance between UWB transmitter and BWA victim receiver.

To protect a BWA victim from impacts of UWB interference, protection criteria, which is called for UWB interference to noise power ratio(UWB INR), to a BWA victim receiver could be described by the generic link degradation in equation (4).

$$\eta = \frac{I_{UWB}+N_{vr}}{N_{vr}} = \frac{I_{UWB}}{N_{vr}} + 1 \tag{4}$$

where, I_{UWB} depicts the permissible UWB interfering signal power to a victim receiver, N_{vr} means the thermal noise power plus noise figure at the end of antenna to a victim receiver. In equation (4), $\frac{I_{UWB}+N_{vr}}{N_{vr}}$ is called for UWB noise rise. The performance of a victim receiver might be affected from UWB noise rise. Therefore, the received interfering signal power, *iR* defined in equation (1), to a BWA victim should be limited by I_{UWB}.

Here, the protection criteria, $\frac{I_{UWB}}{N_{vr}}$, is specified by various characteristics of any victim system and permissible UWB interfering signal powers to a victim receiver is derived from known noise power of a victim receiver.

Ⅳ. Simulation Results

The major parameters for the evaluation of UWB interference impacts are summarized in Table 2.

The impacts of UWB interference on a BWA victim are described in Fig. 2. Interference probability due to multiple UWB interfering transmitters is calculated by averaging the results of happened interference events through "snap-shot" in a given time.

4-1 Interference Effect by UWB Without Duty Cycle

In Fig. 4, the duty cycle of UWB transmitter for interference mitigation to a BWA was not considered. Therefore, UWB interferer would be always set by duty cycle of 100 % for UWB transmission. Also, the impacts of UWB interference on a victim receiver through given UWB PSD Tx. was evaluated without interference mitigation scheme.

Table 2. Parameters for evaluation of UWB interference impacts.

Parameters	Values
Frequency Bands	3.5 GHz
Maximum UWB PSD Tx.	−41.3 dBm/MHz[2]
Nint	20, 40 devices/km^2
G_{vr}	0, 8 dBi
G_i	0 dBi
UWB INR	−6 dB[4]
Duty cycle	below 5 %, 100 %[7]

As shown in Fig. 4, two kinds of antenna gain, 0 dBi and 8 dBi, of a victim were considered.

Also, UWB density of Nint=20 and 40 devices/km^2 was assumed in order to analyze the effects of active multiple UWB transmitters.

Firstly, the analysis for antenna gain of BWA victim showed that the case of G_{vr}=8 dBi gave higher interference impact than the case of G_{vr}=0 dBi.

Secondly, high UWB density caused stronger interfering signal power level to a BWA victim than low UWB density.

As a result, UWB PSD Tx. in dBm/MHz for UWB coexistence with a BWA would be limited by −80

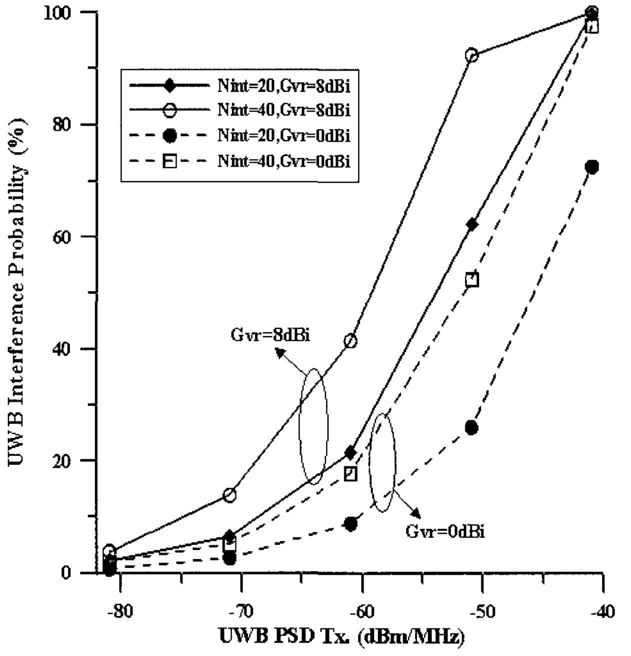


Fig. 4. Interference probability to a BWA victim. (c.f. duty cycle of 100 %)

dBm/MHz in worst case. In addition, antenna gain of 0 dBi and low density of active UWB devices would be needed.

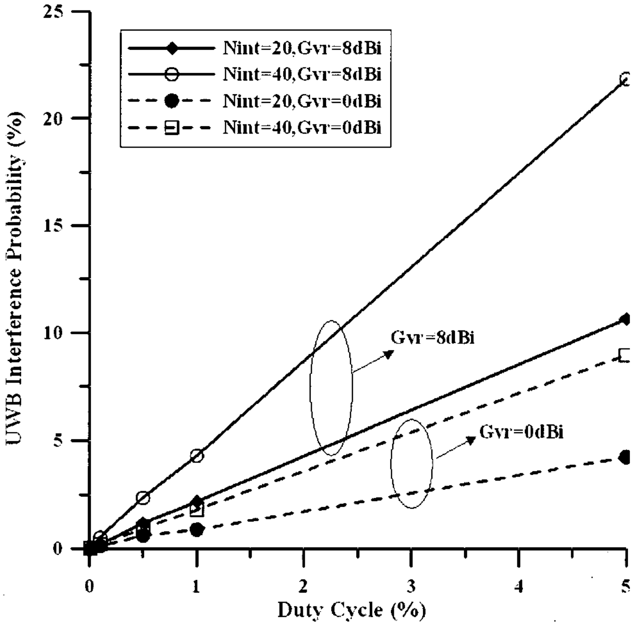
4-2 Interference Effect by UWB with Tx Power Duty Cycle

Here, duty cycle for enabling UWB transmitter to reduce strong interference was deployed.

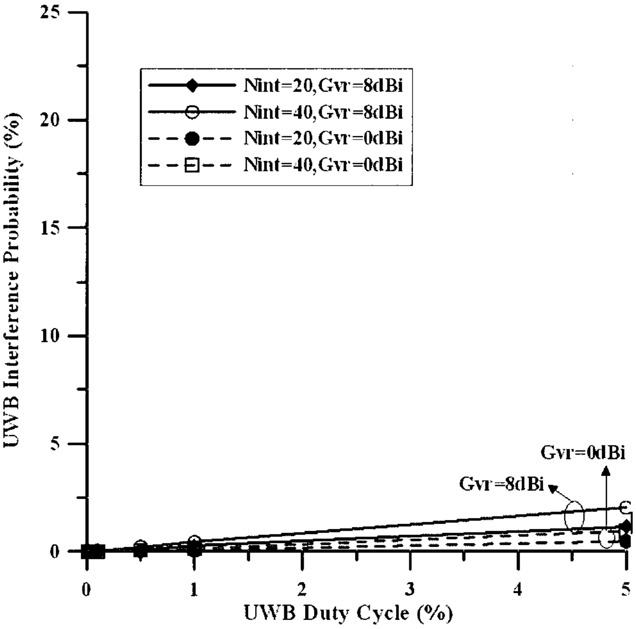
4-2-1 UWB Interference Probability due to Duty Cycle with Fixing UWB Transmitter Transmitting Power

Fig. 5(a) and Fig. 5(b) shows the impacts of UWB interference according to duty cycle on maximum average UWB PSD Tx. of −41.3 dBm/MHz and relatively lower UWB PSD Tx. of −61.3 dBm/MHz, as well.

The effects of UWB interference for lower duty cycle

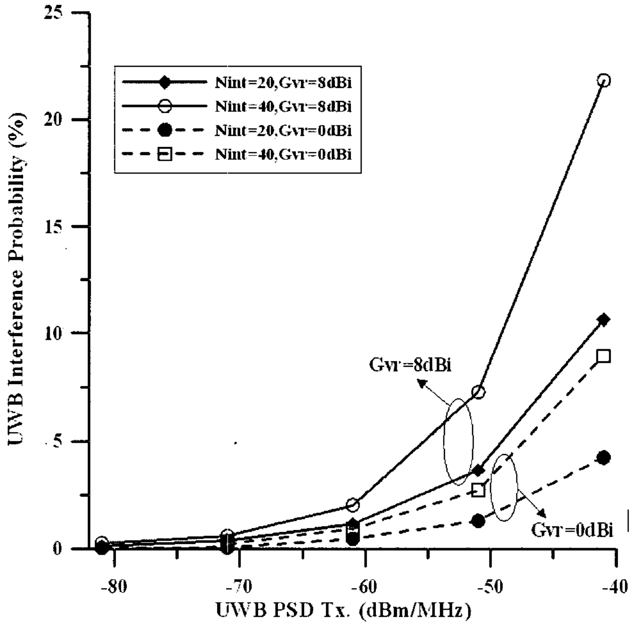


(a) UWB PSD Tx.=−41.3 dBm/MHz

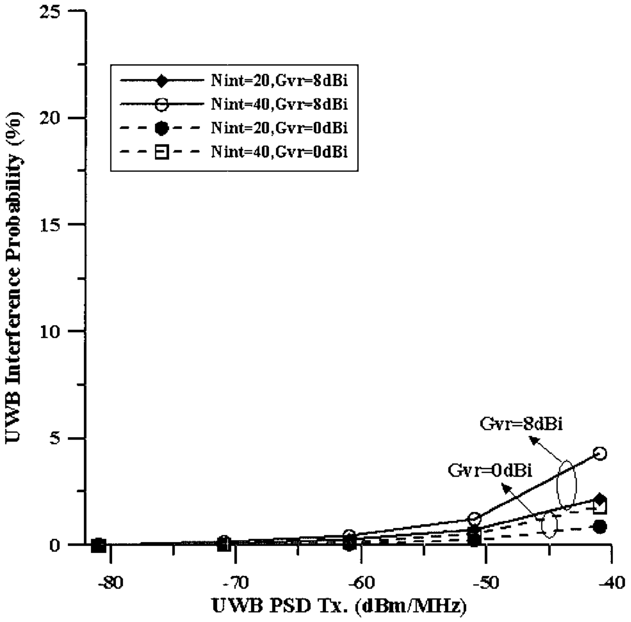


(b) UWB PSD Tx.=−61.3 dBm/MHz

Fig. 5. Interference probability to a BWA victim vs. UWB duty cycle with fixed Tx power.



(a) Duty cycle=5 %



(b) Duty cycle=1 %

Fig. 6. Interference probability to a BWA victim on duty cycle of UWB transmitter.

of UWB transmitter with the emission limit of UWB PSD Tx. of −41.3 dBm/MHz was reduced gradually as shown in Fig. 5(a).

Also, the effects of UWB interference for UWB PSD Tx. of −61.3 dBm/MHz reduced rapidly as shown in Fig. 5(b).

4-2-2 UWB Interference Probability due to UWB Transmitting Power with Fixing Duty Cycle

Fig. 6(a) and Fig. 6(b) shows that the impacts of UWB interference according to UWB PSD Tx. with duty cycle of 5 % in worst case and relatively lower duty cycle of 1 %, as well.

The effects of UWB interference for lower UWB PSD Tx. of UWB transmitter with duty cycle of 5% was decreased gradually as shown in Fig. 6(a).

Also, the effects of UWB interference in case of the duty cycle of 1 % were smaller than in case of the duty cycle of 5 % as shown in Fig. 6(b).

V. Conclusion

This research has shown that UWB emission with FCC provisional limit of −41.3 dBm/MHz is likely to be so harmful to BWA using frequency of 3.5 GHz. On the other hand, the deployment of UWB with LDC could be so effective method for UWB coexistence with BWA in order to mitigate strong UWB interference.

The aggregation of UWB transmitters around a BWA victim under a defined scenario was dealt as a key factor to evaluate the impact of UWB on a BWA. As a result, interference probability for UWB density of 40 devices/km^2 has higher than that for UWB density of 20 devices/km^2 by 4.5 %. When multiple UWB have Tx power of −41.3 dBm/MHz and duty cycle of 5 %, a BWA is still affected by interference from UWB transmitters. Therefore, the UWB transmitter which has −41.3 dBm/MHz should have lower than 5 % of duty cycle.

In a result, LDC should be given to bring better UWB coexistence with a BWA using frequency of 3.5 GHz.

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