Analysis of Interference Impacts by UWB System to WiBro Systems

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

Abstract

This paper evaluates the impacts for interference from UWB system, and determines the tolerable UWB power spectral density(PSD) to the new deploying system, which is called a portable internet service in Korea. It also proposes the interference analysis scheme that can evaluate the characteristics of the performance degradation for portable internet service according to the emission power of UWB systems at the specified frequency bands. The proposed scheme includes a multi-rate and data service environments to deal with interference to portable internet service. It is obtained from simulation results that the transmission PSD of UWB systems should be rigidly restricted by less approximately 10~20 dB than FCC provisional limit for coexistence between UWB and portable internet service already allocated at 2.3 GHz frequency bands in Korea.

Key words : UWB, WiBro, Home Networking.

Ⅰ. Introduction

The importance of ultra-wideband(UWB) techniques is rapidly increasing due to the many desirable features of UWB such as high bit rates support, 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]. 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 and also the conventional scheme in the worst case isn't appropriate to evaluate the performance of data service systems with multi-rate environment.

Therefore, this paper proposes the practical method in order to analyze the effects for interference by UWB the target system providing multi data rate service, which is called wireless broadband(WiBro) or portable internet service. Unlike the conventional scheme in relation to mostly connection-based system, the proposed scheme is able to handle a multi-rate and data service system. The numerical method also appends to evaluate the impacts of interference.

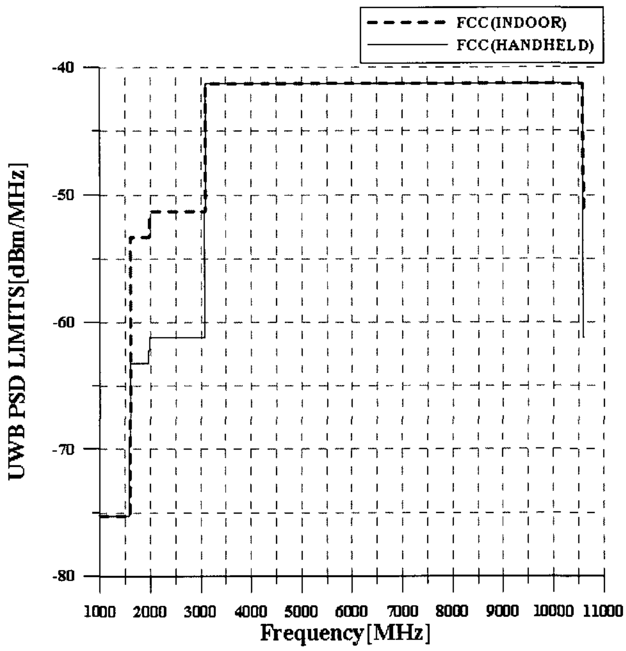

Fig. 1. FCC Provisional mask for UWB emissions.

Ⅱ. WiBro System Features

Let's consider WiBro system at 2.3 GHz frequency

Manuscript received October 4, 2005 ; revised October 31, 2005. (ID No. 20051004-037J)
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Table 1. Parameters of WiBro system.

Parameters	Value
System channel bandwidth	9 MHz
Dimension of FFT	1024
Number of data sub-carriers	768
OFDM symbols over a frame	24
TDD frame length	5 ms
Sub-carrier modulation (Coding rate)	64QAM(R=3/4, 2/3) 16QAM(R=3/4, 1/2) QPSK(R=3/4, 1/2)

bands affected the potential interference by UWB systems. WiBro system is based on orthogonal frequency division multiple access(OFDMA), time division duplex (TDD) scheme, and being deployed in Korea. The basic parameters based on OFDM are shown as Table 1. This is able to exchange the adaptively modulation mode according to the channel environments, which is called the adaptive modulation and coding rate(AMC). AMC in this paper is based on the fallback scheme[4] which changes to support the sub-carrier modulation and coding rate of WiBro system. Target system provides the six modulation modes as shown in Table 1. It is assumed that all of sub-carriers allocated at one frame of WiBro system become fully usage for active mobile stations distributed in single cell.

In addition, *C/(N+I)* in Fig. 2 depicts the ratio of the desired receiving signal power over noise power in WiBro system and the interference power transmitted from UWB systems. The modulation mode in each mobile station becomes fallback if the received *C/(N+I)* is smaller than required *C/(N+I)* according to take away from base station as well as UWB interference power by the adjacent UWB systems.

III. Conventional Interference Analysis

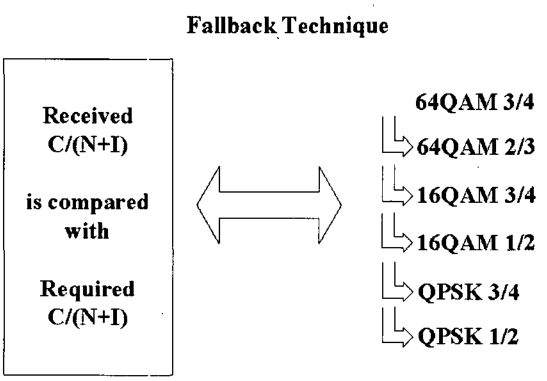


Fig. 2. Fallback model in WiBro system.

In Fig. 3(a), a mobile station just receives the desired signal without interference signal. But, UWB system in Fig. 3(b) may operate close to a mobile station. In this case, a mobile station may receive the desired signal as well as interference signal and its performance may be degraded by interference signal. A UWB transmitter with the maximum transmit power is located on the boundary of A2, which is area with none of UWB systems and with separation distance. In case of the conventional scheme, it assumed that the separation distance between a UWB system and a WiBro mobile station is 0.36 [m][4]. In addition, A1 is the area existing with other UWB systems. Here, the worst case is that a single UWB system has the maximum transmit power and is the closest location to a WiBro mobile station. In conventional interference model, only single interference signal by one UWB system has been taken into account to evaluate the impact of interference by UWB system. Generally, the impact evaluation value of interference by UWB system is the tolerable UWB PSD for the victim system in worst case. In Fig. 3, The victim system affected by UWB system is a WiBro mobile station. The generic link degradation η of the victim system is given by

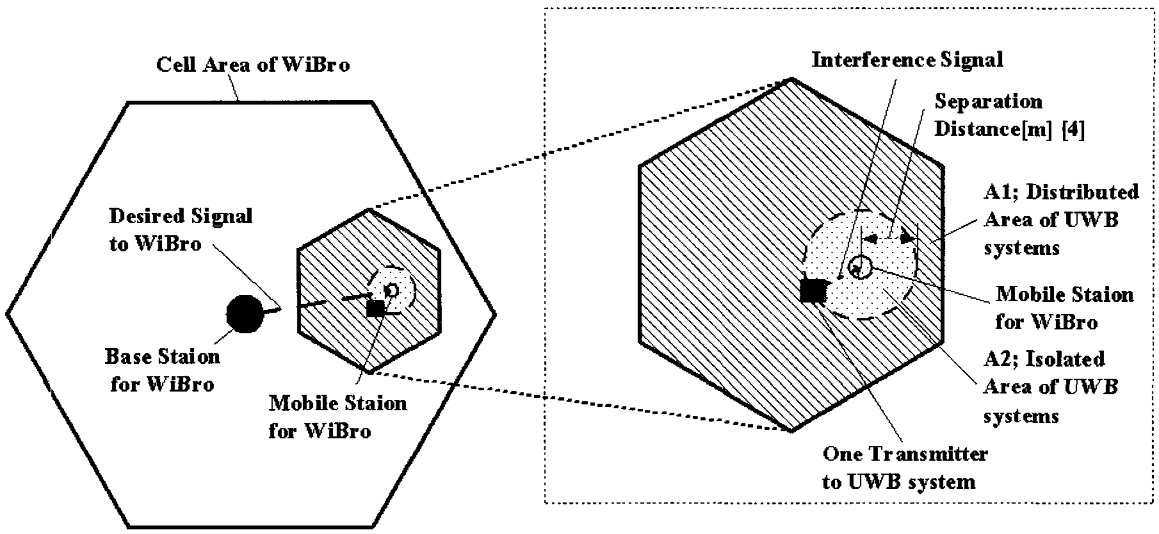
$$\frac{I_{UWB}+N_{V_r}}{N_{V_r}}=\frac{I_{UWB}}{N_{V_r}}+1=\eta \tag{1}$$

where I_{UWB} depicts the tolerable interference to the victim system. N_{Vr} is the thermal noise N_{th} plus noise figure NF_{Vr} to the victim system. This interference ratio in Eq. (1) is called UWB noise rise, whereas the term I_{UWB}/N_{Vr} is called UWB *I/N* ratio. Here, the tolerable interference I_{UWB} to the victim receiver could be calculated with the noise power N_{Vr} and the tolerable UWB *I/N* ratio. The tolerable PSD P_{UWB}, which is the tolerable interference to the victim system, is given by

$$P_{UWB}=N_{th}+NF_{Vr}+(I_{UWB}/N_{Vr})-\Gamma \tag{2}$$

where Γ is assumed the free space propagation path loss.

The conventional interference model has two problems. The first is that when multiple UWB systems exist at a cell area, it isn't able to estimate for the impacts of the interference of all active UWB systems with the protection criteria of UWB *I/N* ratio to victim system. The second is that practically can't calculate the performance degradation of the victim system with multi-rate environment such as portable internet service. Therefore, this paper proposes the interference analysis model to evaluate the impacts for interference by the multiple UWB systems to WiBro system with the multi-rate function.



(a) Geometric downlink model for WiBro (b) Geometric interference model between WiBro and UWB systems

Fig. 3. Geometric downlink model (a) and interference model (b) for the conventional scheme in the single cell.

Ⅳ. Proposed Interference Analysis

4-1 Proposed Interference Model

The geometric interference model in the singe cell for the proposed scheme is shown at Fig. 4 compared with the conventional scheme, a WiBro base station is communcating with the multiple WiBro mobile stations with uniformly distribution within cell area of WiBro system. Each WiBro mobile station just receives the desired signal without interference signal from other WiBro mobile stations. But, the multiple UWB systems in Fig. 4(b) may operate close to the multiple WiBro mobile stations. In this case, the multiple WiBro mobile stations may receive the desired signal as well as total interference signals by the multiple UWB systems with the maximum transmit power. At this time, the least separation distance between a UWB system and a WiBro mobile station assumed 0.36 [m] as the conventional scheme. In Fig. 4, this geometric model employs the AMC function to keep connecting between base station and mobile station. The victim system affected by UWB system is the multiple WiBro mobile stations. At this time, the generic link degradation η of the victim system is given by Eq. (1).

Also, the tolerable PSD $P_{m,1}$ of the multiple UWB systems to the single victim system can be given by

$$P_{m,1}=N_{th}+NF_{Vr}+(I_{UWB}/N_{Vr})-\Gamma_{m,1} \tag{3}$$

where $\Gamma_{m,1}$ is the free space propagation path loss from multiple UWB systems.

In the multiple victim systems and UWB systems, the tolerable PSD P_{INT} is given by

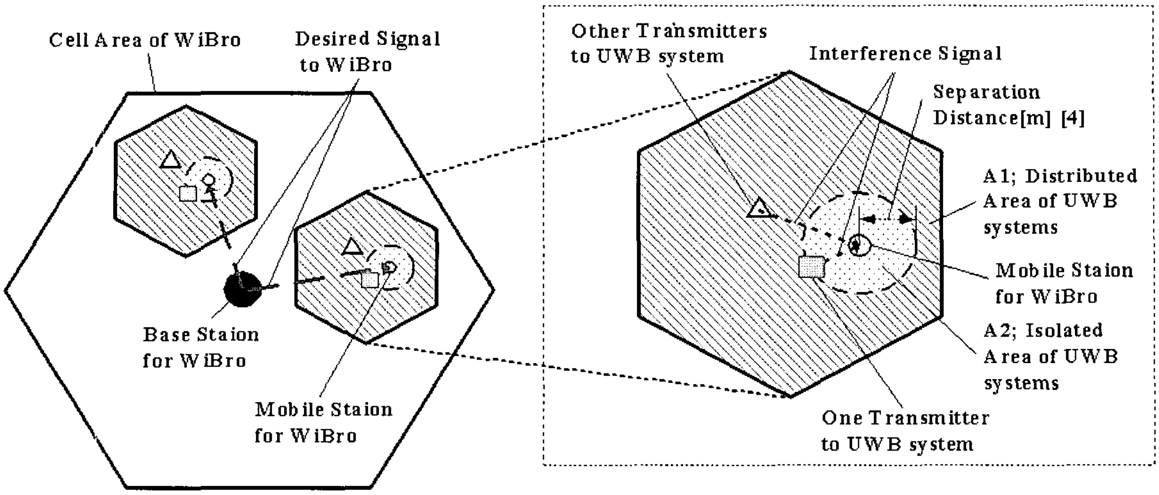
$$P_{INT}=\sum_{j=1}^{J}\sum_{q=1}^{Q}P_{q,j} \tag{4}$$

where the constant j depicts the index of the victim system $j=\{1,\ 2,\ \cdots,\ J\}$. The constant J is the total numbers of the victim systems uniformly distributed in cell area of WiBro system. The constant q depicts the index of each interferer around and close to each victim system j and $q=\{1,\ 2,\ \cdots,\ Q\}$. The constant Q is the total number of UWB systems over unit area km^2.

4-2 Proposed Numerical Analysis Procedure

The numerical method is employed to theoretically evaluate the impacts of interference as shown in Fig. 4. The numerical analysis is the performance evalution of WiBro system considered three factors; total cell throughput loss, outage in mobile station with less than minimum sensitivity at multi-rate, and outage in mobile station with less than sensitivity at single-rate. From performance degradations of WiBro system through the numerical analysis, the tolerable UWB PSD to WiBro system for coexistence between UWB and WiBro system could be obtained. Fig. 5 shows the calculation flow of total throughput loss. From Fig. 5, the total throughput loss is obtained from two steps.

Six adaptively modulation modes of the fallback sche-



(a) Geometric downlink model at WiBro

(b) Geometric interference model between WiBro and UWB system

Fig. 4. Geometric downlink model (a) and interference model (b) for the proposed scheme in the single cell.

me are assumed. It is assumed that the base station gets an equal chance to transmit packets, and that all packets are received from mobile station with no error when the modulation mode is adequately selected by the fallback technique. The $C/(N+I)$ in the location of mobile station is derived. The $C/(N+I)$ is called the received $C/(N+I)$, which is derived from the desired signal power, interference power, and the noise power according to the location of mobile station. Here, the target $C/(N+I)$ is determined by both the required C/N in additive white gaussian noise(AWGN) environment with BER 10^{-6} based on the link level performance and the protection criteria, i.e. the tolerable UWB I/N ratio in WiBro system. It is noted that if the target $C/(N+I)$ is smaller than the received $C/(N+I)$, the wireless link between base station and mobile station for WiBro is assured. Next, the received $C/(N+I)$ is severely degraded according to the distance from the base station.

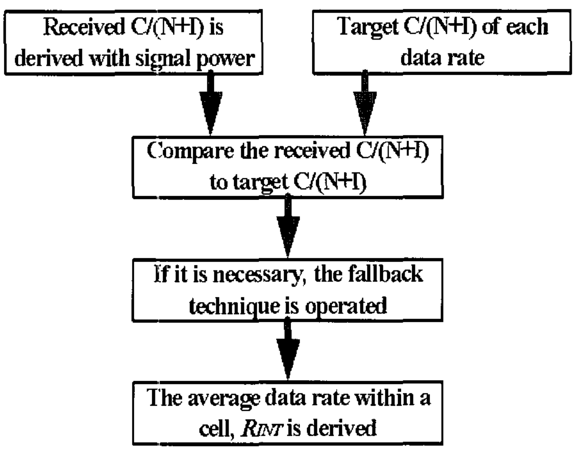


Fig. 5. Derivation step of cell capacity in proposed interference model.

In this case, the modulation mode is adequately selected by the fallback technique to connect the wireless link as well as to keep with the initial target $C/(N+I)$ based on the location of mobile station. As results, the averaged data rate R_{INT} of the cell throughput is derived.

Finally, cell capacity averaging data rate in each mobile station R_{ave} is degraded by the total power of the multiple UWB systems. This is called the total throughput loss and is given by

$$Th_{loss}(\%) = \frac{R_{ave} - R_{INT}}{R_{ave}} \times 100 \tag{5}$$

In addition, the outage in mobile station and the probability of interference is shown as results. The event of outage in mobile station is the case less than the minimum sensitivity of WiBro system with multi-rate. In the other hands, the event of interference based on the location in single cell of each mobile station is the case less than the sensitivity requirement for each modulation mode with single rate selected by the receiving state of each WiBro mobile station.

V. Simulation Results

The major parameters for evaluation are shown at Table 2. It is assumed that multiple UWB systems for P_{INT} locate at outside of the 0.36 [m]. Evaluation of the

Table 2. Parameters for victim receiver and interferers.

Parameters	Value
Frequency bands	2.3 GHz bands
Occupied channel bandwidth	9 MHz
Assumed separation distance	36 cm
UWB *I/N* ratio	−6 dB or −20 dB[4]
UWB Density over unit area km^2	50, 100, 200
Path loss - UWB multiple interferers → mobile station for WiBro - base station transmitter → mobile station for WiBro	Free Space Modified Hata Model

performance for WiBro system with multi-rate as internet service system is obtained from three factors; the total throughput loss, the probability of outage at single-rate, and probability of outage at multi-rate. Each factor is evaluated for UWB PSD as well as UWB density N [devices/km^2]. Here, the total throughput loss depicts the relative throughput loss of the maximum throughput for WiBro system without the interference due to multiple interfering signals from the multiple UWB systems. The probability of outage at single-rate or multi-rate depicts the outage in WiBro mobile station. In this paper, WiBro system provides the multi-rate with fallback technology. Therefore, the outage at multi-rate happens to less than the minimum sensitivity in mobile station. The minimum sensitivity is also derived from minimum modulation mode with QPSK modulation and 1/2 coding rate. In the other hands, the outage at single-rate happens to less than the each sensitivity derived from the six modulation modes given by Table 1. In addition, the outage at single-rate or multi-rate for WiBro system is measured at the same time in current location of mobile station. Finally, the required tolerable UWB PSD P_{INT} to protect WiBro system is estimated from three factors and is compared with that of FCC provision limit at 2.3 GHz frequency bands.

In this paper, it is assumed that the multiple UWB systems in cell area of WiBro transmit the same maximum PSD, which called UWB PSD, and all of them are active state. Therefore, they may affect as interference to WiBro mobile stations, if they close to mobile station and causes to degrade the total throughput for WiBro. UWB *I/N* ratio is criteria for the performance degradation of WiBro system derived in Eq. (1). Therefore, the criteria −20 dB is more critical margin than −6 dB for the impacts of interference. Therefore, WiBro system with the criteria −20 dB must be rigidly protected to interference. If the multiple UWB systems close to a WiBro mobile station don't exist, the total throughput loss and outage are not regard as the performance degradation for WiBro system and this means zero as shown in Fig. 6(a)~Fig. 6(c).

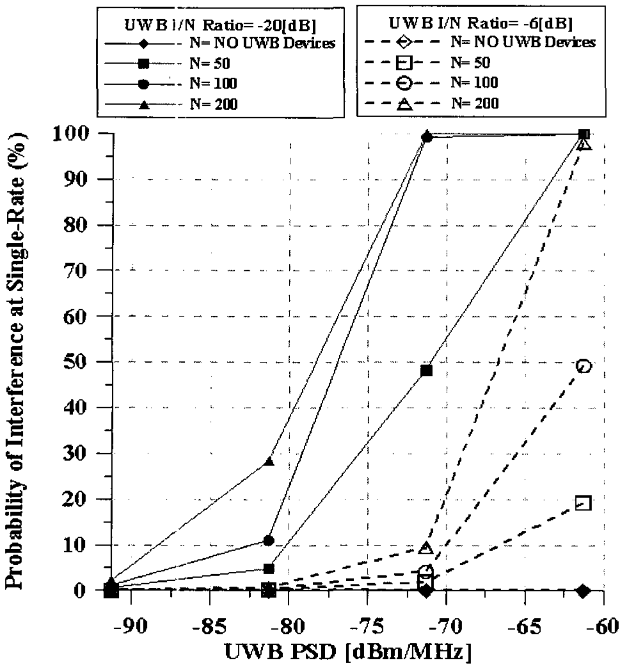
Fig. 6(a) shows that the averaged total throughput for WiBro system with UWB *I/N* ratio of −20 dB or −6 dB tends to decrease according to increasing numbers of the multiple UWB systems, N [devices/km^2], with devices over unit area for a square of km, regarded as the total interference. Here, the total throughput loss is considered for the relative throughput loss of the maximum throughput for WiBro system with non-interference. In this paper, WiBro system provides the multi-rate with the fallback function. And this fallback function is derived from the required $C/(N+I)$ concerned to interfering power, I. Also, the required $C/(N+I)$ is derived from UWB *I/N* ratio. Therefore, total throughput loss of UWB *I/N* of −20 dB is similar to that of UWB *I/N* of −6 dB.

Fig. 6(b)~Fig. 6(c) show that the outage at single-rate or multi-rate in mobile station for WiBro happens due to interference by the multiple UWB systems. Here, the outage at single-rate is compared with one at multi-rate, when the total throughput for WiBro is shown in Fig. 6(a).

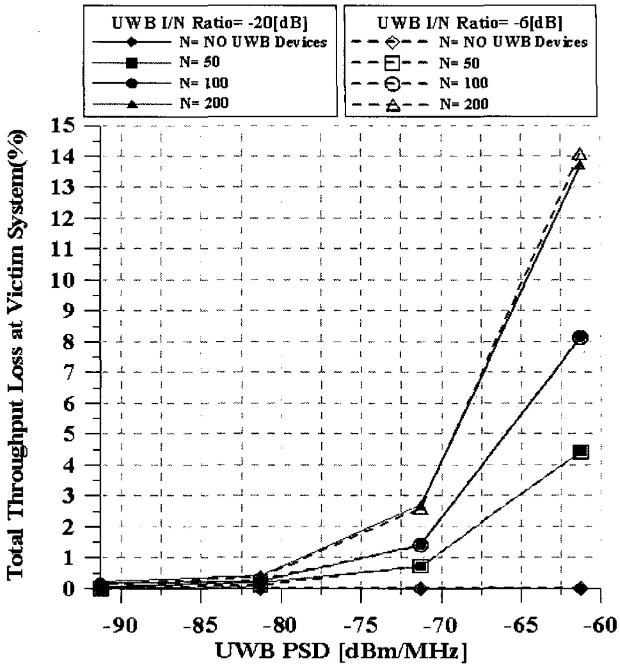
As shown in Fig. 6(b), the outage is drastically increasing according to the multiple UWB systems with the maximum UWB PSD. Although the UWB PSD decreases by −80 dBm/MHz, the outage value in mobile station for WiBro is high. In the other hands, the outage value of mobile station for WiBro with multi-rate using the fallback function as shown in Fig. 6(c) is nearly zero. This means that the WiBro system is not affecting the impact the interference from the multiple UWB systems with UWB PSD of −70 dBm/MHz.

Ⅵ. Conclusion

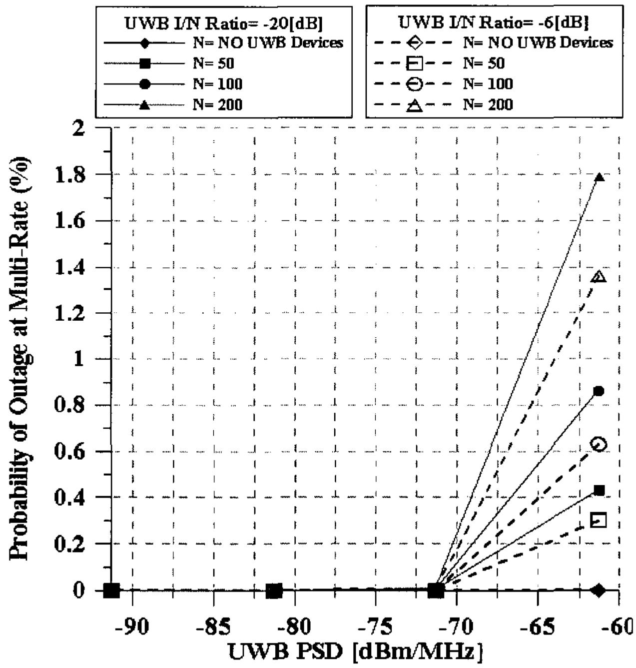
This research has shown that UWB emissions are likely to be so harmful to WiBro system capacity. Multiple UWB systems may affect as interference to WiBro mobile stations, if they close to mobile station and causes to degrade the total throughput for WiBro. UWB *I/N* ratio is criteria for the performance degradation of WiBro system derived. As shown in results of the assessment of the potential interference caused by UWB systems, the tolerable UWB PSD to WiBro system at 2.3 GHz frequency bands must be restricted by the approximatly −70 dBm/MHz and should be rigidly limited by less 10~20 dB than FCC provision limit to guarantee conflict-free coexistence between UWB technology and WiBro system. Also, if the multiple UWB systems close to a WiBro mobile station don't exist, the



(a) Probability of outage at single-rate for UWB PSD



(b) Total throughput loss for UWB PSD



(c) Probability of outage at multi-rate for UWB PSD

Fig. 6. Performance of WiBro system by the impacts for UWB interference.

total throughput loss and outage are not regard as the performance degradation for WiBro system.

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