Experimental Evaluation of Interference from MB-OFDM UWB Systems to Narrowband Wireless Digital Transmission Systems

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Abstract

Multi-band orthogonal frequency-division multiple-access (MB-OFDM) is one of the UWB technologies that realize wireless personal network (WPAN). In this paper, we experimentally investigated the interference from MB-OFDM signal to narrowband QPSK digital transmission system. The bit error rate (BER) performance of the narrowband QPSK system under the interference of UWB signal was evaluated, assuming the white Gaussian noise (AWGN) channel. The experimental results show a curve with BER degradation characteristics. The difference of the BER degradation characteristics according to the modulation parameter of the signal is discussed.

1. Introduction

Ultra wideband (UWB) technologies have been developed to realize ultra-high-speed communication, high precision geolocation, and other applications. In February 2002 , the Federal Communication Commission (FCC) allocated a spectrum from 3.1 GHz to 10.6 GHz for unlicensed indoor use of UWB devices. The FCC defined UWB signals as those having a –10 dB bandwidth greater than 500 MHz. IEEE 802.15 Task Group 3a has been develop to standardize wireless personal area networks (WPAN) use the UWB technology. A bit rate of at least 110 Mb/s at 10 meters is required, and 480 Mb/s is desirable at the super-short range. Within the task group, two proposals remain for the final-stage down selection: multi-band orthogonal frequency division multiplexing (MB-OFDM) and direct spread code division multiple access (DS-CDMA). These are examined for physical layers [1], [2].

UWB systems spread the transmitted signal power over an extremely large frequency band, up to 10.6 GHz. Hence the power spectral density (PSD) of the signal is very low reducing the interference on existing narrowband systems. The effect of the interference that UWB has on narrowband systems and other UWB systems has been reported previously [3], [4], [5], [6]. In these studies a simple model such an impulse radio was used for the simulation. However, they did not necessarily accurately model a real transmission system. Therefore, we decided to experimentally evaluate interference from MB-OFDM to narrowband QPSK systems. In this experiment, the modulation parameter of MB-OFDM and the bandwidth of QPSK were changed. In this paper, when this parameter was changed, the difference of the interference characteristic is discussed.

2. Experimental system

Figure 1 shows a block diagram of the bit error rate (BER) measurement system. The transmission line assumes AWGN channel in this experimental system. The output of the narrow band QPSK digital radio transmitter was connected to the victim receiver via an attenuator, a combiner, and a hybrid with coaxial cables. The attenuator adjusted the received power level. This setup enabled us to eliminate the effects of signal fading, which was not the subject of this study.

The victim RF signal and the culprit UWB signal were combined with the combiner. The UWB signal level was adjusted with another attenuator. The combined signal was applied to a bandpass filter (-3 dB bandwidth = 20 MHz), which emulated the frequency response of a typical victim antenna. The hybrid was inserted to measure the RF spectrum power density using a spectrum analyzer. The victim and culprit power levels were measured by integrating the power density over the transmission bandwidth. The victim receiver demodulated the combined signal. A BER counter computed the average bit error rate of the demodulated data. The average bit error rate was calculated while verifying the desired-to-undesired signal power ratio (D/U), where D is the transmission signal's average power and U represents the power of the interference signal's average power occupying the same bandwidth.

2.1. Narrowband transmission system

Figure 2 and Table I show a block diagram and parameters of a narrow band QPSK digital transmission system for this experiment.

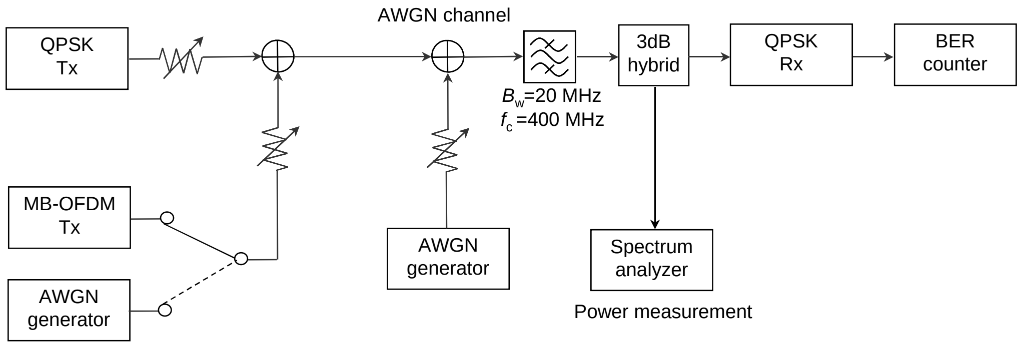

Fig. 1. Block diagram of the bit error rate measurement system.

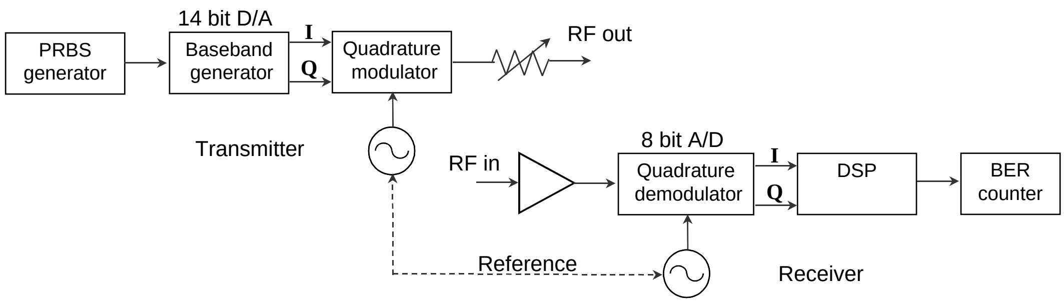

Fig. 2. Block diagram of the narrow band QPSK system.

The transmitter consisted of a base band generator and a DAC. The transmission data which consisted of 15-stage (32,767-bit) M-sequence was input to the QPSK modulator. The baseband modulator generated a baseband signal (8 times over-sampling), which was up-converted to an intermediate frequency (IF) signal with a direct IQ modulator.

The receiver consisted of a direct IQ demodulator, an analog-to-digital converter (ADC), and a digital signal processor (DSP). This receiver employed the synchronous detection. The receiver refers to the phase of the transmission carrier wave. DSP captured the demodulated IQ signal in real time and QPSK demapping.

2.2. MB-OFDM system

The MB-OFDM transmission system consists of 128 sub carriers over a 528 MHz bandwidth that is frequency hopped based on time-frequency code. Table II shows the timing parameter associated with the MB-OFDM PHY.

Figure 3 shows a block diagram of the MB-OFDM transmitter used for this experiment. This MB-OFDM transmitter consists of a baseband generator and a digital-to-analog converter (DAC), and was realized with an arbitrary waveform generator. The baseband generator stores the baseband signal of the MB-OFDM generated by the computer simulation in the memory. This baseband signal was generated using SPW® (Signal Processing Worksystem). The base-band signal was up-converted to 400 MHz and only one sub-band was used, so that frequency hopping was not applied in this study. The waveform in the time domain and the spectra of the signal of this transmitter are shown in Figs. 4 and 5.

TABLE I
Parameters for narrowband QPSK system

Data rate	2, 10, and 20 Mb/s
Modulation	QPSK
Bandwidth	1, 5, and 10 MHz
Roll off factor	0.5
Bit stream	15-stage M-sequence ($X^{15} + X^{14} + 1$)
Data length	32,767 bit
Receiver	Synchronous detection

TABLE II
Parameters for MB-OFDM system

Number of data subcarriers	100
Number of subcarriers	128
Subcarrier frequency spacing	4.125 MHz
Symbol interval	312 ns
Cyclic prefix duration	60.61 ns
Guard interval duration	9.47 ns

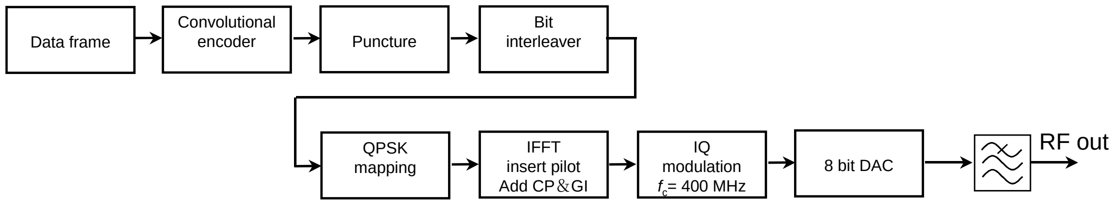

Fig. 3. Block diagram of the MB-OFDM system.

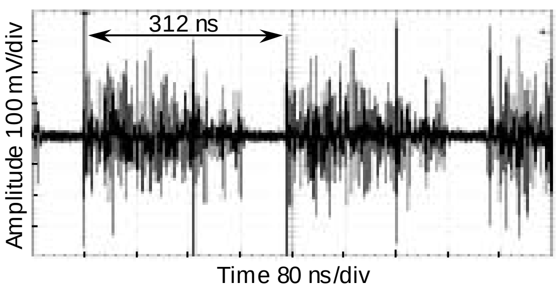

Fig. 4. Time domain waveform of MB-OFDM signal.

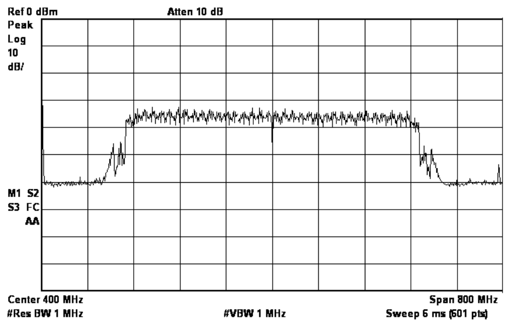

Fig. 5. Frequency spectrum of MB-OFDM signal.

2.3. Consideration of the MB-OFDM signal

In Fig. 5, spectrum peaks might appear every 3.2 MHz when the horizontal axis was expanded. This phenomenon is attributable to two factors:

First, it is because of preamble at the packet head. Figure 6 shows the time domain waveform of one packet. This packet was generated based on the standard physical layer convergence procedure (PLCP) frame format. In this format, the first 30 symbols are used for packet and frame sync sequence and channel estimation. The portion of 21 symbols for packet sync repeats the same pattern. The preamble part was analyzed in FFT, therefore remarkable periodicity appeared to the frequency spectrum.

Second, this was due to the time spreading factor. In the case where the bit rate was 200 Mb/s or less, time spreading occurred. Information spread into two symbols as shown in Fig. 6. As with the influence of preamble, the symbol pattern was repeated. Thus, peaks and valleys appeared in the frequency spectrum.

In the modulation parameter setting shown in Fig. 7(a), the remarkable peaks appeared due to the preamble and the time spreading process. On the other hand, in Fig. 7 (b), periodic peaks did not appear in the frequency spectrum. , Therefore, the difference in power of the peaks and valleys (dip: between the peak and the peak) appeared to be large, that is about 30 dB.

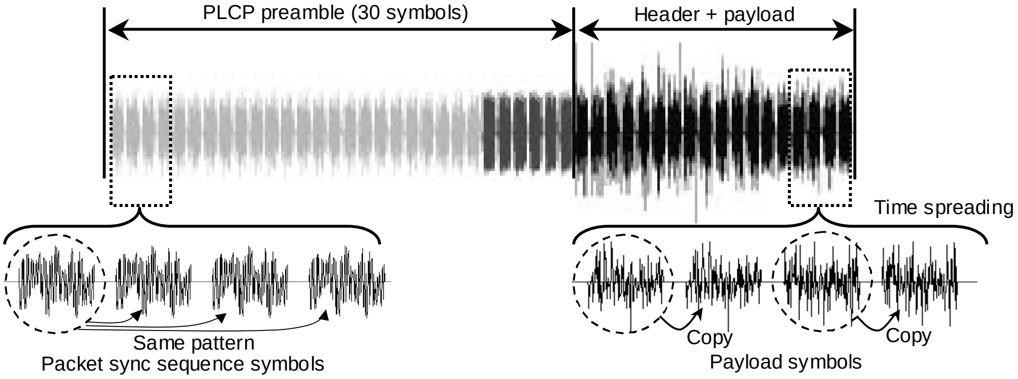

Fig. 6. Time domain waveform of MB-OFDM signal carrying one packet.

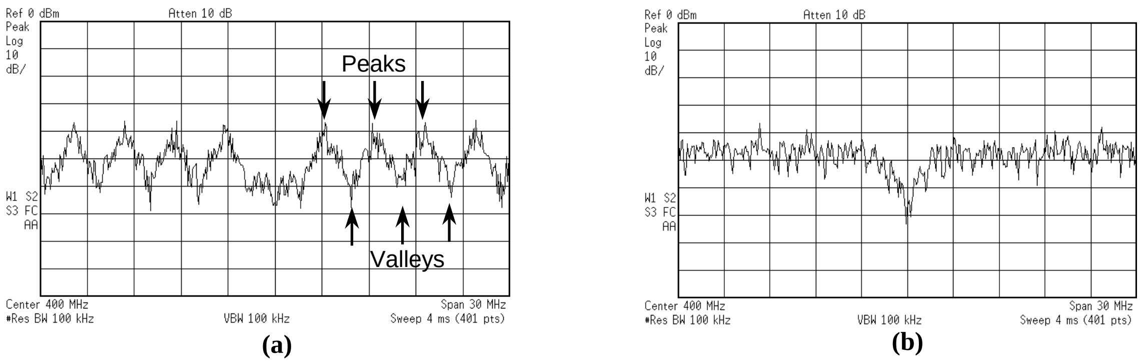

Fig. 7. Difference of frequency spectra: (a) bit rate = 55 Mb/s and payload = 40 bytes and (b) bit rate = 480 Mb/s and Payload = 4,000 bytes.

3. Experimental results

In this section, the results of the experiment are shown, and the difference of the BER degradation characteristic is described

In this experiment, the parameters of MB-OFDM set to bit rate = 480 Mb/s, payload length = 4,000 bytes (Fig. 7 (b)) is defined as MB-OFDM signal-1. The parameters set to bit rate = 55 Mb/s and payload length = 40 bytes(Fig. 7(a)) is defined as MB-OFDM signal-2. The transmission bandwidth of narrowband QPSK was varied from 1 to 10 MHz.

Figure 8 shows the BER performance of the narrow band QPSK under the AWGN interference. Figure 9 shows the BER performance of the narrowband QPSK under the MB-OFDM signal-1 interference. The curve of the broken line in Fig. 9 is the overlay of Fig. 8. Two characteristics are corresponding when the bandwidth of QPSK is 1 MHz, and it is different on 10 MHz.

Figure 10 illustrates frequency spectra of the culprit MB-OFDM signal-2 and victim QPSK signal. In this case, BER performance of the narrowband QPSK that tune to both spectral peaks and valleys of MB-OFDM signal shown in Fig. 11-13 shows under the MB-OFDM signal-2. In Fig. 11-13, no remarkable difference of the interference effects was seen between the peaks and valleys excluding the D/U =10 dB curve.

In any case, degradation in the characteristic was smaller than AWGN at same D/U. The tendency to the characteristic was corresponding to the simulation [4]. This was because the MB-OFDM signal resembled a hopping burst with a non-consecutive time domain signal.

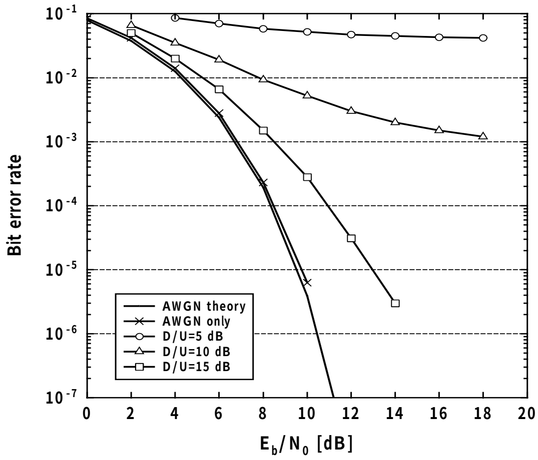

Fig. 8. **QPSK system BER performance interfered by the AWGN (UWB).**

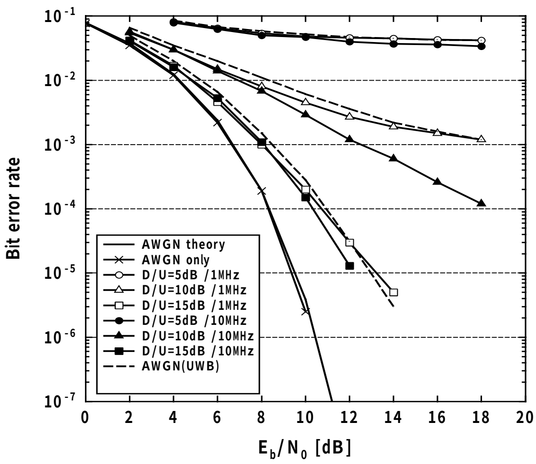

Fig. 9. **QPSK system BER performance interfered by the MB-OFDM signal-1.**

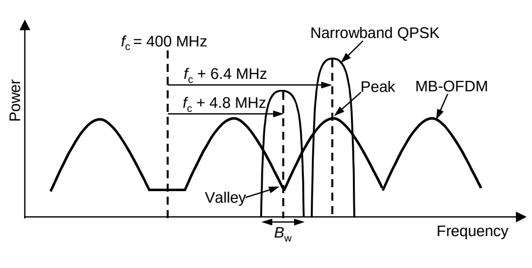

Fig. 10. **Frequency spectra of the culprit MB-OFDM and victim QPSK.**

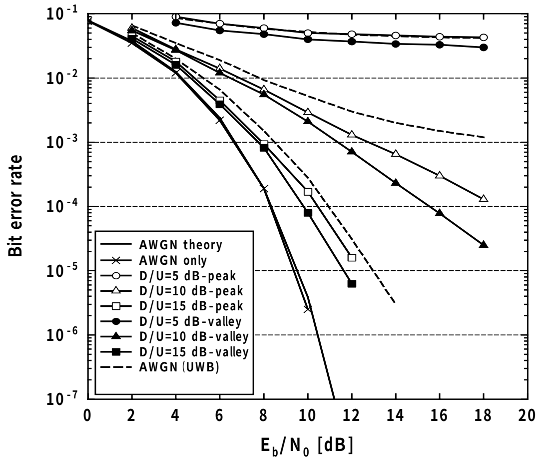

Fig. 11. **QPSK system BER performance interfered by the MB-OFDM signal-2 (QPSK, B_w=1 MHz).**

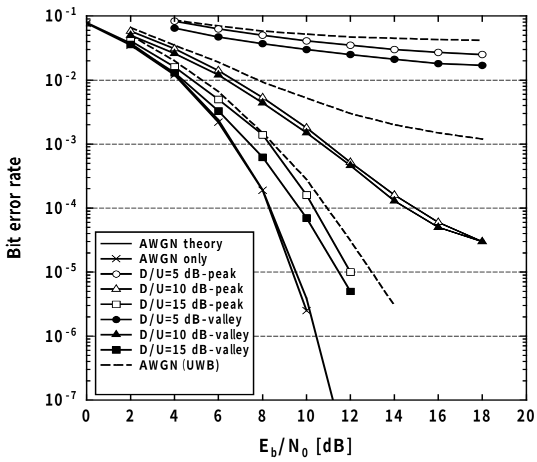

Fig. 12. **QPSK system BER performance interfered by the MB-OFDM signal-2 (QPSK, B_w=5 MHz).**

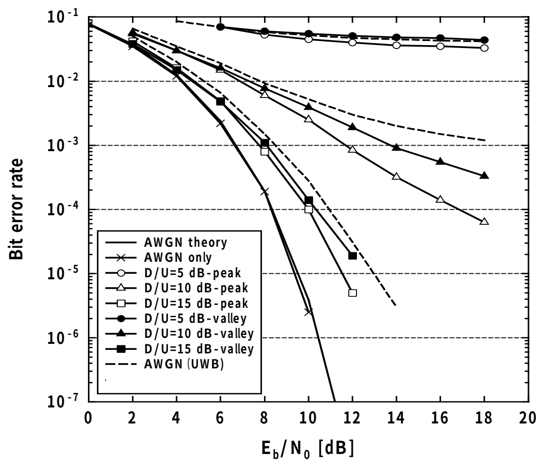

Fig. 13. **QPSK system BER performance interfered by the MB-OFDM signal-2 (QPSK, B_w=10 MHz).**

4. Conclusions

In this paper, we described the peaks and valleys in MB-OFDM signal's frequency spectrum in the case of the single band transmission without frequency hopping. Peaks and valleys interference from the MB-OFDM system to the narrowband QPSK system was evaluated by the experiment. It was found that there was no remarkable difference in the characteristic even if the center frequency of narrow band QPSK was tuned to either the peak or the valley frequency. The effect of interference from MB-OFDM signal becomes smaller than AWGN signal as UWB in this experiment in case of almost.

Our future work will include the evaluation of the interference effects in multi-path environments.

5. Acknowledgements

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6. References

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