Coexistence of OSCR-Based IR-UWB System with IEEE 802.11a WLAN

Weiwei Wu, Han Huang, Huarin Yin, Weidong Wang, and Dongjin Wang

ABSTRACT—Impulse radio (IR) is a competitive candidate for ultra-wideband (UWB) systems. In this letter, we evaluated the coexistence of an IR-UWB system based on an orthogonal sinusoidal correlation receiver (OSCR) with an IEEE 802.11a WLAN through a detailed simulation. The coexistence performance of the two systems is characterized in terms of the receiver's bit-error rates. Then, some approaches to interference mitigation are discussed.

Keywords—IR-UWB, OSCR, IEEE 802.11a, OFDM, interference mitigation.

I. Introduction

The Federal Communications Commission (FCC) has opened up 7,500 MHz of spectrum (from 3.1 to 10.6 GHz) for unlicensed use of ultra-wideband (UWB) products with an indoor emission limit of –41.3 dBm/MHz. Recently, a lot of attention has been paid to impulse radio (IR), which is regarded as a main competitor for UWB communications. The works indicate that IR systems have many desirable characteristics such as low complexity, low power consumption, low cost, high data rate, and the ability of coexistence with other radio systems [1].

As specified by the FCC, many potential interferers (licensed and unlicensed) operating in the allotted spectrum are in existence. Specifically, IEEE 802.11a systems operate at around 5 GHz Unlicensed National Information Infrastructure frequency bands, which overlap the band of UWB signals regulated by the FCC. Because UWB and 802.11a WLAN may be used in close proximity for similar applications, it is the intent of this study to examine the coexistence of these two systems. In this work, we first describe our designed orthogonal sinusoidal correlation receiver (OSCR)-based IR-UWB system, then evaluate its coexistence with an IEEE 802.11a WLAN system through a detailed and faithful-to-the-standard simulation, and provide the results in the form of an interferer's impact on the bit-error rate (BER) of each system. Moreover, some approaches to interference mitigation are also discussed.

This letter is organized as follows. Section II presents the architecture of the IR-UWB system considered. In section III, a simulation model for coexistence of UWB and 802.11a systems is proposed and the parameters involved in the simulation are described. The simulation results are discussed in section IV, and some methods to reduce interference are given in section V. Finally, the letter is concluded in section VI.

II. IR-UWB System Model

A typical time hopping (TH) format with pulse position modulation (PPM) is given by

$$s_{tr}^{(k)}(t)=\sum_{j=-\infty}^{+\infty} w_{tr}\left(t-jT_f-c_j^{(k)}T_c-\delta d_{\lfloor j/N_s\rfloor}^{(k)}\right), \tag{1}$$

where $w_{tr}(t)$ represents the transmitted monocycle, the quantities with superscript k indicate transmitter-dependent quantities, and T_f is the uniform pulse train spacing, which is often called the frame time or pulse repetition time. To eliminate catastrophic collisions in multiple accessing, each link (indexed by k) uses a distinct pulse-shift pattern, $\{c_j^{(k)}\}$, which is called a TH sequence. These hopping sequences are pseudorandom with period N_p, and its element is an integer in the range $0 \le c_j^{(k)} < N_h$. A pulse position modulation is

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considered in this letter. An ideal waveform of the received pulse is given by

$$w_r(t) = \left[1-4\pi\left[\frac{t}{t_{au}}\right]^2\right]\exp(-2\pi\left[\frac{t}{t_{au}}\right]^2)\cdot \qquad (2)$$

The IR-UWB physical architecture that we designed in our demonstration platform is shown in Fig. 1 [2].

The channel coder block uses a low-density parity-check code with a code rate of 1/3. In the receiver of an IR-UWB system, the acquisition and synchronization for an ultra short pulse is one of the critical blocks. We choose the RAKE correlator design in our demonstration platform. The RAKE receiver utilizes multiple correlators to separately detect several strongest multipath components. We designed the RAKE receiver based on the orthogonal sinusoidal correlation architecture; the incoming signal is correlated with the two orthogonal sinusoidal signals generated by the voltage controlled oscillator (VCO). The receiver can provide acquisition, synchronization, and tracking, and can process the components of multipath signals with a time-window based on a precise estimation of phase error between every component of the multipath signals and VCO outputs. Figure 2 shows the basic structure of the proposed OSCR.

In the multipath scenario, several parallel path modules, each of which is the same as shown in Fig. 2, follow the analog multipliers. Each path module distinguishes its signal from the outputs of the two multipliers by its own correlation window. The designed receiver based on OSCR proved to be stable to timing jitter and had good performance in our demonstration platform [3].

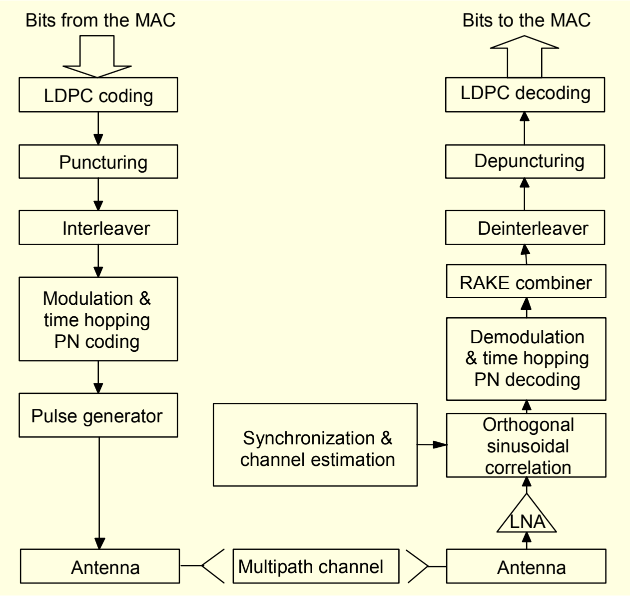


Fig. 1. The IR-UWB system architecture.

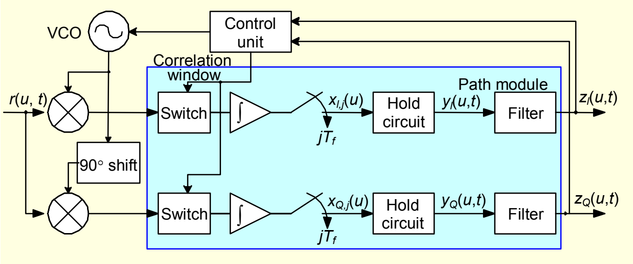


Fig. 2. The basic structure of OSCR.

III. UWB/802.11a Coexistence Simulation

This section describes simulation models used to evaluate the coexistence of UWB/802.11a. The simulator is written in C code and is developed and debugged in a Microsoft Visual C++ (version 6.0) environment.

Figure 3 shows the simulation model of the 802.11a WLAN system [4]. In general, the model consists of a transmitter, an AWGN channel, UWB interference, and a receiver. The interference signal is added from an IR-UWB transmitter as

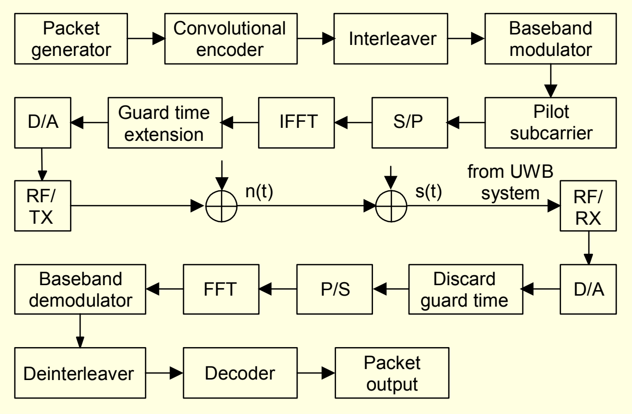
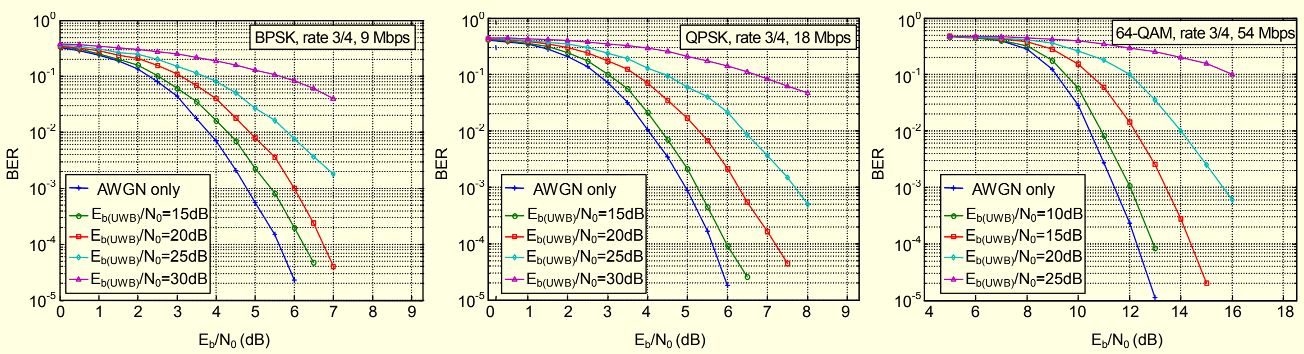


Fig. 3. The basic simulation structure of 802.11a.

Table 1. The Parameters of IEEE 802.11a WLAN.

Date rate	6, 9, 12, 18, 24, 36, 48, 54, 72 Mbps
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Coding rate	1/2, 2/3, 3/4
Number of subcarriers	52
OFDM symbol duration	4 µs
Guard interval duration	800 ns
Subcarrier spacing	312.5 kHz
-3dB bandwidth	16.56 MHz
Channel spacing	20 MHz
Sampling rate (FFT= 64)	50 ns



(a) BPSK, 9 Mbps (b) QPSK, 18 Mbps (c) 64-QAM, 54 Mbps

Fig. 4. The performance of 802.11a with UWB interference on an AWGN channel.

shown in Fig. 1. To validate the impact of the 802.11a system on the IR-UWB system, we added the signal from the 802.11a transmitter to the designed IR-UWB receiver.

Table 1 presents the parameters of the physical layer of 802.11a in GHz. There are 48 data and four pilot subcarriers in one orthogonal frequency-division multiplexing (OFDM) symbol. The parameters of the IR-UWB system in our simulation are the following:

- The pulse repetition frequency is 476 MHz. Each symbol is transmitted using five pulses.
- The second derivative of the Gaussian pulse is adopted with duration 0.3 ns, and t_{au}= 0.124 ns.
- The chip length is 0.42 ns, and the correlation window is chosen as 0.2 ns.
- The pilot frame is a PN sequence with a length of 1000 bits.
- We consider a line-of-sight communication, modeled as channel model scenario CM1 in [5].

IV. Coexistence Simulation Results

Figures 4(a) through 4(c) show the BER performance of an 802.11a system operating at different data rates and modulation types. With the interference signal-to-noise ratio, $E_{b(UWB)}/N_0<15dB$, the IR-UWB interference to 802.11a seems to be tolerable. Compared with the no-interference case, the 802.11a system under binary phase shift keying (BPSK) modulation introduces a degradation of 1 dB, and 1.5 dB under quadrature phase shift keying modulation at the target BER of 10^{-4} when $E_{b(UWB)}/N_0<20dB$. The performance of an 802.11a WLAN system will be greatly impacted by the severe interference from UWB when $E_{b(UWB)}/N_0<25dB$. Also, the results in Fig. 4 show that the 802.11a system is more vulnerable to UWB interference operating at higher date rates and higher order modulation types.

Figure 5 shows the BER performance of the designed IR-UWB system in CM1 and interference conditions. The results show that the 802.11a system operating at a rate of 9 Mbps under BPSK modulation causes little interference to IR-UWB when $E_{b(802.11a)}/N_0<20dB$ (here, referring to the interference signal from the 802.11a transmitter). The UWB system will be intolerable to interference from 802.11a when $E_{b(802.11a)}/N_0>30dB$.

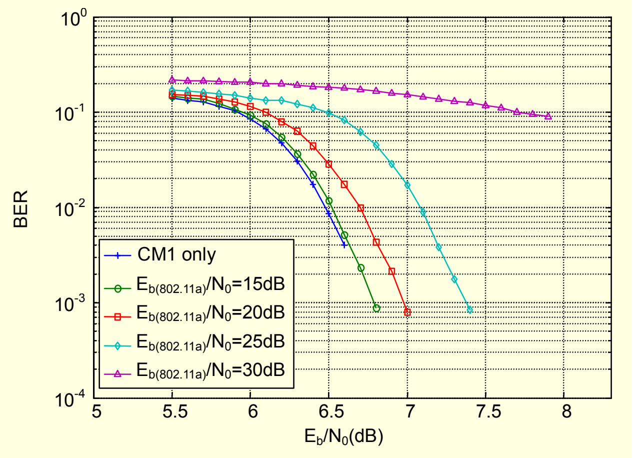


Fig. 5. The performance of IR-UWB system with 802.11a (9 Mbps) interference in CM1.

V. Interference Mitigation

From section IV, we notice that our OSCR-based IR-UWB system was proven to have good ability to resist interference from 802.11a and causes little interference to 802.11a in common conditions. However, when the two systems are placed very closely, they will severely affect each other. Therefore, we propose a filter to remove the interference from an 802.11a system. Figure 6 shows the improvement with an eighth-order Chebyshev bandstop filter that is applied before the OSCR. The frequency response of this filter is illustrated in Fig. 7. The ripple of the filter is under 0.2 dB, and the attenuation is –20 dB at the 5.22 GHz center frequency of IEEE 802.11a. The BER performance of IR-UWB is deteriorated about 0.7 dB because of the filter when the 802.11a interferer does not exist. However, when the interference from 802.11a is severe, the performance improvement of the filter is significant.

In an IR-UWB system transmitter, there is a possibility to use a linear combination of the fifth derivative of a Gaussian pulse and delayed pulse to adapt the spectrum to the 802.11a interference situation. This will help both the compatibility with 802.11a and the performance in interference environments. The combination of the pulses also helps to maximize the useful energy within the transmit band.

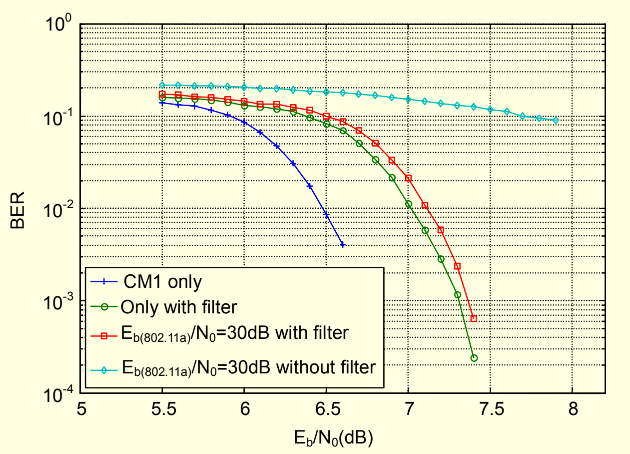


Fig. 6. The performance of the IR-UWB system using a filter with severe interference in CM1.

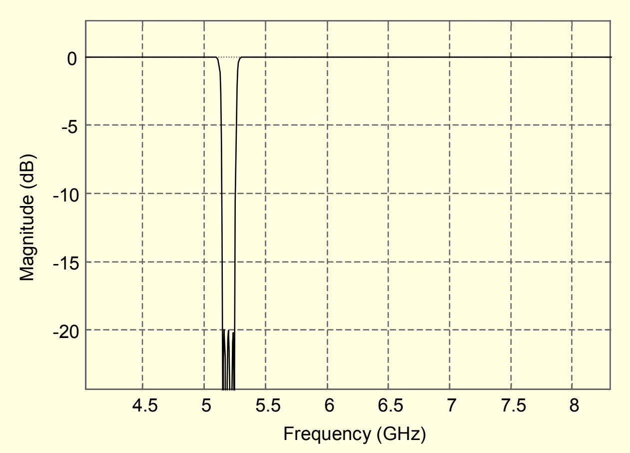


Fig. 7. The frequency response of eighth-order Chebyshev bandstop filter.

VI. Conclusions

We have completed an evaluation of the interference between our designed OSCR-based IR-UWB system and 802.11a WLAN through a detailed simulation. It is shown that the IR-UWB system has good ability to resist interference from 802.11a and causes little interference to 802.11a in common conditions. Furthermore, the topic of interference suppression is of great importance when strong interference exists. Thus, some approaches to interference mitigation are proposed and proved to be feasible. More efficient methods of interference excision are topics for further research.

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