Original Research Article

On the performance of a fast synchronization scheme for IR-UWB receivers

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Abstract: Because of the norrow signal duty cycles, SYNC is the most critical issue in UWB-IR systems. Some synchronization schemes like a SD-IR-UWB receiver have been proposed to synchronize received signals rapidly. Yet, SD IR-UWB receiver is not suitable for operation in multi-user stiution because of MAI. By taking advantage of FD-IR-UWB receivers, we propose a PFD-IR-UWB receiver to do so. Our proposed PFD IR-UWB receiver manifests better immunity against message passing interface and MAI than the SD IR-UWB. Based on this PFD IR-UWB receiver, search regions are limited to one frame duration without any symbol-level synchronization sheme. Performance of PFD and SD receivers are compared by simulations, showing that the proposed PFD receiver not only achieves significantbit error rate performance but also better and more robust results than the SD receiver in this paper.

Keywords: UWB(Ultra-Wide Band); SYNC(synchronization); IR(impulse radio); TH(time-hopping)

1. Introduction

UWB technology, characterized by low power, high data rates, and ability to coexist with extant service in the spectrum[1], has recently drawn increasing attention in both academia and industry and In TH UWB systems, data are transmitted with trains of pulses on the order of nanoseconds, the occupied frequency band from near DC to several Giga hertz. Because pulse duration is neno, TH-UWB systems achieve fine multipath resolution capability, making them viable candidates for communications in dense multipath environments: for example, short range or indoor wireless communication[1–3]. UWB systems provide wireless transmission with a high data rate, thus attracted much from both industry and academia.Still, timing synchro- nization poses formidable obstacles[4,5]].

2. Signal model

This research studies a BPSK random TH IR-UWB system. Each data bit di ∈ {+1; —1} is modulated by BPSK and transmitted by Nf successive frames with one monocycle pulse in each frame. Generally, polarities of Nf successive pulses used to represent an data symbol are always the same. Recently, the pulse-based polarity randomization scheme has been evaluated[15]. Other than BPSK, each pulse is also modulated by a random polarity code. Modulating with the random polarity code can eliminate power spectral lines to fit the FCC's spectral mask while providing more robustness against multiple access interference.

Figure 1 diagrams a known random polarity sequence bj ∈ {+1; —1} as DM on monocycle pulses, where j ∈ Œ0; Nf — 1] is the pulse index in a symbol. With BPSK and random polarity code superimposed that is, each pulse differentially modulated by both BPSK and random polarity sequence differentially modulated pulse-polarities are a i;j +1 = a i;j dibj and a i+1;0 = a i;Nf -1d ibN f -1, where i is the symbol index. Transmitted signal of this FD-UWB system can be expressed as

$$s_k(t) = \sum_{i=-\infty}^{\infty} \sum_{j=0}^{N_f-1} d_{k,i} w(t - iT_s - jT_f - c_{k,j}T_c),$$

where …. {cj }j $\overset{f}{=}$0 is the TH code ,Dp = Tf + .c Œp+1]Nf — cp/Tc , $\tilde{w}(t)$ represents transmitted pulse waveform that is non-zero for t ∈ .0; Tp/; Tp is one pulse duration; i symbol index; j frame index; Tf pulse repetition time ; Ts symbol duration; Tc duration of a hopping time slot, and sum Dp=0 defined.

$h_k(t) = \sum_{l=0}^{L_k} \alpha_{k,l}\delta(t - \tau_k - \tau_{k,l})$,Here, the UWB multipath is modeled as a linear filter with the impulse response as

3. Proposed parallel df impulse radio UWB receiver

Figure 2 shows the proposed PFD IR-UWB receiver consisting of a total of Nf parallel branches, each branch contains Nf sets of delay and multiplier elements. Delays in the first branch are denoted by D Nf -1,DNf -2 ,. . . , D0; delays in the second branch by D0 , DNf -1 , . . . ,D 1; and FCC's spectral mask while providing more robustness against multiple access interference.

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ζq;k SIW , where q ∈ Œ0; Nf — 1] and k ∈ [0; $\frac{T_f}{\Delta}$ — 1]

are the search step indexes. The ζq;k = iTs 0+CqTc +kΔ is the integration time, where Δ is the time offset between two candidate time offsets. Output of the first branch Z0 can be expressed as

4. Simulations

In simulations, we test the performance of the proposed PFD and SD receiver [13]. In all cases, channels are gener- ated according to UWB CM1 and CM4 [16], with param- eters for CM1 and another is CM4. These two models represent diametrically opposite channel sutiation: CM1 based on LOS (0–4 meters) channel measurements, CM4 generated to fit 25 ns PMS delay spread to represent extreme NLOS propagation multipath. In CM1, about 92% channel energy can be obtained from the previous 20 paths, 70% from the previous 10 paths, and 50% from the previous 6 paths. In CM4, about 92% channel power could be obtained from the previous 66 paths, 70% from the previous 33 paths, and 50% from the previous 22 paths. Also, frame duration is specified as Tf = 100 ns, each symbol containing Nf = 20 frames, chip time Tc = 1 ns.

4.1. Detection error rate

The DE describes a situation when inaccuracy of an estimated symbol boundary exceeds SIW/2. Because delay spread in CM4 is about three times larger than that in CM1, SIW in CM4 is also about three times larger than that in CM1 required to capture an equal amount of signal energy. **Figure 3** shows two DER simulations under different user numbers; we observe that as the number of users rises, DER worsens. Comparing **Figure 3** with two channel models, we see the performance of the same detector worse in the UWB CM4. Delay spread of UWB CM4 is much longer than CM1 channel models, with variations of amplitude of UWB CM4 more violent than that of CM1 channel models. It is clear that DER in CM1 is better than that in CM4. The proposed detector can achieve acceptable BER performance despite an increasing number of active users.

Figure 4 shows two DER simulations, with Δ differing. In **Figure 4**, when Δ is equals to 20 ns, the performance is not good; with Δ smaller than SIW/2, the perfor mance is good. Also, **Figure 4** shows DER with different Δ in CM4. Variation tendency of this figure is the same as that in **Figure 4**, but the performance is worse. From the aforementioned discussion, we conclude that when the Δ is smaller, the DER is better. From the results of **Figure 4**, we observe that, when different Δ is below SIW/2, that is, when Δ < 10 ns, DER performance of the IR-TH UWB system improves, as different Δ decreases.

Figure 2 shows branch's output value as a summation of Nf integration results, multiplication output signals during SIW. For complexity reduction, we use only A sets of delay element and multiplier in each branch: A [Œ1; Nf]. In **Figure 5**, we make A equals to 20, 15, and 10. When A is equals to 10, the performance is about 2 dB worse than when A is equals to 20,but only 10

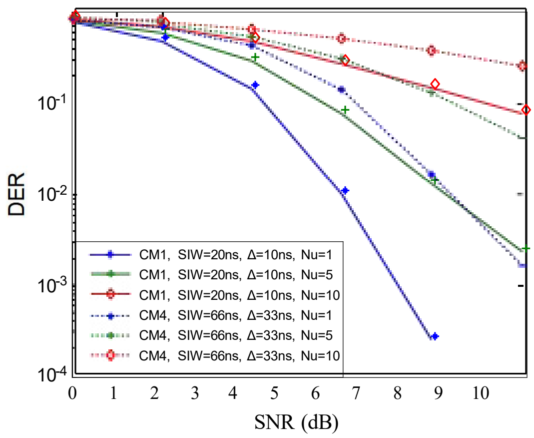

Figure 1. Detection error rate for different number of users inCM1, with SIW = 20 ns; Δ = 10 ns and in CM4, with SIW =66 ns; Δ = 33 ns when Nu = 1, 5, 10.

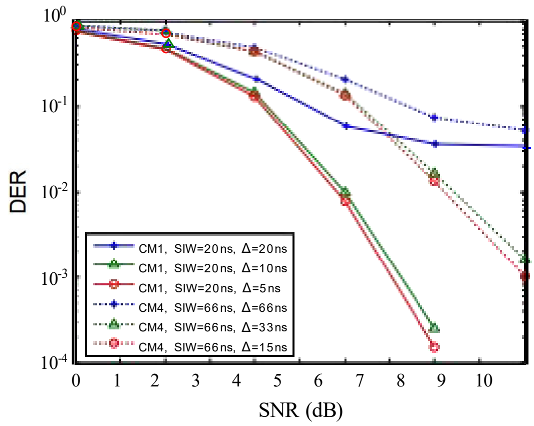

Figure 2. Detection error rate for different shift time offsets in CM1, with SIW = 20 ns; Δ = 20, 10, and 5 ns and in CM4, with SIW = 66 ns; Δ = 66, 33, and 15 ns, and Nu = 1.

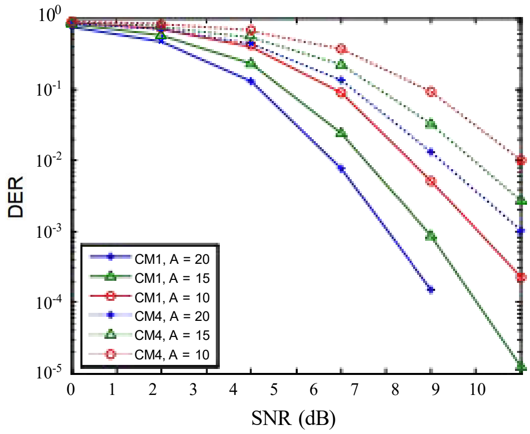

Figure 3. Detection error rate for complexity reduction scheme in CM1, with SIW= 20 ns; Δ = 5 ns and in CM4, with SIW=66 ns; Δ = 15 ns, and Nu = 1.

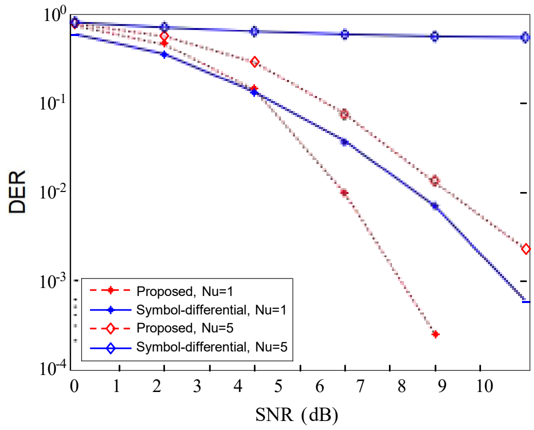

Figure 4. Detection error rate for the proposed algorithm and symbol-differential scheme in CM1, with SIW = 20 ns; Δ =10 ns, and Nu = 1, 5.

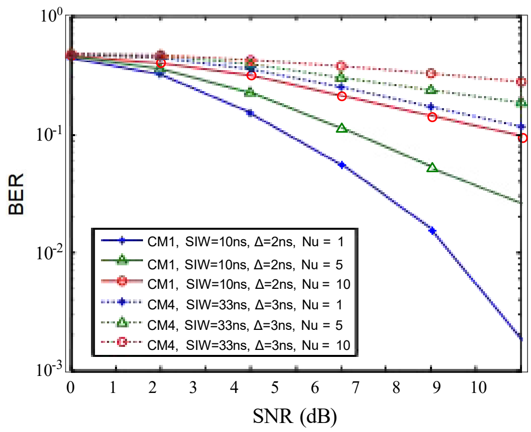

Figure 5. Bit error rate for different number of users in CM1,with the width of SIW= 10 ns; Δ = 2 ns and Nu = in CM4,with SIW = 33 ns; Δ = 3 ns, and Nu = 1, 5, 10.

5. Conclusions

With our proposed PFD IR-UWB receiver, uncertain regions are limited to one frame with no symbol-level SYNC required. It greatly reduces total search time in SYNC process. The proposed SYNC shows better DER and BER performance than SD in simulatio making the proposed scheme more practicable in multipath and multi-user stuiations. Although the proposed scheme can achieve fast SYNC and better DER and BER performance, higher complexity is a formidable issue for system realization. How to reduce the number of delay elements, multipliers, and low enegy feature is a topic worth future reaserch.

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