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Interference Mitigation in Transmitted-Reference Ultra-Wideband (UWB) Receivers

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Abstract– The transmitted-reference (TR) ultra-wideband transceivers [4] have recently become increasingly popular for their simplicity, capability to reduce the stringent UWB timing requirements, and robust performance in multipath channels. However, the performance of TR receivers is considerably limited by the severity of noise-on-noise component introduced by various types of channel noise such as additive white Gaussian noise (AWGN) or narrowband interference (NBI) on the transmitted signal [6]. It is expected that such receivers will perform poorly at low signal-to-noise ratio links, or in the presence of strong narrowband interferers. In this paper we propose a novel technique that maximizes the extraction of information from reference pulses for UWB-TR receivers. The scheme efficiently processes the incoming signal to suppress different types of interference prior to signal detection. The method described introduces a feedback loop mechanism to enhance the signal-to-noise ratio of reference pulses in a conventional TR receiver. The performance of a conventional TR receiver and a feedback loop TR receiver in the presence of AWGN and strong narrowband interference is investigated by analysis and computer simulations. Our studies show that the reference enhancing feedback loop mechanism greatly improves the robustness of the link performance of TR receivers in the presence of non-UWB interferes with modest increase in complexity.

I. INTRODUCTION

Ultra-wideband (UWB) technology provides the potential of delivering large amount of data with low power spectral density due to modulation of extremely short duration pulses [1]. The short duration of UWB pulses spreads their energy across a wide range of frequencies from near DC to several GHz and enables UWB signals to share the frequency spectrum with the coexisting narrowband and wideband communication systems [2]. Although UWB communications offers a promising solution to an increasingly overcrowded frequency spectrum, the overlay of UWB signals on coexisting narrowband systems implies interference concerns for both UWB and narrowband systems. Studies have shown that UWB systems are not considered as a serious threat to most narrowband systems due to their low power spectral densities [3]. However, strong interference from narrowband systems on UWB devices can be detrimental to low powered UWB waveforms and should not be overlooked. Therefore, proper interference mitigation techniques are essential to a successful UWB receiver design. In this paper we introduce a simple and novel interference suppression method for transmitted-reference (TR) receivers [4-5] using a feedback loop mechanism and investigate the performance improvement of such receivers in the presence of white noise and sinusoidal narrowband interference. Although TR modulation achieves high performance in multipath channels, it performs poorly in low signal-to-noise-ratio environments due to an increase in the received signals' noise-on-noise interference component [6]. This paper investigates the performance improvement of TR receivers by employing a feedback loop structure to process the received signal and suppress various types of interferences. The organization of this paper is as follows. Section II briefly discusses the effect of multiple narrowband interferes on TR receivers. Section III introduces the feedback loop mechanism for interference suppression in TR receivers and examines the SNR improvement of feedback loop TR receivers using computer simulations. Concluding remarks are summarized in Section IV.

II. NARROWBAND INTERFERENCE IN TR RECEIVERS

Due to overlay of UWB and narrowband signals in frequency spectrum, the presence of narrowband interference in UWB communication systems is often an unavoidable problem. Narrowband interferers

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may have less energy than the UWB signal, but since their energy is concentrated over a narrow bandwidth, they can mask low power UWB signals. Although UWB communication systems have high processing gain that can provide an inherent immunity to narrowband interference, their performance can suffer considerably in the presence of strong NBIs. Therefore, applying additional interference suppression techniques become necessary in successful UWB receiver design. In this section we consider a situation where UWB signals are received with a TR receiver in the presence of AWGN and interference from coexisting narrowband wireless systems as shown in Fig. 1.

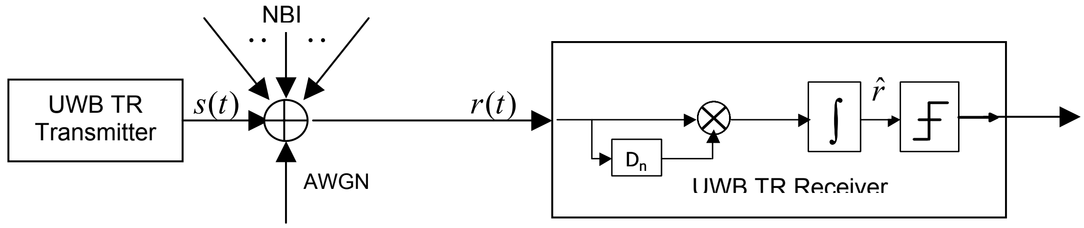


Figure 1: A simple model of the transmit-reference UWB transceiver with a transmission channel consisting of AWGN and multiple narrowband interferers.

The received signal *r(t)* includes UWB signal, *s(t)*, cumulative NBI from K narrowband interferes with different carrier frequencies, $\sum_{k=1}^{K} m_k(t)$, and AWGN, *n(t)* as follows

$$r(t) = s(t) + \sum_{k=1}^{K} m_k(t) + n(t) \tag{1}$$

The sinusoidal NBI can be expressed in a simple form as

$$m_k(t) = M_k . \sin(\omega_k\, t) \qquad (k = 1, ..., K) \tag{2}$$

where $\omega_k = 2\pi f_k$. Fig. 2 compares the performance degradation of a conventional TR receiver in an AWGN only channel with a transmission channel consisting of AWGN plus strong NBI from multiple interferers. Please note that in all computer simulations the BER performance is based on assuming perfect synchronization and prior knowledge of the exact integration period, T_{in} [6].

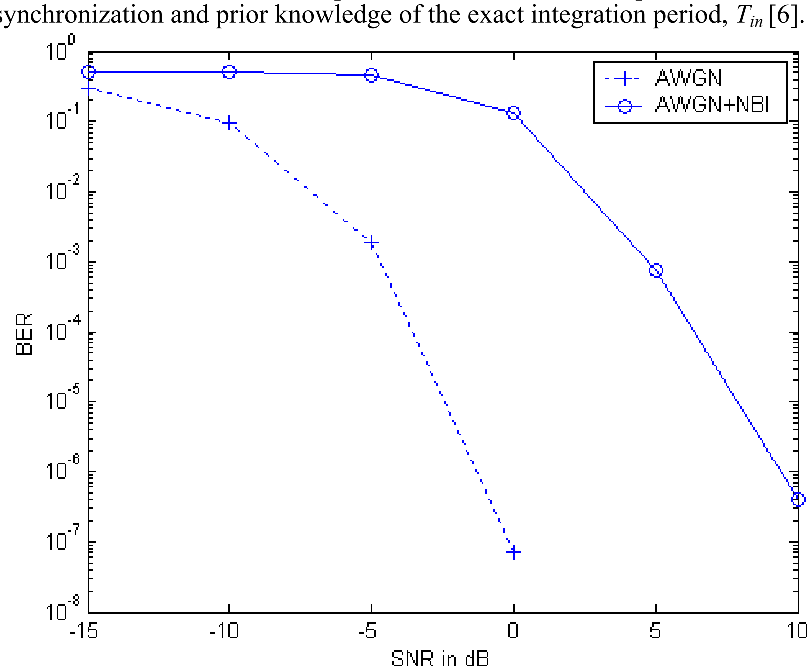


Figure 2. Performance degradation of a TR receiver due to AWGN and aggregate effect of multiple strong narrowband interferers.

Fig. 2. shows that the performance of a TR receiver in the presence of narrowband interferers is about two orders of magnitude worse than its performance in an AWGN only channel.

III. INTRFERENCE SUPPRESSION IN TR RECEIVERS

In this section we introduce a simple and novel method to actively suppress interference in TR receivers while preserving the desired UWB signal. Interference suppression is achieved by introducing a feedback loop mechanism to enhance the "Rf" pulses in TR doublets. The feedback loop contains an averaging delay, T, equal to the symbol repetition period and a loop loss factor α smaller than 1. The block diagram of the proposed "Rf" enhancing feedback loop mechanism for TR receivers is shown in Fig. 3.

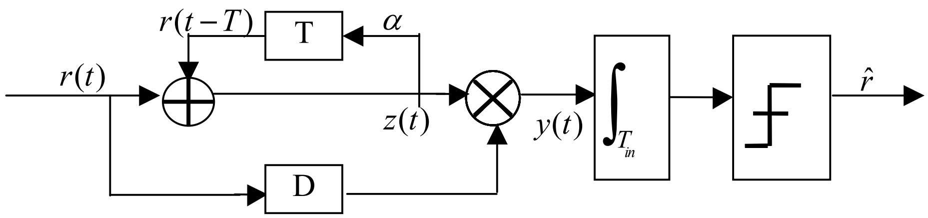
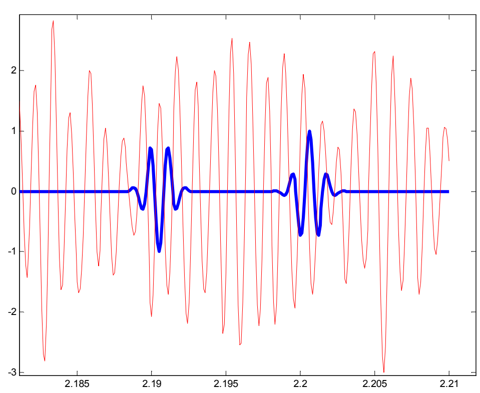
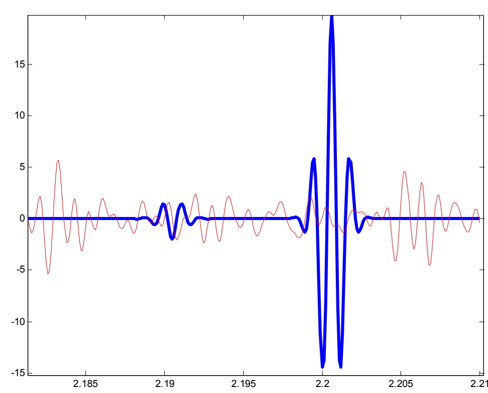


Figure 3: Block diagram of a modified TR receiver with "Rf" pulse enhancement feedback loop mechanism. D represents the delay between the pulses in a doublet [refer to 4-6], T corresponds to symbol repetition period, α is the loop loss factor (smaller than 1), and T_{in} denotes the finite integration period of overlapped "Rf" and "Tr" pulses.

As shown in Fig. 3, the received signal goes through multiple iterations around the feedback loop. With the loop delay, T, set to the symbol repetition period, the "Rf" pulses captured in each iteration will overlap and their signal power is enhanced each time. This mechanism works based on the assumption that interference is uncorrelated with signal, hence each circulation of input signal through the feedback loop makes "Rf" pulses cleaner by rejecting the interference. Please note that the feedback loop mechanism only improves the SNR of "Rf" pulses, since "Tr" pulses may have opposite polarity depending on the transmitted data, hence they do not experience the same resonance all the time. Fig. 4 provides an example of "Rf" pulse cleaning in a transmission channel consisting of AWGN and NBI.



(a)



(b)

Figure 4: "RF" pulse cleaning in a transmission channel consisting of AWGN and NBI. (a) An UWB TR doublet (solid lines) in the presence of strong interference (dotted lines). (b) Cleaned "Rf" pulse after 100 loop iterations with α=0.95. Note, "Tr" pulse has not experienced the resonance.

As shown in Fig. 4, the signal-to-interference ratio of "Rf" pulses increase significantly as the number of loop iterations increases. This method always works well for signals corrupted by AWGN channels, since different samples of white noise are uncorrelated, although some correlation will be introduced by the feedback loop filter. Further, for a successful NBI rejection, T should not be equal to integer multiples of interfering narrowband signal period to avoid resonating the NBI. Fig. 5 illustrates a comparison of BER performance improvement for a TR receiver with feedback loop mechanism and a conventional TR receiver in a combined AWGN/NBI transmission channel.

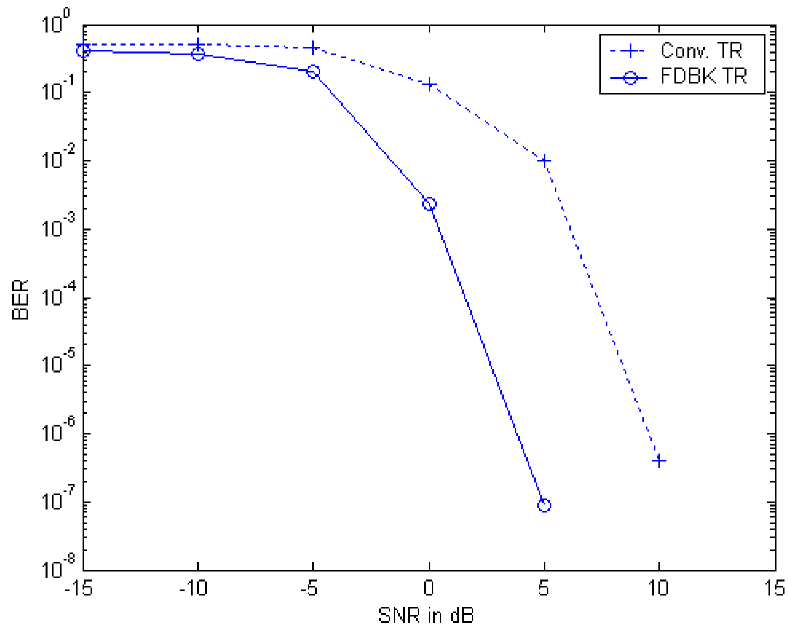


Figure 5. BER performance versus SNR performance comparison of a conventional TR receiver and a TR receiver with reference enhancing feedback loop mechanism.

IV. CONCLUSIONS

A novel and simple interference mitigation method employing a feedback loop mechanism to enhance the "Rf" pulses in TR doublets is proposed in this paper. The BER performance of a conventional TR receiver in the presence of AWGN and strong NBI is investigated. Our results reveal that the proposed interference cancellation method has proven to be effective for providing sufficient degree of interference rejection capability for various kinds of non-UWB interference in UWB TR receivers.

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