

Analysis of Non-coherent Receivers for Suppression of NBI in UWB Communication System

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Abstract-A new promising technique adopted by 4G community is Ultra-Wide Band (UWB) technology, which offers a solution for high bandwidth, high data rate, low cost, low power consumption, position location capability. One type of UWB communication is impulse radio. The paper discusses the effectiveness of major UWB schemes using non coherent receivers i.e AR receivers: the Transmitted Reference (TR) scheme, Averaged Transmitted Reference (ATR) and Differential Transmitted Reference (DTR) scheme. Performance comparison using Matlab Simulation reveals that ATR and DTR receiver outperforms the conventional TR receiver by 3 – 4 dB in IEEE 802.15.4a environment.

I. INTRODUCTION

Ultra-wideband (UWB) systems off late has attracted everybody's attention in the field of wireless communication for its role in commercial, security and military services [1]. Also it plays a pivotal role in spectrum management by sharing the already occupied radio spectrum rather than using any new bands, thereby obeying the overlay principle. UWB communication is a radio technology, used for short range and high bandwidth communication because its transmitted power is of low level [2]. Impulse Radio (IR) UWB systems convey information using ultrashort (short duration typically subnanosecond) [3] baseband pulses having low power density, high time resolution, rich multipath diversity. According to Federal Communications Commission (FCC), signals possessing a bandwidth exceeding 500 MHz or a fractional bandwidth f_b more than 0.2 are said to be UWB [4], [5]. The fractional bandwidth f_b is given by:

$$f_b = \frac{2(f_h - f_l)}{(f_h + f_l)} \quad (1)$$

where, f_h and f_l correspond to higher and lower -10 dB frequencies. UWB devices are operational in the frequency bands 3.1 – 10.6 GHz and also above 10.6 GHz, thereby allowing 7500 MHz of spectrum for unlicensed use [6]. UWB technology is a hot topic of research because of the numerous advantages it presents in the form of wide unlicensed bands, high data rate, low power spectral density (PSD), high multipath resolution, multiple access, low cost, low power consumption, improved channel capacity, fine delay resolution and enormous bandwidth. Also higher bandwidth upto GHz range signifies that multipath is resolvable upto the order of

nanosecond, thereby reducing fading. As a matter of fact interest in UWB communication has further motivated the researchers in their studies. Coherent IR-UWB RAKE receiver is found to be optimal over AWGN and non-ISI multipath channel in the sense that it minimizes the chances of error in detection. In spite of its better performance criteria, IR-UWB RAKE receiver requires accurate channel estimation and precise synchronization to extract multipath energy, thereby leading to computational complexity [7], [8]. Also each path in the UWB channel distorts the UWB pulses in such a way that it requires the template signal available at each RAKE correlator to be adaptable, so as to achieve an optimal performance [9]. The problems faced by coherent IR-UWB RAKE receiver were circumvented with the onset of non-coherent IR-UWB autocorrelation (AR) receiver. Non-coherent IR-UWB receivers are preferred over coherent IR-UWB receivers because of less complexity, low data rate applications and robustness to synchronization errors [10]. AR receivers exploit multipath diversity by correlating the received signal with its delayed version. The non-coherent AR receivers discussed in this paper are Transmitted Reference (TR), Averaged Transmitted Reference (ATR) receiver and Differential Transmitted Reference (DTR) receiver. TR scheme, proposed by Hoor and Tomilson [11], transmits two pulses per frame wherein the first pulse is an unmodulated reference pulse followed by a data modulated pulse. Wastage of energy due to the transmission of reference pulse is a major drawback of this scheme. The only difference between a TR scheme and ATR scheme is in the receiver structure. The receiver section in ATR scheme averages all the previous reference signals over N_f frames prior to demodulation. However, the transmitter sections for a TR and ATR scheme are similar in nature [12], [13]. A modified version of the TR scheme, DTR scheme, sends a single data pulse over the current frame by differentially modulating it with the data sent

over the previous frame. As a result, bit rate of DTR scheme is doubled and performance improved as compared to TR scheme [14],[15]. Our analysis clearly shows the superiority of DTR and ATR receiver over TR receiver by 3 – 4 dB in terms of BER performance. The paper examines the BER performance of TR, ATR and DTR receiver in UWB channels. The signalling technique used for transmission and reception is Pulse Amplitude Transmission (PAM). The paper is divided into four sections. Section II throws light on system model, Section III discusses the Simulation Results, Section IV concludes the paper while Section V briefs us about the Future Work. It makes many important aspects not need manager to complete on the scene, which saves a lot of manpower and material resources and improves labor productivity.

II. SYSTEM MODEL

The paper discusses the system model for the various non-coherent IR-UWB schemes such as TR, ATR and DTR. The system model comprises of signal model, channel model. The modulation scheme used is PAM signalling and the system considered is a single user system.

A. UWB Signal Model

1. TR Scheme

The difficulties faced by coherent IR-UWB RAKE transceiver were mitigated using a non-coherent IR-UWB transceiver. TR transceivers work by transmitting a train of pulses i.e. two pulses per frame [15], [9]. The first pulse transmitted over each frame is an unmodulated reference signal followed by a data modulated pulse [16]. A number of frames constitute a bit or a symbol. The conventional transmitted TR signal is expressed as:

$$s_{TR}(t) = \sum_{i=0}^{\infty} \sum_{j=0}^{N_f-1} [\sqrt{E}p(t - (iN_f + j)T_f) + b_i \sqrt{E}p(t - (iN_f + j)T_f - T_d)] \quad (2)$$

where $s_{TR}(t)$ represents the TR signal, $b_i \in (-1,1)$, represents the information symbol, N_f corresponds to the number of frames in one symbol, E denotes the energy per pulse, $p(t)$ represents the transmitted gaussian pulse with pulse duration T_p , T_f signifies the frame duration and T_d corresponds to the delay between the reference and data modulated pulse. Also, $T_s = N_f T_f$ represents the symbol duration.

2. ATR Scheme

The transmitted sequence for ATR scheme is same as that of the conventional TR signalling scheme. The conventional ATR scheme too transmits two pulses per frame where the first pulse denotes the unmodulated reference signal followed by the data modulated signal.

3. DTR Scheme

DTR system wastes no energy in transmitting a reference pulse, hence are preferred over TR system. As a result, DTR scheme requires less energy transmitting the same information as TR scheme. In this scheme, instead of transmitting a separate pulse, a single data pulse is sent over each of the

frames by differentially modulating it with the data pulse in the previous frame, thereby saving energy [14], [17], [18]. Each pulse represents a frame and number of frames correspond to a bit or symbol. The transmitted DTR scheme is represented as:

$$s_{DTR}(t) = \sum_{j=0}^{\infty} \sum_{i=0}^{N_f-1} b_j \sqrt{E} p(t - (jN_f + i)T_f - D) \quad (3)$$

where N_f corresponds to the number of frames in one symbol, E denotes the energy per pulse, $p(t)$ represents the transmitted gaussian pulse with pulse duration T_p , T_f signifies the frame duration and D corresponds to the delay between the frames.

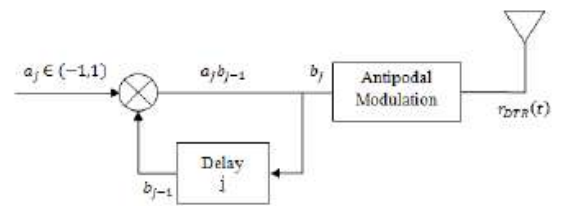


Fig. 1. DTR Transmitter

Also, the channel symbol b_j is transmitted every $T_s = N_f T_f$ seconds which represents the symbol duration in a UWB transmitter as seen in Fig 1. Also b_j corresponds to the information bits $a_j \in (-1,1)$ by a differential encoding rule which states that $b_j = a_j b_{j-1}$.

2. UWB CHANNEL MODEL

The accurate design of channel model is a significant issue for ultra wideband WPAN communication system [10]. Large-scale models are necessary for network planning and link budget design and small-scale models are necessary for efficient receiver design. The most famous multipath UWB indoor channel models are tap-delay line Rayleigh fading model, Saleh and Valenzuela (S-V) model and Δ -K model. The S-V channel measurement shows that the multipath components are arriving in a cluster form. The different paths of such wide band signal can rise to several multipath components, all of which will be part of one cluster. The arrival of multipath components is modeled by using Poisson distribution and thus the inter arrival time between multipath components is based on exponential distribution. The multipath arrival of UWB signals are grouped into two categories: cluster arrival and ray arrival within a cluster. This model requires several parameters to describe indoor channel environments. Ray arrival rate is the arrival rate of path within each cluster. The cluster arrival rate is always smaller than the ray arrival rate. The amplitude statistics in S-V model are based on lognormal distribution, the power of which is controlled by the cluster and ray decay factor. Indoor channel environments are classified as CM1, CM2, CM3, and CM4 following IEEE 802.15.3a standard [11].

2.1 Channel parameters

- CM1 describes a line-of sight (LOS) scenario with a maximum distance between transmitter and receiver of less than 4m.
- CM 2 describes the same range as of CM1, but for a non-line-of sight (NLOS) situation.
- CM 3 describes a NLOS medium for separation between transmitter and receiver of range 4-10m.
- CM 4 describes an environment of more than 10m with strong delay dispersion, resulting in a delay spread of 25ns with NLOS medium

III. SIMULATION RESULTS

The non-coherent IR-UWB receiver structures described in the previous section were simulated not only in IEEE 802.15.4a UWB indoor environment. In this paper, the UWB structures considered are applicable only for a single user.

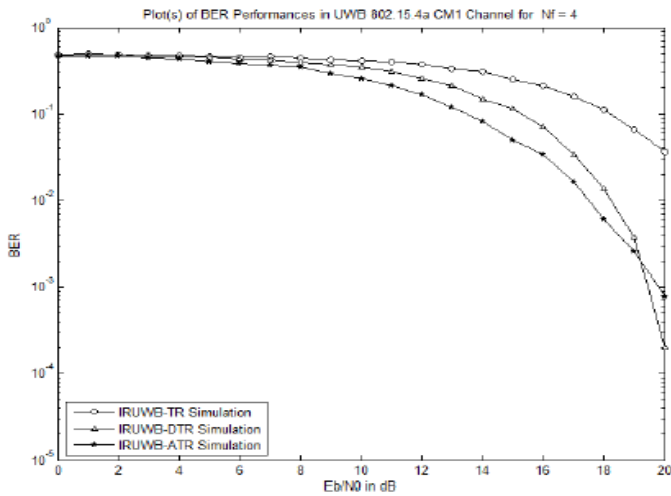


Fig.2: performance of TR, ATR and DTR receiver in IEEE 802.15.4aCM1channel

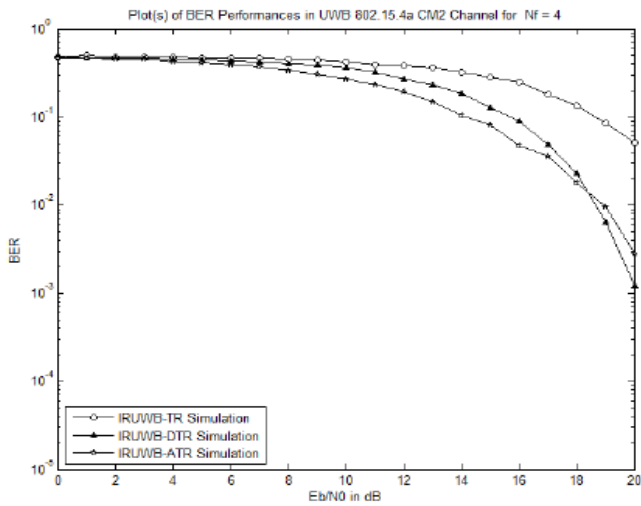


Fig.3: performance of TR, ATR and DTR receiver in IEEE 802.15.4aCM1channel

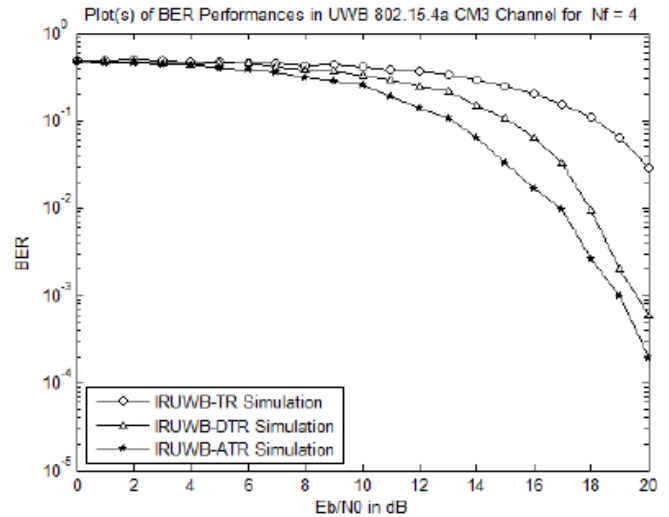


Fig.4: performance of TR, ATR and DTR receiver in IEEE 802.15.4aCM1channel

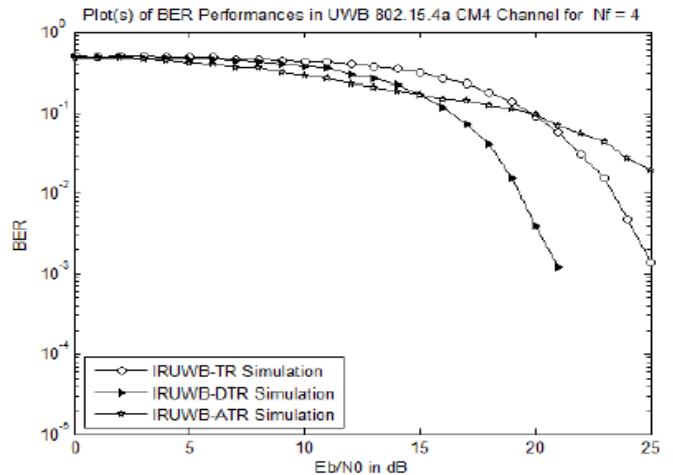


Fig.5: performance of TR, ATR and DTR receiver in IEEE 802.15.4aCM4channel

The Fig 2 illustrates the performance of TR, ATR and DTR receiver in IEEE 802.15.4a CM1 channel. CM1 corresponds to a residential Line Of Sight (LOS) environment that covers a range of 7–20 m. It is observed that for a BER of 5×10^{-2} , ATR receiver performs the best and achieves a gain of 4 dB over TR receiver. At low SNR, ATR receiver gives a performance gain of 1 dB over DTR receiver while at high SNR, DTR receiver outperforms ATR receiver by 1 dB.

The Fig 3 explains the performance of TR, ATR and DTR receiver in IEEE 802.15.4a CM2 channel. CM2 too maintains a residential environment covering a distance of 7 – 20 m and is Non Line Of Sight (NLOS) in nature. Thus, it can be concluded that the performance of all the non-coherent IRUWB receiver degrades as the channel changes from CM1 to CM2. It is observed from the figure that at a BER of 0.1, TR, ATR and DTR receiver have a SNR of 19 dB, 16 dB and 15 dB respectively. It is also noted that at lower SNR, ATR receiver outperforms DTR receiver while at higher SNR, DTR receiver gives a much better performance than ATR receiver. The Fig 4 clearly explains the BER performance of TR, ATR and DTR receiver in IEEE 802.15.4a CM3 channel. CM3 environment is exclusively designed for LOS indoor office environment covering a distance of 3 – 28 m. At a BER of

5×10^{-2} , TR receiver shows a performance loss of 3 dB with respect to a ATR and DTR receiver. Another interesting fact noted is throughout the simulation analysis, ATR receiver shows a marginal gain of 1 dB over the DTR receiver.

The Fig 5 illustrates the BER performance of TR, ATR and DTR receiver in IEEE 802.15.4a CM4 channel. Channel CM4 is designed for NLOS residential environment. As we move from channel CM3 to CM4, BER performance degrades. The DTR receiver outperforms the TR receiver by a margin of 3 dB at a BER of 10^{-3} . It is also noted that the performance of ATR receiver degrades with increase in SNR. At low SNR, ATR receiver performs better than the other non-coherent IRUWB receiver such as TR and DTR but with increase in SNR, performance of ATR receiver falls abruptly and is even worse than a TR receiver.

IV. CONCLUSION

The paper examines the performance of non-coherent IRUWB receiver IEEE 802.15.4a channel i.e. CM1, CM2, CM3 and CM4. The simulation results clearly show that BER performance in IEEE 802.15.4a UWB channel. UWB simulated channels, CM1 gives the best performance compared to the other UWB channels. CM1 and CM3 being LOS channels outperform NLOS channels, CM2 and CM4. For all simulated channels, TR receiver shows a performance degradation of 3 – 4 dB compared to ATR and DTR receiver due to the usage of noisy unmodulated reference template. However, ATR and DTR receiver give comparable performances.

V. FUTURE WORK

Further, the combination of UWB communication with cooperative relay communication can be viable and a cost efficient method form proving the system performance quality of service and coverage area. Our future endeavour would be to club UWB communication with cooperative communication.

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