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Performance Analysis of Coherent IR- UWB Receiver and Non-Coherent IR -UWB Receivers

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Abstract— ***UWB exists with the other narrowband and wideband systems, hence causes the interference for both the systems. By equalizing signals from different paths and efficient in handling multipath fading, RAKE receives are consider for UWB system but alone SRAKE receiver fails to cope up with the NBI combination of SRAKE-MMSE with the different numbers of RAKE fingers and equalizing tabs are used. Coherent IR- UWB Receivers requires accurate channel estimation and to extract multipath energy requires precise channel synchronization so causes the computational complexity. No channel state information required for the Non-coherent IR UWB Autocorrelation (AR receivers). MATLAB simulation is used to analysis the BER performance of the Coherent IR UWB receivers and non coherent IR UWB receivers on IEEE 802.15.3a UWB channel models (CM3 and CM4).Non –Coherent receivers considered in this paper are TR, ATR and DTR. Study shows that the BER performance non-coherent IR –UWB receivers perform better than Coherent IR-UWB RAKE receivers.***

Index Terms— **IR-UWB, IEEE 802.15.3.a, Coherent and non-coherent IR- UWB AR**

I. INTRODUCTION

UWB technology offers a high bandwidth, high data rate, low cost, low power spectral density (PSD), high multipath resolution, and fine delay line resolution as well exact location finding capability hence it is emerging as a modern wireless system to achieve better quality technique. It belongs to IEE 802.15.a (TG3a) standard of Wireless Personal Area Network [1].It shares the spectrum with other Narrow band and wideband systems and obeys the law of overlay. As per Federal communications commission (FCC) the signal is said to be UWB if it possessing a bandwidth greater than 500 MHz or a fractional bandwidth more than 0.2[2].The fractional bandwidth is given as.

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

fh and fl are higher and lower frequencies of the spectrum. As per the FCC norms UWB can operates for the frequency band from 3.1 to and above of 10.6 GHz, hence allowing 7500 MHz of spectrum for unlicensed use [3]. As UWB co-exists with the Narrowband signal, so it may cause interference with the UWB systems. UWB system should be able to cope up with this interference. RAKE receivers are considered as they are capable to efficiently handle the multipath fading. UWB can deal this interference with the high processing gains. The performance of the Rake receivers degrades with increases in the number of the Rake fingers. RAKE receiver alone fails to combat NBI. Hence combination of rake receiver with the equalizer SRAKE –MMSE is considered. Analysis is performed with different numbers of RAKE fingers and equalizing tabs. Investigation shows that at low SNR Rake fingers performs well and at high SNR number of equalizer tabs plays an important role to boost the performance of the system. Also the analysis shows that for high frequency selective channel (CM4) the Decision feedback equalizer perform better whereas as for low frequency selective channel CM3 Linear equalizer performed well so for high selective channel model (CM4) the linear equalizer structure is replaced by the decision feedback equalizer. The performance of the Coherent IR-UWB RAKE receiver is limited by various types of the channel noise such as Additive white Gaussian Noise (AWGN).These receivers required exact channel estimation as well as to extract the multipath energy accurate synchronization is also required which increases the complexity of computation process. [4] Non-Coherent IR UWB AR (autocorrelation) receivers are simple in structure and do not required channel estimation. AR receivers: Transmitted Reference (TR), Average transmitted reference (ATR) and Differential Transmitted References (DTR) are discussed in this paper and MATLAB simulation performed to find BER performance. The objective of the paper is to find the difference in BER performances of the coherent IR UWB receivers with the Non coherent IR UWB AR receivers. Investigation shows that, the BER performances of the Non-coherent IR UWB AR receivers are better than the BER performances of the coherent IR UWB receivers.

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II. UWB CHANNEL MODEL AND COHERENT IR-UWB RECEIVERS

A. UWB Channel Model

The Saleh and Valenzuala model is consider for the channel modeling. As per S –V model, the multipath is arriving as the cluster form [5]. UWB signals are grouped into two categories: Cluster arrival rate and Ray arrival. For this paper there are two channel model CM3 andCM4 are considered. These models are derived from the IEEE 802.15 channel modeling working group. CM3 describes a non-line of sight communication with range 4-10 meters and CM4 corresponds to an environment of more than 10 meters with strong delay dispersion resulting in delay spread of 26 ns with NLOS medium .The channel impulse response

$$h(t) = X\sum_{l=0}^{L-1}\sum_{k=0}^{K-1}\alpha_{k,l}\,\delta(t - \mathrm{T}_l - \tau_{k,l}) \;............ (2)$$

Where $\{\alpha_{k,l}\}$ are the multipath gain coefficient . $\{T_l\}$ is the arrival time or delay of the first path of lth cluster. X is the log normal shadowing term. $\tau_{k,l}$ is the delay of the k^{th} multipath component within the l^{th} cluster relative to arrival rate.

Continues transmitted data stream is given as [8]

$$s(t) = \sum_{k=-\infty}^{k=+\infty} d(k).p(t - k.T_s) \;...................... (3)$$

Where d (k) are stationary uncorrelated BPSK data and Ts is the symbol duration. The UWB pulse p(t) has duration $T_{UWB.}$

The Impulse response can be

$$h(t) = \sum_{p=0}^{M} h_p.\delta(t - \tau_p) \;.......................... (4)$$

M considered as the total numbers of paths in the channel

B. RAKE Receiver Structure

Fig.1 shows Rake Receiver, the receiver model consists of matched filter, tapped delay line and correlators called as Rake fingers [8]

The received signal first passes through the receiver filter matched to the transmitted pulse and is given as

$$r(t) = s(t) * h(t) * p(-t) + n(t) * p(-t)$$

$$= \sum_{k=-\infty}^{+\infty} d(k) \sum_i h_i m(t - k.\mathrm{T}_s - \tau_i) + \hat{n}(t) \;...... (5)$$

Where p (-t) represents the receiver matched filter & n (t) is the AWGN with zero mean and variance N_0 /2.

$$m(t) = p(t) * p(-t)$$

$$n(t) = n(t) * p(-t) \;........................ (6)$$

Combining the transmitter pulse shape with the channel impulse response and the matched filter

$$\hat{h}(t) = p(t) * h(t) * p(-t)$$

$$= \sum_{i=0}^{M} h_i m(t - \tau_i). \;.. (7)$$

The received signal sampled at the l^{th} rake finger in the n^{th} data symbol interval is given as

$$v(n.T_s + \tau_l' + t_0) = \sum_{k=-\infty}^{+\infty} \tilde{h}((n-k).T_s + \tau_l' + t_0).d(k) \quad \ldots\ldots\ldots\ldots \quad (8)$$

τ_l' is delay time corresponding to the l^{th} rake finger and is an multiple of Tm. Tm is the minimum Rake fingers separation which is given by Ts /Nu. Nu is the is chosen as the largest integer value that would result in Tm. Rake output at time t=n.Ts is

$$y[n] = \sum_{l=1}^{L} \beta_l v(n..T_s + \tau_l') + l = \sum_{l=1}^{L} \beta_l.\hat{n}.(n.T_s + \tau_l') \quad \ldots\ldots\ldots\ldots \quad (9)$$

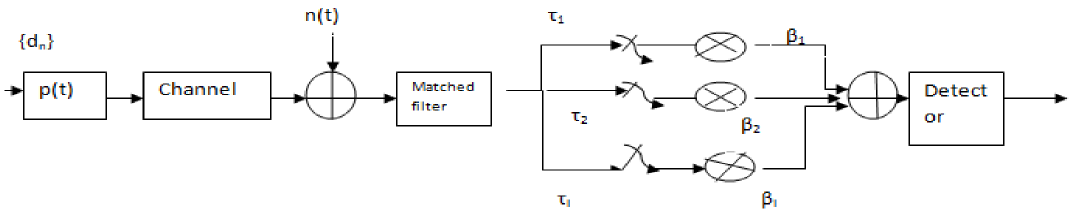

Fig. 1.RAKE Receiver Structure [8]

C. UWB SRAKE Receivers in presence of NBI (Narrowband Interference)

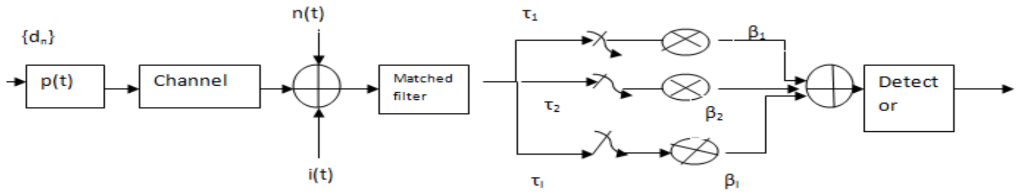

Fig. 2.SRAKE Receiver Structure with NBI

UWB signals exist with other narrowband system, so narrowband signals may cause interference at the receiver side. These signals are the extra unwanted signals and can degrade the performance of the system. UWB systems must combat with these unwanted interferences with the high processing gain. As shown in the fig. 2[8] the interference i(t) is considered in the channel and then passes through the UWB receiver

$$i(t) = \sqrt{2I_B}.\cos(\omega_i t + \theta i) \quad \ldots\ldots\ldots\ldots \quad (10)$$

Where i(t) is the received interfere signal with ransmitted power of I and these signal passes through the filter matched is given by [8]

$$r(t) = A(t) * h(t) * p(-t) + n(t) * p(-t) + i(t) * p(-t) \ldots (11)$$

Rake receiver alone is not able to cope up with the Narrowband interference.

D. UWB SRAKE-MMSE Receiver

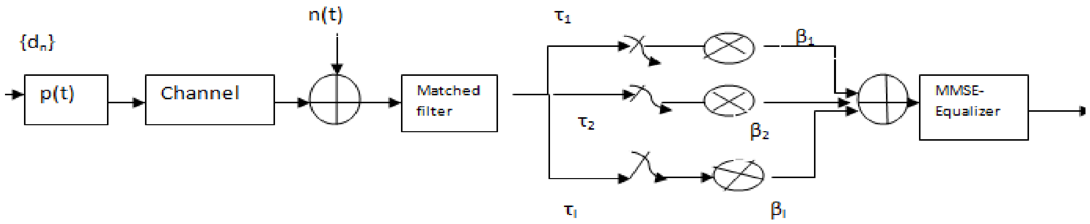

Fig. 3.SRAKE-MMSE Receiver Structure

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For handling the multipath propagation if increases Rake fingers, system performance of RAKE receiver degrades. To overcome with this issue and handle NBI efficiently combination of SRAKE with the MMSE time domain equalizer is considered. Fig. 3 [8] shows SRAKE followed by MMSE receiver. SRAKE-MMSE considered with both the effects of rake fingers and equalizer tabs. The major benefit of this scheme is precise knowledge of interference parameters are not required. This scheme selects the first strongest multipath components and combines them using a SRAKE receiver based on the minimum mean square error (MMSE) criterion.

E. UWB SRAKE-MMSE Receiver with NBI

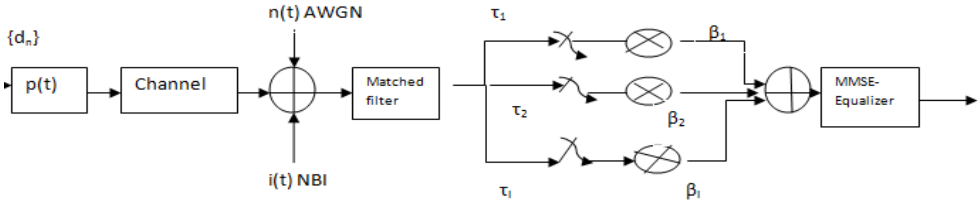

Fig. 4.SRAKE-MMSE Receiver Structure with NBI

The SRAKE- MMSE receiver structure is shown in Fig. 4.[8]Here considered the interference i (t).The received signal sampled at the l^{th} Rake finger in the nth data symbol interval is given by equation. The Rake combiner output at time t = n.Ts is [8]

$$y[n]=\sum_{l=1}^{L}\beta_l.v(n.T_s+\tau_l{}')+\sum_{l=}^{L}\beta_l.i(n.T_s+\tau_l{}') + \sum_{l=1}^{L}\beta_l.\hat{n}(n.T_s+\tau_l{}') \quad \ldots\ldots.. (12)$$

The Rake output can be expressed now in a simple form as

$$y[n]=\alpha_0 d(n)+\sum_{\substack{k\neq -n1\\ k=0}}^{n2}\alpha_k.d(n-k)+\tilde{i}(n)+\tilde{n}(n) \quad .... (13)$$

$$c=(R+I_N+N)^{-1}.p \quad .... \quad (14)$$

Where R,I_N ,N are autocorrelation of the signal, the NBI and Noise respectively

$$J_{\min}=\sigma_d{}^2-p^T(R+I_N+N)^{-1}.p$$
$$\sigma_d{}^2=E[d(n)]^2 \quad .... (15)$$

This way the noise and NBI can be suppressed by the receiver structure.

III. NON-COHERENT IR –UWB RECEIVERS

Coherent IR UWB receivers perform well for AWGN and for non ISI multipath channel and hence minimize the chances of error in signal detection. Although having better performance, it requires precise channel estimation and to extract multipath energy accurate channel synchronization is required, so increases the computational process [9] and [10]. Non-coherent IR-UWB receivers are less complex and preferable for low data rate applications also not required prior knowledge of the noise signal. By correlating the received signals with the delayed version the multipath diversity is being utilized by the AR receivers. There are three AR receivers are considered in this paper which are Transmitted Reference (TR), Average Transmitted References (ATR) and Differential Transmitted References (DTR).

- **Transmitted Reference (TR) scheme**: Transmits two pulses, first pulse followed by the second pulse. First pulse is only reference pulse whereas second pulse is modulated data pulse.

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- **Average Transmitted References scheme (ATR)**: There is only difference the receiver structure f the ATR scheme, it averages all the previous reference signals over frames before demodulating the signals.
- **Differential Transmitted References scheme (DTR**): There is no reference signals are transmitted where as the signals in the previous frame is utilized.DTR scheme, transmits a single data pulse present frame by differentially modulating it with the data send by the previous frame. As a result of the BER performance of the DTR is better than other two schemes.

IV. SIMULATION RESULTS AND ANALYSIS

A. Channel Impulse response for CM3 and Cm4

In this paper we have consider the model proposed by the IEEE 802.15.3a channel modeling group [6] this model is based on modification of the Saleh and Valenzuela [5]. S-V model considers the Clustering phenomenon [5] and [11]. The channel impulse response for CM3 and CM4 is as shown in fig.5 and fig.6. The data rate is considered as 200 Mbps, one of rates proposed for IEEE World Academy of Science, Engineering and Technology standard. The cluster arrival rate (1/sec) is 0.667 and ray arrival rate (1/sec) is taken as 2.1[5].

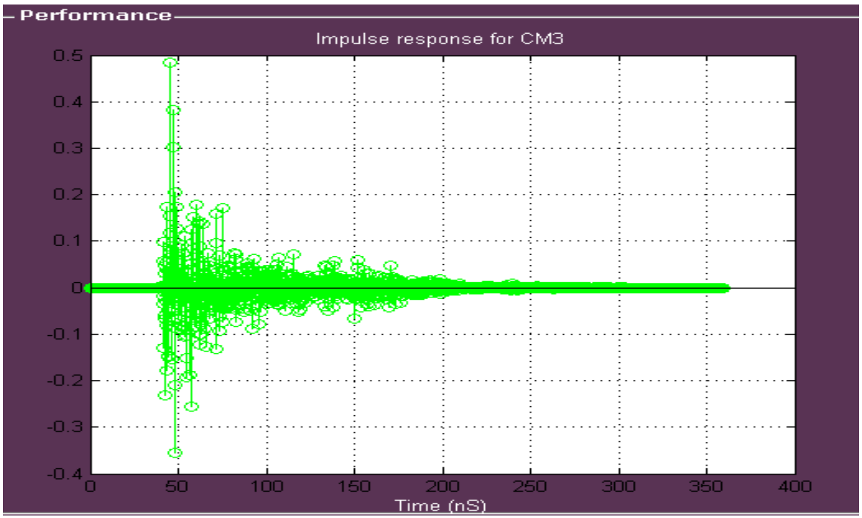

Fig. 5.Channel Impulse Response of CM3

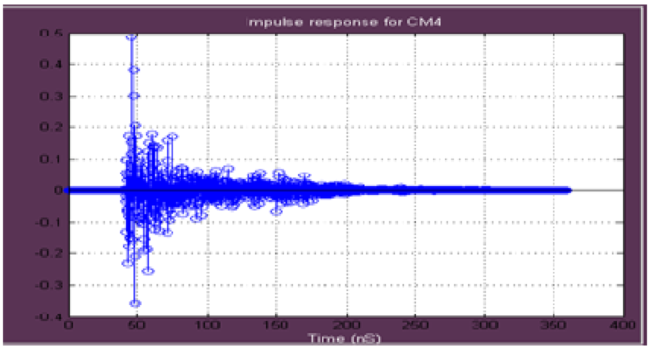

Fig. 6.Channel Impulse Response of CM4

B. Performance of the UWB-SRAKE-MMSE receivers

The performance of SRAKE –MMSE receiver with different numbers of rake fingers and equalilizing tabs considering for CM3 and CM4 are shown in fig.7 and Fig.8. Analysis shows that keeping the number of rake fingers constant i.e. k=3 and changing the equalizing tabs from L=10-20, there is SNR gain of almost 1db at a BER level of 10-3 is observed. And if keeping the equalizing tabs constant and varying rake fingers, there is SNR gain of almost 4db is observed. Further with DEF (Decision Feedback equalizer there is increase in the performance by

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5db. By comparing the BER performances, it is analyzed that that LE performance degrades at high SNR's for both the CM3 and CM4 whereas DEF performs well even at high SNR's. A DFE performs well as compare to linear equalizer of the same filter length, and the performance increases with more equalizer tap length. ISI affects the system performance at the high SNR's values, whereas the system noise affects the performance at low SNR .So receiver with high rake fingers perform well at high SNR.

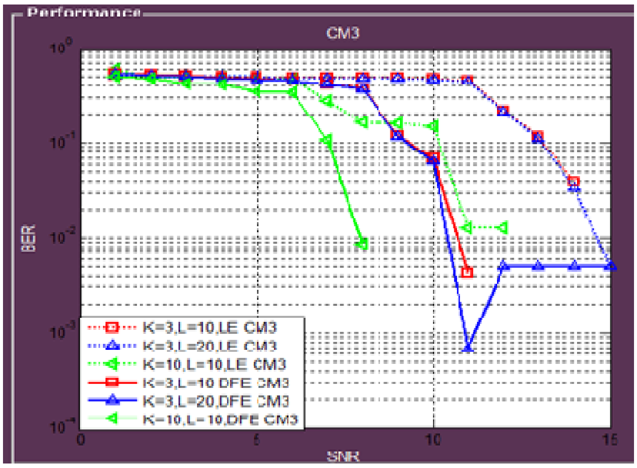

Fig.7 Performance OF UWB SRAKE-MMSE receiver for CM3 (Varying equalizing tabs and rake fingers)

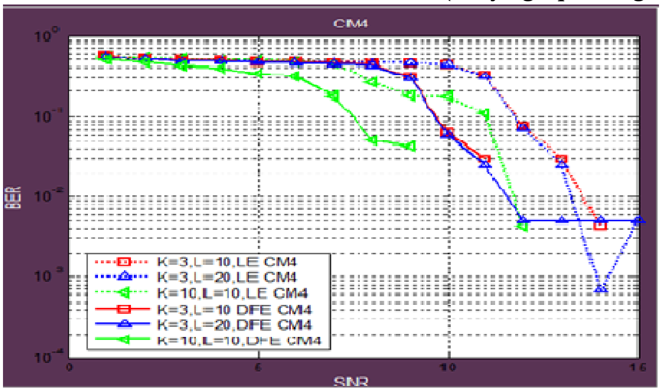

Fig 8 Performance OF UWB SRAKE-MMSE receiver for CM4 (Varying equalizing tabs and rake fingers)

C. SRAKE-MMSE receiver with NBI

Fig.9 and fig.10 shows that the UWB SRAKE-MMSE, BER performance improves even in presence of narrowband interference when compare with the SRAKE without equalizer

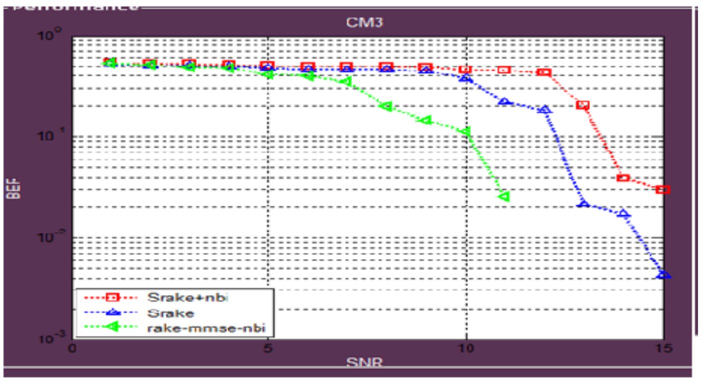

Fig.9. Performance OF UWB SRAKE-MMSE receiver for CM3

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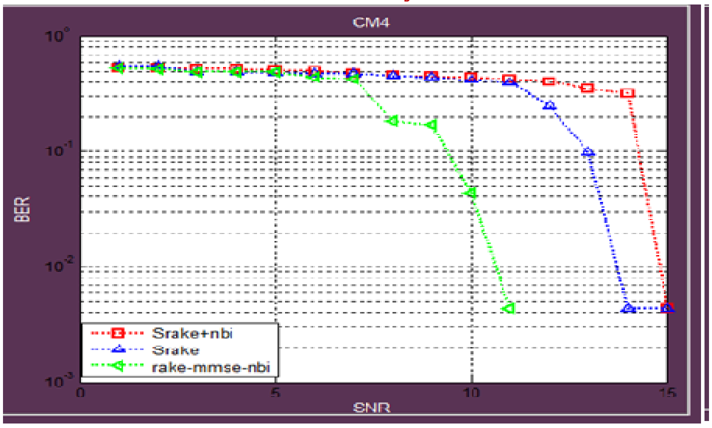

Fig.10. Performance OF UWB SRAKE-MMSE receiver for CM4

D. BER Performance Comparison of RAKE-MMSE with TR, ATR and DTR receiver with NBI

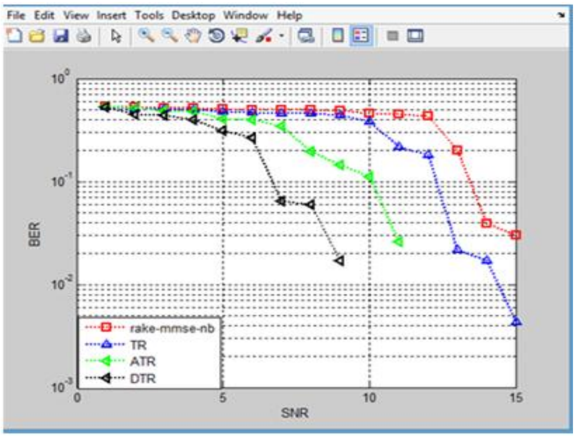

Fig.11. BER Performance Comparison of RAKE-MMSE with TR, ATR and DTR.

From fig 11.shows that the BER performance of the non-coherent IR-UWB and coherent-IR UWB receivers. Analysis shows that with DTR there is SNR gain of almost 4db is observed. Fig. it is clearly observed that the BER performance of the Non-coherent IR-UWB receivers are better than coherent IR-UWB receivers.

VI. CONCLUSION

The paper examines the performance of Coherent IR-UWB receiver in both AWGN and IEEE 802.15.4a channel i.e. CM3 and CM4. Also examines the performance of the Non- coherent IR-UWB receivers. The simulation results clearly show that BER performance of SRAKE with DFE performs well as compare to linear equalizer of the same filter length, and the performance increases with more equalizer tap length. ISI affects the system performance at the high SNR's values, whereas the system noise affects the performance at low SNR .So receiver with high rake fingers perform well at high SNR. Also the SRAKE with LE and DEF performed well in presence of AWGN and NBI. Coherent IR -UWB receiver increases the computational complexity so this paper examines the BER performance of the Non coherent IR-UWB receivers i.e. TR, ATR and DTR and analysis results shows that Analysis shows that with DTR there is SNR gain of almost 4db is observed. Fig. it is clearly observed that the BER performance of the Non-coherent IR-UWB receivers are better than coherent IR-UWB receivers.

VII. FUTURE WORK

In future we are looking forward to examine the performance of Non-coherent IR –UWB receivers in presence of Additive white Gaussian noise (AWGN) and also the performance behavior on different Channel models i.e. CM1,

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CM2, CM3 and CM4 of IEEE 802.15.4a.Further we are looking forward to evaluate the efficiency of UWB communication with cooperative relay communication and finding proficient methods to improve the Quality of service and the system performance.

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