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Suppression of Interference by Fifteen Users in UWB System

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Abstract:In Wireless Personal Area Network (WPAN) when no of users will access channel then interference will be observed, this will degrade the system performance. In this paper we are going to introduce the method based on Least Bit Error Rate (LBER) criteria for interference suppression and extended the results upto fifteen no of users. Receiver performance is analysed by varying the no of users & no of rake fingers. Analysis is done by generating the conditional probability density function. Final result analysis will show that designed receiver will supress the interference caused by fifteen no of users more effectively as that of by other methods.

Keywords:Ultra Wide Band, Rake, Least Bit Error rate, Multiple user Access Interference.

I. Introduction

Wireless Personal Area Network (WPAN) works on the technology named as Ultra Wide Band (UWB). This technology is adapted to provide high speed digital communication between PC & digital equipment's [1-2]. UWB can be used at short range high bandwidth communication and it works at low energy level. Data rate provided by UWB may be exchanged for range by aggregating pulse energy per data bit. UWB overcomes the multipath interference problems of narrow band communication. The most important ability of UWB is to compensate the multipath interference problem. This will help to design rake receiver to recover multipath generated components to improve the receiver performance[3-4].

Short pulse by UWB will gives multipath components which will cause degradation in system components. Conventional narrowband receiver is unable to suppress multipath access interference (MAI) due to different reduction capabilities. So to achieve expected receiver performance it is required to design a rake receiver which will supress the interference caused by no of users & to achieve desirable bit error performance.

UWB has two standards as OFDM-UWB and DS-UWB. DS-UWB uses CDMA technique. DS-UWB is simple and flexible [5,7]. In this paper we are mainly focusing DS-UWB. To suppress MAI all codes should be orthogonal. It is achieved only in uplink communication rather than downlink communication. In uplink communication no of user causes MAI, to eliminate this various multiple user detection techniques have been proposed. [3-4, 5-6]. Adaptive multiuser detector (MUD) is one of the multiuser detection techniques which uses minimum mean square error criteria to suppress intersymbol interference & MAI [8-9]. In this method the rake receiver resolves the multipath components. The MMSE criteria is mainly gathers combined weight of fingers to suppress MAI. But MMSE will not be able to achieve minimum bit error rate (BER) [7-8].

In this paper we have applied least bit error rate (LBER) criteria too suppress MAI for fifteen no of users. The proposed adaptive rake receiver uses least mean square (LMS) algorithm [7] which is known as adaptive least bit error rake receiver (LBER). Bit error comparisons done between maximum ration combining (MRC) rake receiver, MMSE receiver & LBER receiver for fifteen no of users. Output is analysed by generating probability density function (cpdf).

II. Multi user UWB system model

Let b(t) is BPSK modulated signal [1] as

$$b(t) = \sum_{i=-\infty}^{\infty} d[i]p(t - iT_s)\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

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Where, {d[i]}ϵ{-1,1} represents the BPSK bit stream and p(t) is the UWB pulse with a symbol duration, Ts= JTc,

$p(t) = \sum_{j=0}^{J-1} c[j]g(t - jT_c)$…………………..(2)

Where, {c[j]}ϵ{1,0} represents the jth chip of the UWB chip spreading of length J and Tc=chip duration. g{t}=1st or 2nd derivative Gaussian pulse.

The composite multi-user CDMA-UWB signal in the uplink can be expressed as:

$s(t) = \sum_{n=1}^{N} S_n(t) b_n(t)$…………………..(3)

WhereN is the total number of users, and $b_n(t)$ is the nth UWB signal with information bit streams.

The multipath channel model is standard and derived from the Saleh-Valenzuela model with slight modifications which consists of L clusters and K rays can be written as:

$$h_i(t) = X_i \sum_{l=0}^{L} \sum_{k=0}^{K} \alpha_{k,l}^i \delta(t - T_l^i - \tau_{k,l}^i) \text{………….. (4)}$$

where Xi represents the log-normal shadowing, T_l^i is thedelay of the l^{th} cluster,$\alpha_{k,l}^i$ are the gain coefficients and$\tau_{k,l}^i$ is the delay of the k^{th} multipath component relative tothe l^{th} cluster arrival time (T_i), and i refers to the i^{th} realization. δ(.) is the Dirac delta function.

The received signal passes through themultipath channel is given as,

$r(t) = \sum_{m=0}^{M} h_i(t) S'(t) + n'(t)$……………..(5)

Where,

s'(t) = s(t)*p(-t) and
n'(t) = n(t)*p(-t)

Where p(-t) = Impulse response
N(t) = Additive white Gaussian Noise (AWGN) with variance $N_0/2$
M= No of paths in channel
Correlator bank is to be created through which received signal is passed to receiver information bit.
Output of n^{th}Correlator is

$$y_n(t) = r(t).S_n(t) \text{…………………........…(6)}$$

For the first user Correlator output is,

$$y_1(t) = r(t).S_1(t) \text{………………………………….(7)}$$

$$= \sum_{m=0}^{M} h_i(t) s'(t) S_1(t) + n'(t) S_1(t) \text{……………………………….(8)}$$

$$= \sum_{m=0}^{M} h_i(t) d_1 + \sum_{m=0}^{M} \sum_{n=2}^{N} h_i(t) S_n(t) d_n + n'(t) S_1(t) \text{……………………………….(9)}$$

Where the first term in Equation (9)represents desired user information, the second term denotes the MAI, and the third term is the noise component.

Our aim is to remove second term that means to suppress the MAI.

III. ADAPTIVE RAKE FOR CDMA-UWB

Figure1 shows output of conventional rake receiver.

Samples output f(k) is

$$f(t) = \sum_{l=0}^{L-1} \beta_l y\ (t - \theta_l) \text{…………………………..(10)}$$

Where L=No of fingers

where $\beta_l = [\beta_0, \beta_1, \beta_2, …, \beta_{L-1}]$ are the Rake coefficients, and $\theta_l = [\theta_0, \theta_1, \theta_2, …, \theta_{L-1}]$ are the finger delays

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oversampled output signal can be written as,

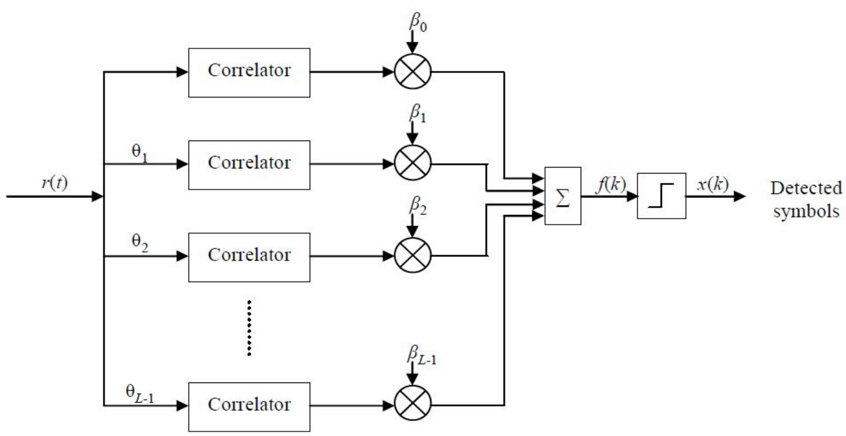

Fig.1 Conventional rake receiver

$f(k) = \sum_{l=0}^{L-1} \beta_l y_1 \ '(k-l)$…………………………..(11)

Wherey'_1(k) is the oversampled received signal.
The final outputx(k) of the detected symbols is simply obtained from the sign of f(k)
x(k) = sgn[f (k)] …….……………………………..(12)

A. Adaptive MMSE Rake Receiver

Rake coefficient is given as

$\beta_{MMSE} = arg \ \frac{min}{\beta} MSE$……………..…………………..... (13)

Mean square error,

MSE = E[(f(k)-x(k-D)2], ………………..…………. (14)

D= Delay Parameter
Adaptive algorithm can be obtained as

$\beta_{l+1} = \beta_l - \mu[f(k) - x(k-D)]y_1'(k)$ ……..…………….(15)

Where, µ is the step size.

B. Adaptive LBER Rake Receiver

To minimize the BER for equalization,

$\beta_{MMSE} = arg \ \frac{min}{\beta} P_E$……….……………..……………….(16)

Where P_E= Probability of error, which is given as,

$P_E = \int_{-\infty}^{0} p(z;\beta)dz$……………….……………….……… (17)

Probability density function is

P(Z: β) = $\frac{1}{k\sqrt{2\pi 6}\sqrt{\beta_l^T.\beta_l}} \sum_{K=1}^{K} \int_{\infty}^{0} \exp\ [\frac{-(z-z'(k))^2}{2\sigma^2\beta_l^T\beta_l}]\ dx$……..………… (18)

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K= possible sequence of b(t)
σ^2= AWGN, z & z'(k) = x(k).f(k) is the decision signed variable[ ]
BER expression for rake receiver is

$$P_E = \frac{1}{k\sqrt{2\pi 6}\sqrt{\beta_l^T.\beta_l}} \sum_{K=1}^{K} \int_{\infty}^{0} \exp\left[\frac{-\left(z-z'(k)\right)^2}{2\sigma^2\beta_l^T\beta_l}\right] dx$$

$$= \frac{1}{k}\sum_{k=1}^{k} Q(g(k)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(19)}$$

Where $g(k) = \frac{\beta_l}{\sigma\sqrt{\beta_l^T.\beta_l}}$ and Q is Q function.

When we replace oversampled output f(k) from rake finger, the probability gradient P_E with respect to β_l is

$$\nabla P_E = \frac{1}{k\sqrt{2\pi\sigma}} \sum_{K=1}^{K} \exp\left[\frac{-(f(k))^2}{2\sigma^2}\right] x(k).y_1'(k) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(20)}$$

By steepest descent algorithm the rake finger coefficient can be obtained as,

$$\beta_{l+1} = \beta_l - \mu\nabla P_E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(21)}$$

By replacing k= 1, σ is the radius parameter by ρ, the proposed LBER rake receiver is given by

$$\beta_{l+1} = \beta_l + \frac{1}{\sqrt{2\pi\rho}} \sum_{K=1}^{K} \exp\left[\frac{-(f(k))^2}{2\rho^2}\right] x(k).y_1'(k) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(22)}$$

IV. RESULTS

This section of paper represents a result analysis for MRC rake receiver, MMSE rake receiver, and adaptive rake receiver.
Bit error rate performance of these receivers obtained by using multipath model

A. Simulation Parameters

Initially the UWB chip spreading, c[j] is set to [1 0 0 0]. The step size μ used by both the adaptive MMSE-Rake and the proposed adaptive LBER-Rake receivers is 0.002, respectively. The radius parameter of the proposed receiver is chosen as $\rho^2 = 0.79\sigma$. The receivers' performances are studied by varying the number of Rake fingers l and the number of total users, N. Simulations are performed over N_c= 100 channel realizations of channel model CM1. The generated impulse responses are averaged over 100 channel realizations. Gold sequence spreading codes of length 31 are used for all simulations. We assume that the receiver has perfect synchronization, and the fingers' delay, θ_l is chosen to give optimal performance gain.

B. BER performance comparisons

Figure 2 shows the BER performance of different UWB receivers. A total of fifteen simultaneous users are simulated. It is observed that the proposed LBER-Rake receivers significantly than the MRC-Rake and MMSE-Rake receivers.

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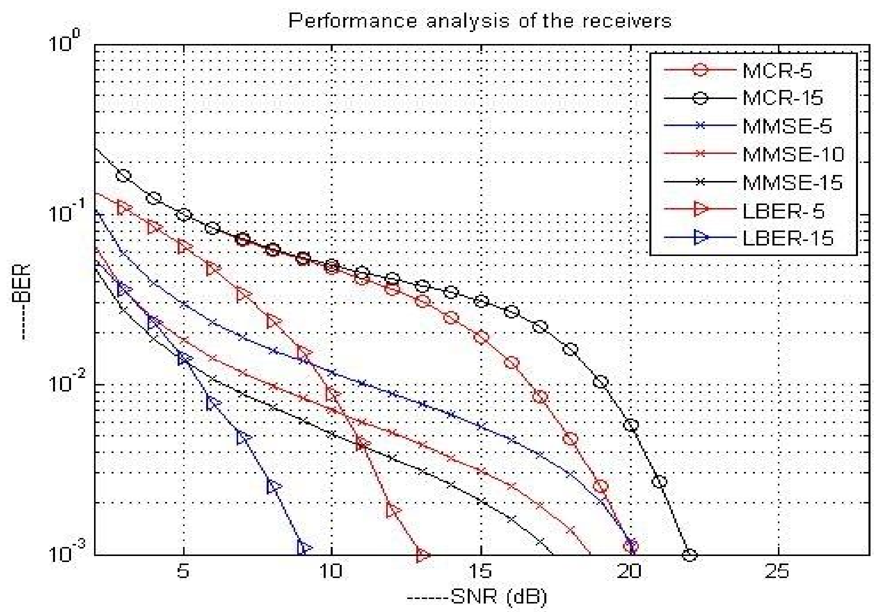

Fig.2Performance analysis of the receivers

C. Result Analysis

We analyse the performance of different receivers by studying the conditional pdf of the output signal, P(f(k)|d[i] = ±1) with a 5-finger Rake at an Eb/No = 25 dB in channel CM1. The number of simultaneous users is set to N = 15. All parameters are chosen so that ISI suppression is sufficient and MAI becomes the major interference to the received UWB signals. Fig. 3 shows the histograms for the conditional pdfP(f(k)|d[i] = ±1) of the output signal from the three receivers. It is observed that the two conditional pdfs of the conventional MRC Rake receiver are inseparable, which implies that it fails to eliminate interference effectively.

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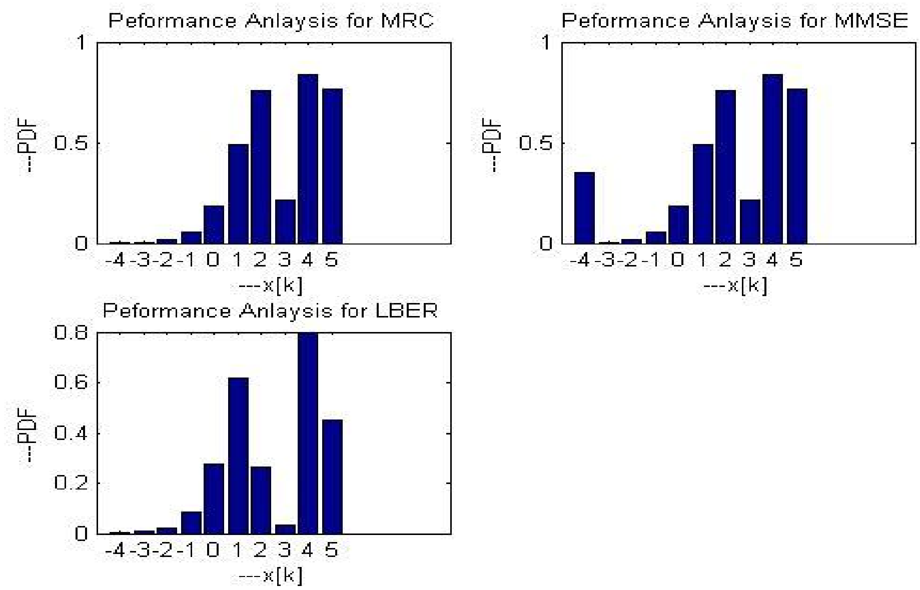

Fig-3 Result Analysis

The two conditional pdfs of the output signals from the proposed adaptive LBER-Rake receiver are well separated with a mean value closer to the transmitted signal levels than that of the MMSE-Rake receiver. It is observed that the LBER-Rake receiver attempts to calculate the best conditional pdf which has a wider curve width, whereas the MMSE-Rake only attempts to reduce the noise variance of the conditional pdf by minimizing the MSE of the output signal which has a narrower curve width. The MSE minimization is limited by the amount of AWGN noise present in the channel as discussed. That's why the proposed LBER-Rake receiver can suppress the MAI introduced by the UWB multipath fading channel more effectively and thus obtains a better BER performance.

D. Conclusion

An adaptive multi-user Rake receiver using the LBER criterion in the design of the finger coefficients has been proposed to resolve the multipath components as well as to mitigate ISI and MAI in realistic UWB multipath fading channels. It has been demonstrated using the standard channel models that the LBER-Rake receiver using fewer fingers is capable of achieving better BER performances over the traditional MRC-Rake and MMSE-Rake receivers. From the result analysis, the LBER-Rake receiver is found to have better ability in suppressing MAI compared with the MMSE-Rake receiver for fifteen noof users. Hence, it can be concluded that the proposed adaptive LBER-Rake receiver is more favourable in CDMA-UWB channels characterized by severe MAI effects.

Future work can be achieved by extending the proposed Rake receiver for more no of users.

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