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Performance Analysis of RAKE Receiver for Ultra Wide-Band Bandwidth

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Abstract —**A comparative study of different forms of RAKE receivers (namely; P-RAKE, S-RAKE, A-RAKE) in terms of bit-error-rate (BER) for Ultra Wide-Band (UWB) system is proposed in this paper. The simulation has been performed in MATLAB.**

Keywords — **RAKE receivers, P-RAKE, S-RAKE, A-RAKE, UWB, MATLAB.**

I. INTRODUCTION

Ultra-wide information (UWB) spread - spectrum (SS) multiple access methods have obtained considerable attention since last two decades [1]. UWB is meant for short-range high bandwidth communications that uses a large portion of the radio spectrum and doesn't interfere with other narrow band signals [2]. The Federal Communications Commission (FCC) has allocated 7,500 MHz of spectrum for unlicensed use of ultra-wideband devices (UWB) in the 3.1 to 10.6 GHZ frequency band [2]. The UWB spectrum made available by the FCC can be utilized with impulse radios that have been developed to date [2].

The UWB spectral allocation is the first step toward a new policy of open spectrum initiated by the FCC in the past few years. More spectral allocation for unlicensed use is likely to follow in the next few years [3]. Ultra-wideband (UWB) may be used to refer to any radio technology having bandwidth exceeding the lesser of 500 MHz or 20% of the arithmetic center frequency, according to Federal Communications Commission (FCC) [4].

UWB signals are generally transmitted using the wireless transmission medium. Which when transmitted in the non-line of sight transmission mode, by virtue of which, the phenomenon of multipath propagation comes into impact and it makes the wireless transmission systems susceptible to three fundamental types of essential types of techniques namely reflection, which occurs when the electromagnetic signal encounters an area relatively large to the wave length of the transmitted signal, diffraction, which occurs when the signals encounters an edge of an impenetrable body which is large compared to the wavelength of the signal and the third one, scattering, which occurs when the electromagnetic signal encounters an obstruction which is equal or greater than the order of its wavelength. In this third technique, the incoming signal scatters in several weaker outgoing signals. Therefore the transmitted signal needs to be recovered in some way.

A way to utilize all the multipath components is UWB environment is to use the so called RAKE receiver. RAKE receivers combine different signal components that have propagated through the channel by different paths. This can be characterized as a type of time diversity. The combination of different signal components will increase the signal-to-noise ratio (SNR), which will improve link performance [5].

The RAKE receivers are used to receive multipath components of a signal spread in time. The RAKE receivers are utilized in different forms namely All RAKE (A-RAKE), Partial RAKE (P-RAKE) and Selective RAKE (S-RAKE).

The optimal diversity combining scheme, in terms of performance, is the All-RAKE (A-RAKE) receiver which combines all the resolvable paths [6]-[9]. However the performance gain comes at the cost of power consumption and increased complexity of the utilized hardware, which are significant factors in environments with more than 100 MPCs (Multipath Components), such in UWB applications [10]. A RAKE receiver that overcomes these obstacles at the cost of performance is the selective RAKE(S-RAKE) receiver [6]-[9]. S-Rake combines the L_b strongest resolvable paths, but still requires full estimation of the channel coefficients which may not always be available. Recently, partial RAKE (P-RAKE) receiver was proposed in [11]. P-RAKE combines only the first arriving L_p paths out ofthe available resolvable MPCs, and therefore requires only synchronization, but not full channel estimation.

II. RAKE RECEIVER

The amount of multipath energy that can be collected at the receiver and the receiver complexity are commonly used to determine the performance and robustness of a wireless

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communication system [12]. The RAKE receiver is used in any kind of spread spectrum communication system to accumulate the energy in the significant multipath components [13]. The use of RAKE receiver in UWB systems is also common to collect the available rich multipath diversity.

A RAKE receiver consists of a bank of correlators, also called fingers, and each finger is matched (synchronized) to a particular multipath component to combine the received multipath coherently [13]. In order to enable symbol-rate sampling, the received UWB signal can be correlated with a symbol-length template signal, and the correlator output can be sampled once per symbol [14]. The drawback of RAKE receiver is that the number of multipath components that can be utilized in a typical RAKE combiner is limited by power consumption issues, design complexity, and the channel estimation [15]. Secondly, each multipath undergoes a different channel in UWB systems, which causes distortion in the received pulse shape and makes the use of a single LOS path signal as a suboptimal template [16].

A tapped delay line channel with K number of delays provides us with K replicas of the same transmitted signal at the receiver [13]. Hence, a receiver that processes the received signal in an optimum manner will achieve the performance of an equivalent K^{th} order diversity system [13].

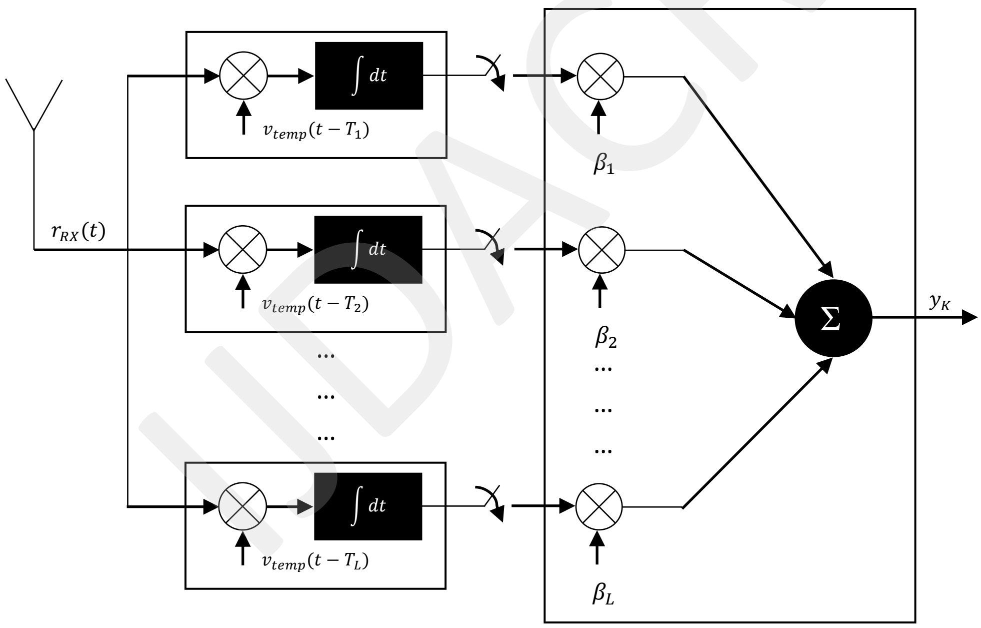

Figure 1: A RAKE receiver structure for UWB system.

In practice, only a subset of total resolved multipath components is used in the RAKE receivers[15].The RAKE types based on the number of multipath components used are given as follows [15].

- *All RAKE (A-RAKE):* The RAKE receiver which combines all the K resolved multipath components is called all RAKE (A-RAKE).
- *Selective RAKE (S-RAKE):* The S-RAKE receiver searches for the M bestpaths out of K resolved MPCs to use them as RAKE fingers.
- *Partial RAKE (P-RAKE):* The P-RAKE receiver uses the M first arrivingpaths out of K resolvable multipath components.

III. RAKE COMBINING SCHEMES

The outputs of the correlators (fingers) are passed to the RAKE combiner. The RAKE receiver can use different combining schemes such as maximal ratio combining (MRC) and equal gain combining (EGC) scheme.

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Maximal Ratio Combining (MRC):

If maximal ratio combining (MRC) technique is used, the amplitudes of the received MPCs are estimated and used as weighing vector in each finger.

The performance and optimality of the MRC consequently depend upon the receiver's knowledge of the channel [16].

Let $\beta = [\beta_0, \beta_1, \ldots, \beta_{K-1}]$be theRAKE combining weights which are different for different RAKE types.

- In case of A-RAKE, the combining weights are chosen equal to the fading coefficients of the channel, $\alpha = [\alpha_0, \alpha_1, \ldots, \alpha_{K-1}]$, i.e.,
$$\beta = \alpha$$
- For S-RAKE, if the set of indices of the M best fading coefficients with largest amplitude is denoted by S, then the combining weights β arechosen as follows [17],

$$\beta = \begin{cases} \alpha_k, & k \epsilon S \\ 0, & k \notin S \end{cases}$$

- For P-RAKE, using the first M multipath components, the weights of MRC combining are given by [17],

$$\beta = \begin{cases} \alpha_k, & k = 0, \ldots \ldots M-1 \\ 0, & k = M, \ldots \ldots K-1 \end{cases}$$

Where $M \leq K$.

V. Simulation and Results

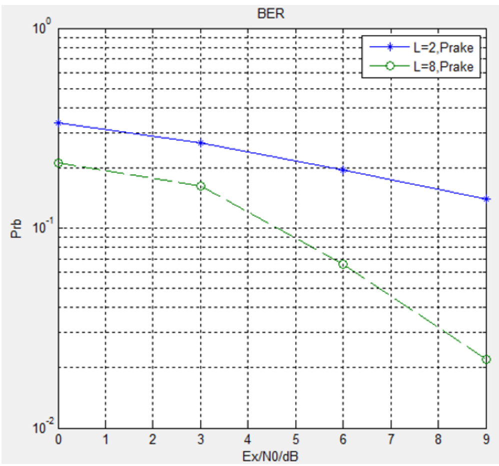

Figure 2: The BER of Partial-RAKE Receiver

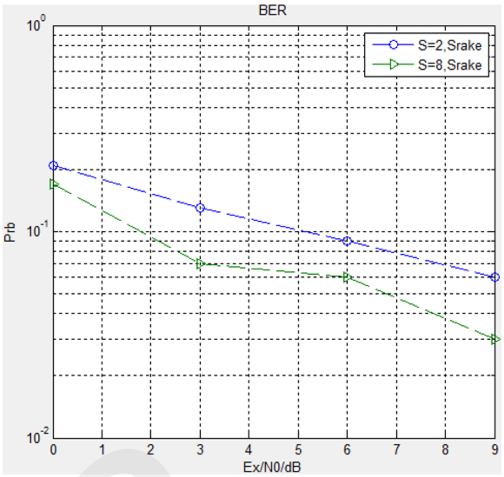

Figure 3: The BER of Selective RAKE Receiver

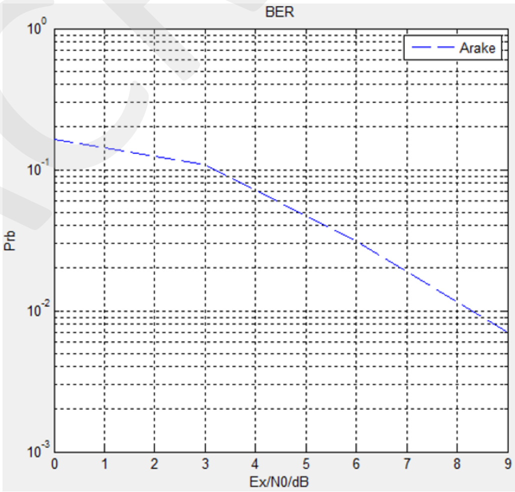

Figure 4: The BER of ALL-RAKE Receiver

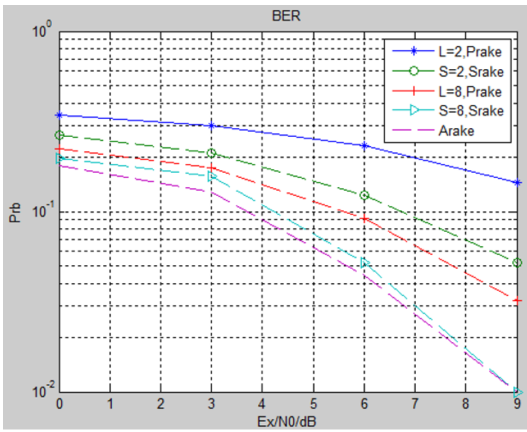

Figure 5: Comparison of BER among the different RAKE Receivers

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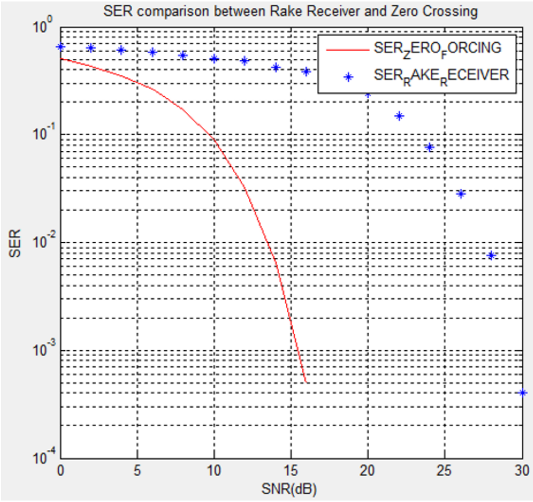

Figure 6: Implementation of Zero-Forcing in RAKE Receiver

VI. Conclusion

MATLAB Simulation results shows the performance of different RAKE receivers for Ultra Wide-Band Bandwidth. Comparison of BER among the P-RAKE, S-RAKE and A-RAKE, has been shown. It is shown that the P-RAKE perform better than the S-RAKE and A-RAKE. Zero forcing implementation for RAKE receiver also shown in this paper.

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