Performance of Rake Receiver with Spreading Bandwidth in Multipath Rayleigh Faded Channel

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***Abstract*- A signal transmitted through the wireless channel may be severely distorted due to co-channel interference, adjacent channel interference (or multiple access interference), thermal noise, and multipath fading. The most severe distortion comes from fading, which changes the symbol error rate (SER) curve from an exponential to a linear curve [1]. One technique the rake receiver employs to combat these distortions is diversity. There are different diversity techniques, including frequency, time, and space. In this paper a transmitted QPSK baseband signal through rayleigh faded multipath channel was analyzed, where propagation delay was considered for each path. The rake receiver is used to detect the user and combat the above mentioned channel environments. Diversity technique is employed over the spreading bandwidth to analyze the performance of reduced complex rake receiver.**

I. INTRODUCTION

Ultra-wide bandwidth (UWB) spread-spectrum (SS) multiple access techniques have recently received considerable attention for future commercial and military wireless communication systems. The potential strength of the UWB radio technique lies in its use of extremely wide transmission bandwidths, which results in desirable capabilities including accurate position location and ranging, lack of significant fading, multiple access, covert communications, and possible easier material penetration. The open literature now contains numerous publications on all aspects of spread spectrum signal analysis and design. Moreover, the application of SS signaling techniques to interoffice commercial communications, mobile radio communications and digital cellular communications are widely known. Commonly, these radios communicate with trains of short duration pulses with low duty cycle, and thus spread the energy of the radio signal very thinly over a wide range of frequencies. This provides inherent ability to resolve multipath components having differential delays of the order of nanoseconds (approximately equal to the inverse of the spreading bandwidth), which makes UWB SS radio a viable candidate for wireless communications in dense multipath environments [4]. The ability to resolve multipath components essentially transform dense multipath channels and create a high degree of path diversity that can be utilized by a Rake like architecture. Spread spectrum signals used for the transmission of digital information are distinguished by the characteristic that their bandwidth W is much greater than the information rate R in bits/s. In this work we have shown how a Rake receiver well performs while the signal is spreaded. Since coded waveforms are also characterized by a bandwidth expansion factor greater than unity and since good coding is an efficient method for introducing redundancy, we have exploited the generation of PN sequences that has received a considerable attention in the technical literature [5].

II. CHANNEL ESTIMATION

If a signal $s(t)$ is transmitted, a multipath channel with M physical paths can be presented (in equivalent low-pass signal domain) in form of its Channel Impulse Response (CIR) [2]

$$h(t) = \sum_{m=0}^{M-1} a_m e^{j\phi_m} \delta(t - \tau_m) \qquad (1)$$

where M is the number of multipath components. The received (equivalent low-pass) signal is of the form

$$r(t) = s(t) * h(t) = \sum_{m=0}^{M-1} a_m e^{j\phi_m} s(t-\tau_m) \qquad (2)$$

The CIR can also be presented in sampled form using N complex-valued samples uniformly spaced at most $1/W$ apart, where W is the RF system bandwidth:

$$h(t) = \sum_{n=0}^{N-1} a_n e^{j\phi_n} \delta(t - n \cdot \Delta\tau) \qquad (3)$$

III. DIVERSITY TECHNIQUE

In a Rayleigh fading channel, the Maximum Ratio Combining (MRC) diversity technique is the best, followed by Equal Gain Combining (EGC), and then Space Diversity (SD). The idea of MRC comes from- the strong signal components are given more weight than weak signal components. The complex-valued Rake finger outputs are phase-aligned using the following simple operation [3]:

$$Z = \sum_{i=1}^{n} a_i\, e^{-j\phi_i} \cdot a_i\, e^{j\phi_i} \qquad (4)$$

The signal value after Maximum Ratio Combining of an n-finger rake-receiver is

$$Z = \sum_{i=1}^{n} a_i^2 \qquad (5)$$

IV. RAKE RECEIVER

A rake receiver is a radio receiver designed to counter the effects of multipath fading. It does this by using several "sub-receivers" each delayed slightly in order to tune in to the individual multipath components. Each component is decoded independently, but at a later stage combined in order to make the most use of the different transmission characteristics of each transmission path. This could very well result in higher Signal-to-noise ratio (or Eb/No) in a multipath environment than in a "clean" environment.

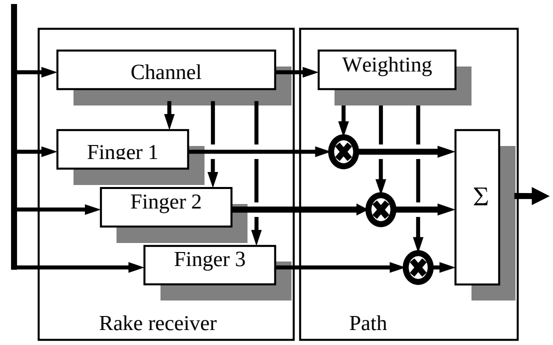

Fig 1: Rake Receiver and Diversity

The rake receiver is so named because of its analogous function to a garden rake, each finger collecting bit or symbol energy similarly to how tines on a rake collect leaves. Rake receivers are common in a wide variety of CDMA and W-CDMA radio devices such as mobile phones and wireless LAN equipment [2].

V. RECEIVED SIGNAL

The received signal consists of desired component along with signals from same user with some delay and from other users and noise. We can represent the received signal as-

$$\begin{aligned} r(t) &= z(t) + v(t) + w(t) \\ &= a_i e^{j\phi_i}\, s(t-\tau_i) + \sum_{\substack{n=1 \\ n\neq i}}^{N} a_n e^{j\phi_n} s(t-\tau_n) + w(t) \end{aligned} \qquad (6)$$

If we correlate the received signal with the Pseudo Number (PN) code, then what we will obtain can be expressed by the following equation.

$$\begin{aligned} C_i &= \int_0^T [z(t) + v(t) + w(t)]\, s(t)dt \\ &= a_i e^{j\phi_i} \int_0^T s^2(t)dt \\ &+ \sum_{\substack{n=1 \\ n\neq i}}^{N} a_n e^{j\phi_n} \int_0^T s(t-\tau_n+\tau_i)\, s(t)dt + \int_0^T w(t)s(t)\, dt \end{aligned} \qquad (7)$$

If the codes are good, that has good autocorrelation with the same sequence and good cross correlation with the other sequence, then the first term of the above equation would be of higher value in comparison with the other terms. The most widely known binary PN sequences (longcode) that are the maximum length shift-register sequences were used for the simulation purpose.

VI. RESULTS

Figure 2 shows the transmitted QPSK baseband signal.

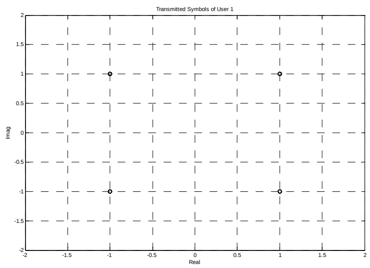

Fig. 2: Transmitted QPSK Baseband Signal

The Rake receiver used by a user received a noisy signal from the transmitted signal for five users. The received noisy signal is shown in figure 3.

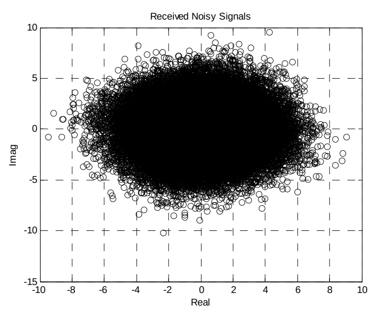

Fig. 3 : Received Noisy Signal by Rake Receiver for a User

The Rake receiver equalized the first user's 1000 signal from the received 5000 noisy signal and then scaled them. The Processing Gain for this particular problem was chosen to be 50. The equalized and scaled signal is shown in figure 4.

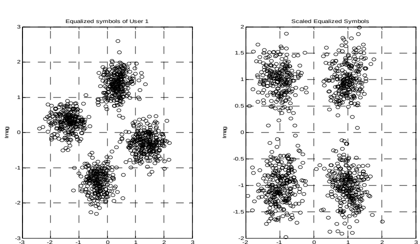

Fig. 4 : Equalized and Scaled signal for a User

The symbol error rate of rake receiver was analyzed over the spreading bandwidth. The Processing Gain was varied from 10 to 70, where the rake receiver's equalizer length was chosen to be 3 times the channel length. As expected, we observed a drastic enhancement in the performance of the rake receiver over the spreading bandwidth.

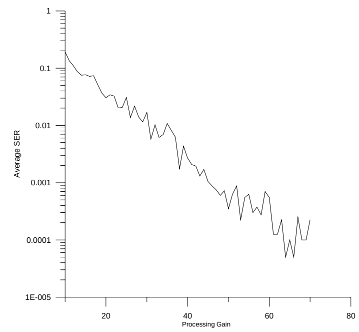

Fig. 5: Average SER of Rake Receiver over spreading BW

VII. ACKNOWLEDGEMENT

The authors wish to thanks King Fahd University of Petroleum & Minerals for financial support.

VIII. REFERENCES

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