Volume: 01, Issue: 04, Pages: 236-240 (2010)

A Rake Receiver Model for Filtering White Nose Presence in the Receiving Signals

V. Umadevi Chezhian
Department of Computer Science, University of Asmara, State of Eritrea
Email: yazh1999@gmail.com
Dr. K. Ramar
Department of Computer Science Engineering, National Engineering College, Kovilpatty
Email: kramar_nec@rediffmail.com

ABSTRACT

The third-generation universal mobile telecommunications system uses the high signal bandwidth for the WCDMA system (5 MHz) allows the received signal to be split into distinct multipath with high resolution. The rake receiver combines the received signals from different paths into a composite signal with substantially better characteristics for demodulation than a single path and maximizing the amount of received signal energy. This paper derived both the combination of rake receiver and equalizer. The output of the rake receiver is fed to the equalizer for filter the white noise presence in the receiving signal. This will give us a good reception of WCDMA signal at the receiver end.

Keywords: **Equalizer, Multipath, Rake receiver, WCDMA, White noise.**

Date of Submission: December 14, 2009 Date Accepted: February 01, 2010

1. Introduction

The Rake Receivers use maximum ratio combining and multi-user interference suppression to obtain a considerable increase in performance in DS-CDMA system such as WCDMA. WCDMA is the multiple access technique selected for the 3G mobile communications systems and it has a significant role in the research beyond 3G systems. WCDMA systems over wireless channels have to cope with fading multipath propagation, which makes the channel estimation an important issue in Rake receivers. Despite a significant amount of scientific literature on Rake receivers, there are still open problems regarding the multipath delay and coefficient estimation in hostile environments and the design of low-complexity DSP-based channel estimators for WCDMA applications [1]. Multipath fading is one of the major practical concerns in wireless communications. Multipath problem always exists in the mobile environment, especially for a mobile unit which is often embedded in its surroundings. The RAKE receiver has been used to reduce the multipath fading in a wideband spread spectrum mobile system [2]. However, the tap weights of the multipath channel model need to be estimated. We explore the possibility of using advanced signal processing algorithms to estimate the multipath channels and propose a least-squares approach to tap weight estimation based on chip rate channel estimates to investigate the performance of the RAKE receiver in a realistic mobile environment [2].

Weaker interfering users are modelled by adding white Gaussian noise to the channel [3]. The potent ional benefits of using an equalizer are an increasing capacity on the one hand as well as improvement in throughput and greater coverage for high data rate service on the other [4]. At the same time for maximal ratio combining (MRC) Rake receiver, the paths with highest signal-to-noise ratio(SNR) are selected, which is an optimal scheme in the absence of interfering users and inter-symbol interference(ISI). For a minimum mean error (MMSE) Rake receiver, the conventional finger selection algorithm is to choose the paths with highest signal-to-interference-plus –noise ratios (SINR) [5]. Multipath fading in wireless communication is modelled by several distribution methods at the same time the gain of each channel is made proportional to signal level and inversely proportional to the noise level [6].

2. Objectives

Million dollars industry, the wireless communication business will benefit from Rake- Receiver, with increased mobility for the users, as well as the service providers. In addition further development potential of the receiving signal with good reception of WCDMA, whose results reflects on Defense, Mobile communication etc., areas.

A breakthrough in Rake –Receiver could spring the wireless industry to higher level of efficiency. Hence the following objectives are determined:

- To improve the Signal to Noise Ratio (SNR) at the receiver.
- Provides a separate correlation receiver for each of the multipath signals.

- To utilize the advantages of diversity techniques channel parameters.
- Reducing white noise presence in receiving signal.

3. Basic Channel Plans

Channel No.	Channel fc	-4.3 dB (signal)		-10 dB (FCC)	
1	4.000 Ghz	3.6Ghz	4.4Ghz	3.4Ghz	4.6Ghz
2	4.800 Ghz	4.4Ghz	5.2Ghz	4.2Ghz	5.4Ghz
3	5.600 Ghz	5.2Ghz	6.0Ghz	5.0Ghz	6.2ghz
4	6.400 Ghz	6.0 Ghz	6.8 Ghz	5.8Ghz	7.0Ghz
5	7.200 Ghz	6.8 Ghz	7.6Ghz	6.6Ghz	7.8Ghz
6	8.000 Ghz	7.6Ghz	8.4Ghz	7.4ghz	8.6Ghz
7	8.800 Ghz	8.4Ghz	9.2Ghz	8.2Ghz	9.4Ghz
8	9.600 Ghz	9.2Ghz	10.0Ghz	9.0Ghz	10.2Ghz

Table 1. Basic Channel Plan

The Rake receiver module implements the basic channel plans including channel estimation and Maximum Ratio combining of 'Number of Fingers" phase corrected multipath components. The model reads:

'Blocklength' * 'Oversampling' (1)

The incoming data signal calculates:

'BlockLength'/'SpreadingFactor' (2)

During the demodulation, a time –tracking of finger delays is done.

The De-spread block reads:

'SpreadingFactor' * 'OverSampling' (3)

The channel estimation block reads:

'LengthPNSequence'+'MaxDelay'*'Oversampling' (4)

The Guassion noise is computer by:

Factor*pow(10,(-SNR/10))*Signal Power (5)

Where the Signal-to-Noise Ratio (SNR) in [dB]. Signal power is the power of the signal in [Watt], and the factor is used to scale the SNR [7]. The parameter Signal Power Flag determines whether variance of the Gaussian noise process is determined by the parameter Signal Power or from the input values during the simulation run the result as follows:

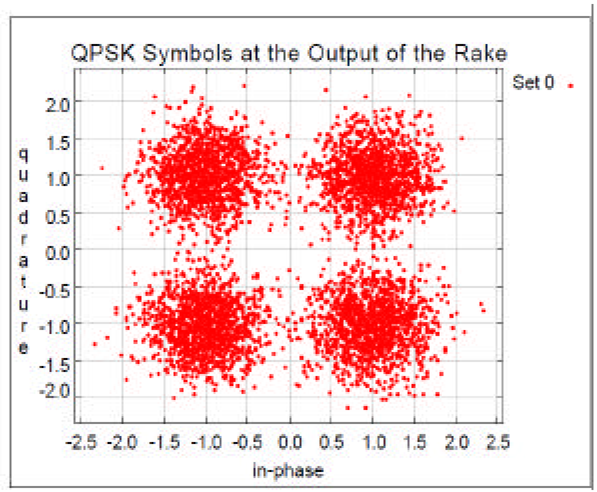

Fig 1: Basic Channels QPSK output from Rake receiver

4. Configuration of The Rake Receiver And The Equalizer

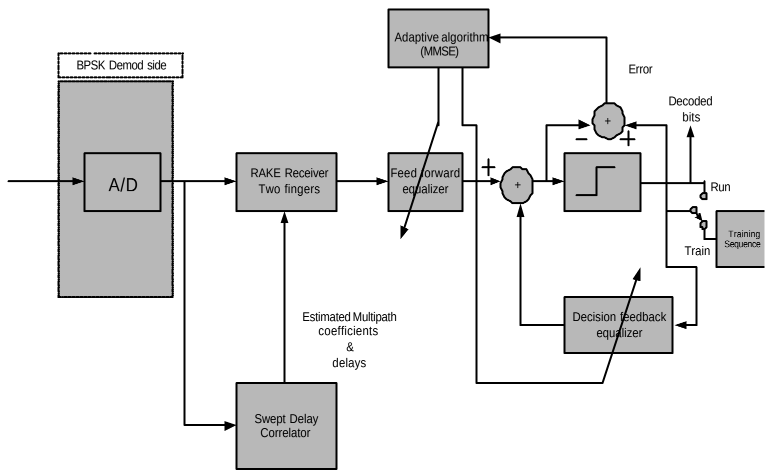

Fig 2: Configuration of the Rake receiver and the Equalizer.

In the implementation of the Rake receiver, it is assumed that 10 PN sequences of length 31 are transmitted per channel are necessary to estimate the multipath coefficients and delays.

Each of the 10 PN sequences is assumed to be independent and uncorrelated, such that:

$$\Lambda(n) = \frac{1}{31}\sum_{1}^{31} PN(n) * PN(n+k) = 1 \qquad k = 0$$
$$\approx 0 \qquad k \neq 0 \qquad (6)$$

Multipath delays are estimated using a Swept Delay Correlator (SDC). SDC provides the multipath amplitude and delay coefficients.

Assume that a PN sequence carries information of L multipaths, and no other impairments, then, this PN sequence at the receiver after down conversion can be written as:

$$r(n) = \sum_{j=1}^{L} C_j PN(n - t_j) \qquad (7)$$

Where, Cj is the complex path coefficient corresponding to the path delay tj. The output of the SDC can be written as,

$$y(n) = \frac{1}{31}\sum_{k=0}^{30} PN(k) \sum_{j=1}^{L} C_j PN(n-k-t_j) = C_j \quad when \ n = t_j$$
$$= 0 \quad otherwise \qquad (8)$$

In this implementation, L=2. The structure of the SDC is shown below:

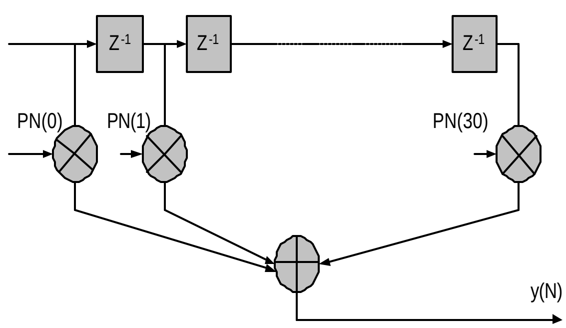

Fig 3: The structure of SDC

The amplitude and delay coefficients, t_j and C_j respectively, are the fed to the Rake fingers. There are only 2 Rake fingers. It was determined that 2 Rake fingers are sufficient to combat the multipath effect if a PRF rate of ¼ for 2 nsec pulse width is used, ie: a 6 nsec time gap and 8 nsec repetitive time period.

5. Gaussian Filer Shape Channel Plan

Given that the required SNR is about 11 dB for BPSK before conventional coding gain, then the required link budget can be constructed.

There is a 10.7dB path loss difference between 3.1 Ghz and 10.6 Ghz. Therefore transmission on the top band will have to be compensated by this amount for the link to be balanced.

Although there are a number of ways compensation can be made, however, an optimum solution with minimum cost objective is still being studied. At this point, high channel numbers at 480 Mbps is below link margin, and can only operate at 3 meter range [8]. Following Link budget [8] Table 2. is used in this environment.

	Ch1	Ch8	Ch1	Ch8
Throughput	100	100	480	480
Over-the-air bit rate	275	275	1320	1320
PRF rate	11	11	11	11
Average TX power (P_T) dBm	-3.5	-0.5	0	0
Tx Antenna gain (G_T) dBi	0	0	0	0
f_c: center frequency of waveform Ghz	4.0	9.6	4.0	9.6
Path loss at 1 meter (L_1) dB	44.5	52.1	44.5	52.1
Path loss at d meter (L_2) dB	20	20	20	20
Rx antenna gain (G_R) dBi	0	0	0	0
Rx Power (P_R = P_T+G_T+G_R-L_1-L_2) dBm	-68	-72.6	-64.6	-72.2
Noise bandwidth at antenna port (Mhz)	800	800	800	800
Noise Power (N = -174 + 10*log(Rb)) dBm	-89.6	-89.6	-82.8	-82.8
Rx Noise Figure (N_F) dB	7	7	7	7
Rx Noise Power (P_N = N+N_F) dBm	-82.6	-82.6	-75.8	-75.8
Processing Gain (P_G)	1	1	1	1
Minimum C/N (S) dB	6	6	6	6
Link Margin (M = P_R + P_G –P_N- S)	5.6	1.0	2.2	-5.4
Proposed Minimum Rx sensitivity level dBm	-75	-75	-75	-75

Table 2. Link Budget

6. Resultant BPSK Constellation after Configuration of Rake Receiver and Equalization

UWB system has a large bandwidth; it generally contains large number of multipaths. The most common way to combat multipath fading is to use a Rake receiver. In the presence f MAI (multiple access interface), bit error rate probability performance exhibits an error floor. In order to cancel MAI, Rake receiver employs the weight vector to perform bit level equalization in each finger.

The output of the Rake receiver is fed to the Equalizer which consists of a feed forward filter and a decision feedback filters. The equalizer is trained with a PN sequence that is 500 bits long. The equalizer used is a basic textbook adaptive MMSE equalizer.

The M feed forward taps and N feedback taps are related in the following manner using M=16 and N=16:

$$e(k) = I(k) - \tilde{I}(k)$$
$$F_i(k+1) = F_i(k) + me(k)X(k-i) \qquad for \quad i = 0...M-1$$
$$D_i(k+1) = D_i(k) + me(k)I(k-i) \qquad for \quad i = 0...N \qquad (9)$$

Finally, in a graphical form, the of figures traces through the receive chain:

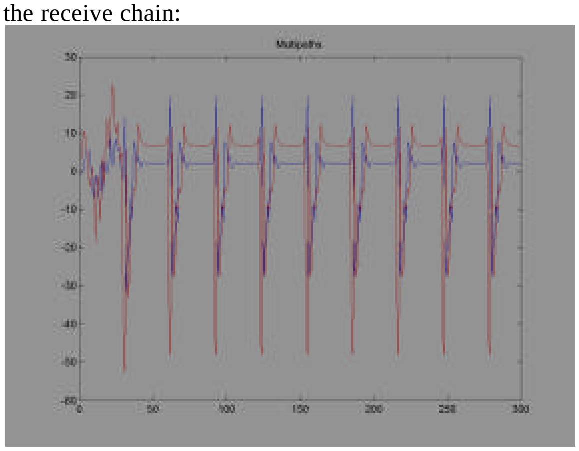

Fig 4: Multi-path complex real and imaginary signals.

The Rake receiver multipath channels performance is showed in the following QPSK simulation result. Compare with the basic channel plan result, we observed the better result in the receiving signals. It offers significant improvement in MAI cancellation in multipath channels.

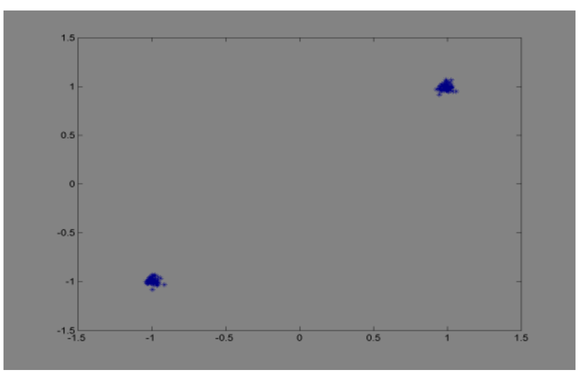

Fig 5: Resultant BPSK constellation after Rake receiver and equalization

7. Result and Discussion

Using basic channel plans the receiving signal gain is spreads with white noise, it decreases the quality of signals and voice , Designing Rake receiver with Equalizer filter technology we can get loss less reception of signals. This type of rake receiver as disclosed, in effect forms a matched filter to the combination of the channel with the signal waveform. However, the rake receiver was designed around the concept of sampling only once per chip. The bandwidth of the signal is slightly greater than the chip rate for a typical waveform shaping factor, such as square root of the raised power cosine and therefore the minimum sampling rate required to meet the sample theorem requirements is not fully met. Where the sampling takes place in such a way that samples align exactly with the peak of the signal response, there is no loss due to the mis-sampling in time. However, where this is not the case there will be some small loss if the signal being received is one of an ensemble of nominally orthogonal signals.

One major advantage is increased capacity through more efficient use of the spectrum. Greater capacity enables the WCDMA wireless network to handle higher call density at a lower cost. New algorithm used WCDMA technology increases the reliability and quality of service by reducing static noise and improving voice clarity. The soft handoff is completed minimizing dropped calls and speech distribution.

8. Conclusion

The Rake receiver is well known for multipath fading channel technique in the presence of narrow band interface and additive white Gaussian noise (AWGN). The major drawback is the high computational complexity. The Rake receiver which performs with the basic channel parameters, the Signal Power Flag determines whether variance of the Gaussian noise process is determined by the parameter Signal Power. The configuration with Link Budget channel estimation the output of the rake receiver is fed to the equalizer for filter the white noise presence in the receiving signal. This will be maximizing the amount of received signal energy and give us a good reception of receiving signal at the receiver end.

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Author's Biography

V.Umadevi Chezhian has involved in various research activities. She published articles and research papers. She had good teaching experience in Arulmigu Palaniandavar Arts and Science College for Women, India, Cyryx Information Technology in Male, Republic of Maldives and currently working as a lecturer in the College of Business and Economics, University of Asmara, State of Eritrea. She finished M.Sc., (CS & IT), M.Phil, (Computer Science), D.C.S., (Diploma in Computer Software), and pursuing her PhD. She has interested in Research activities related to networking.

Dr. K. Ramar, Vice Principal and Head of the Department, Computer Science Engineering, National Engineering College, Kovilpatty, Tamilnadu, India. Recognised guide in Manonmaniam Sundaranar University, Anna University in Chennai and Tirunelveli , Mother Teresa University, and Dravidian University in Andra Pradesh. Visited abroad Japan, Malaysia for various internaltional conferences. Expert member of Acted and Affiliation Committee member to affiliate colleges under Anna University. Senate member in Manonmanium Sundaranar University. Board of studies member for various colleges in India. He published two books. He has given Radio talks and involved in Guest lecturer activities. He has organized many Conferences. Technical committee member of Wasada University, Japan.