SNR Performance Analysis of Rake Receiver for WCDMA

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Abstract

The communication industry is experiencing an explosion in the demand for personal communications services. Telecommunications service providers and network operators are embracing the recently adopted global third generation (3G) wireless standards in order to address emerging user demands and to provide new services like voice communications, high-speed data and multimedia services. WCDMA is the required technology for above mention services. WCDMA was designed to meet such high data rate up to 3.84 Mcps and high bandwidth. The higher bandwidth causes a more channel distortion. It is modeled as a multi-path phase and amplitude distortion. Two major effects resulting from multipath propagation first, the signal energy may arrive at the receiver across clearly distinguishable time instants and second is fast fading. To overcome these effects Rake receiver is used which combines delayed dispersive energy. We examined the SNR performance of Rake Receiver with, varying spreading factor, Rake fingers and number of multipath. We also examined performance of LMS Algorithm for channel estimation. From the results we have seen that the SNR performance of Rake Receiver is affected by varying these parameters and it gives useful insight for implementation.

Keywords: *WCDMA, Rake Receiver, LMS Algorithm, Channel Estimation, MRC, Multipath channel.*

1. Introduction

The trend in today's wireless communication is towards achieving unparalleled wireless access that has never been possible earlier. Communications using Voice over Internet Protocol (VOIP), multi-megabyte Internet access and very high network capacity are just some of the features, which 3G developers are looking at. All such high data rate applications come with an increase in system bandwidth. The increased bandwidth leads to a more distorted channel, which behaves in a frequency selective fashion and is modeled as a multi-path phase and amplitude distortion. This leads to further complexity in receiver design.

To address issues like high data rate, computationally intensive algorithms, cost efficient systems etc., the 3G evolution for CDMA systems lead to cdma2000, while for GSM and IS-136, it lead to Wideband CDMA (W-CDMA)[1]. It was designed to support high data rates of up to 3.84 Mcps.

To extract the channel diversity provided by the frequency selective channel (wide band channel), a Rake receiver, that uses Maximal Ratio Combining (MRC) is used. Since the receiver requires channel knowledge, a channel estimation algorithm forms a part of the receiver design.

Due to reflection from obstacles a wideband radio channel can consists of many copies (multipath) of originally transmitted signals having different amplitude, phase, and delays. If the signal components arrive more than duration of one chip apart from each other, a Rake Receiver can be used to resolve and combine them. The Rake Receiver uses a multipath diversity principle. The Rake Receiver process several signal multipath components. [2]- [4] This combining is done to improve Signal to Noise Ratio (SNR) at receiver. Rake Receiver proceeding a maximal Ratio combining (MRC) becomes an optimum receiver in the sense of highest SNR [6]-[8].

In section 2 Rake receiver system is described. In this section block diagram of Rake receiver and working of each block is given. Section 3 deals with system model. In section 4, code development steps (flow chart) for Rake receiver is given. In section 5, simulation results for channel estimation and for different parameters like number of Rake fingers, spreading factors etc. are presented. Finally in section 6, conclusion and directions of future work are given.

2. Rake Receiver

The received signal energy can be improved in a

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multipath fading channel by utilizing diversity technique, such as the Rake receiver [2]. 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.

Figure 1 shows a block diagram of a Rake receiver with three fingers according to these principles. Digitised input samples are received from the RF front-end circuitry in the form of I and Q branches (i.e. in complex low-pass number format). Code generators and correlator perform the despreading and integration to user data symbols. The channel estimator uses the pilot symbols for estimating the channel state which will then be removed by the phase rotator from the received symbols. The delay is compensated for the difference in the arrival times of the symbols in each finger. The Rake combiner then sums the channel compensated symbols, thereby providing multipath diversity against fading [13]. Also shown is a matched filter used for determining and updating the current multipath delay profile of the channel. This measured and possibly averaged multipath delay profile is then used to assign the Rake fingers to the largest peaks.

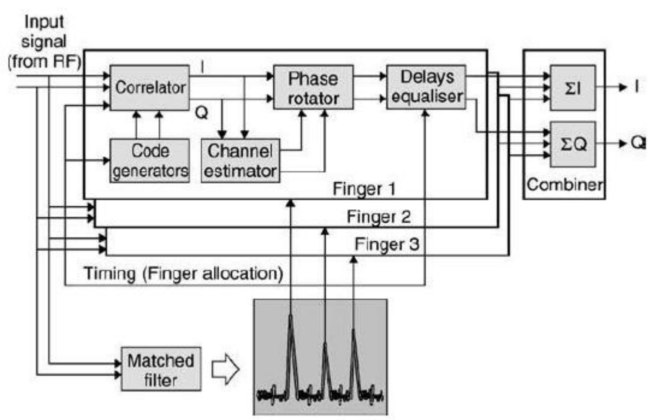

Fig. 1 Block diagram of the CDMA Rake receiver

3. System Model

In M-finger Rake receiver, multiple correlators are used to separately detect M strongest multipath components. Each correlator detects a time-shifted version of the original transmission, and each finger correlates to a portion of the signal, which is delayed by at least one chip in time from the other fingers. The outputs of each correlator are weighted to provide better estimate of the transmitted signal than is provided by a single component. Outputs of the M correlators are denoted as Z1, Z2,….., and ZM and they are weighted by α1, α2,…, and αM, respectively. Demodulation and bit decisions are based on the weighted outputs of the M correlators.[5]

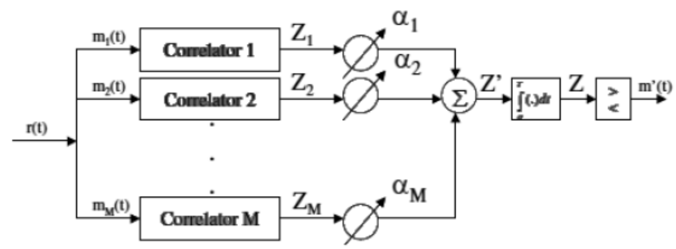

Fig. 2 An M-branch Rake receiver

The weighting coefficients are based on the power or the SNR (Signal-to-Noise Ratio) from each correlator output. If the power or SNR is small out of a particular correlator, it will be assigned a small weighting factor, α. If maximal-ratio combining is used, following equation (1) can be written for Z'.

$$Z' = \sum_{m=1}^{M} \alpha_m Z_m \qquad (1)$$

The weighting coefficients, αm, are normalized to the output signal power of the correlator

$$\alpha_m = \frac{Z_m^2}{\sum_{m=1}^{M} Z_m^2} \qquad (2)$$

There are many ways to generate the weighting coefficients. Due to Multiple Access Interference, Rake fingers with strong multipath amplitudes will not necessarily provide strong output after correlation. By Choosing weighting coefficients based on the actual outputs of the correlator yields to better Rake performance.

4. Code Development

In this chapter, simulation code development for WCDMA Rake receiver is explained in detail.

4.1 Code Development steps (Flow Chart) for channel Estimation

In below figure 3 code development steps for channel estimation [9]-[11] using LMS Algorithm is given. For this we developed different codes like OVSF code, Scrambling code [12] and Gold code.

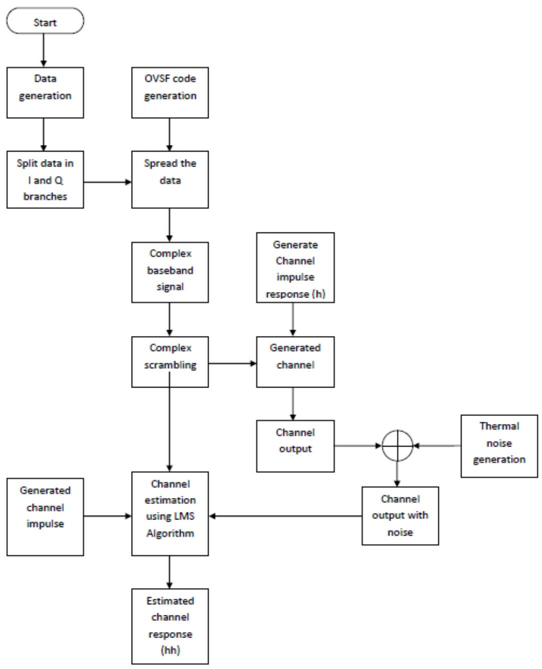

Fig. 3 Flow chart for Channel Estimation

2.2 Code Development steps (Flow Chart) for Rake Receiver

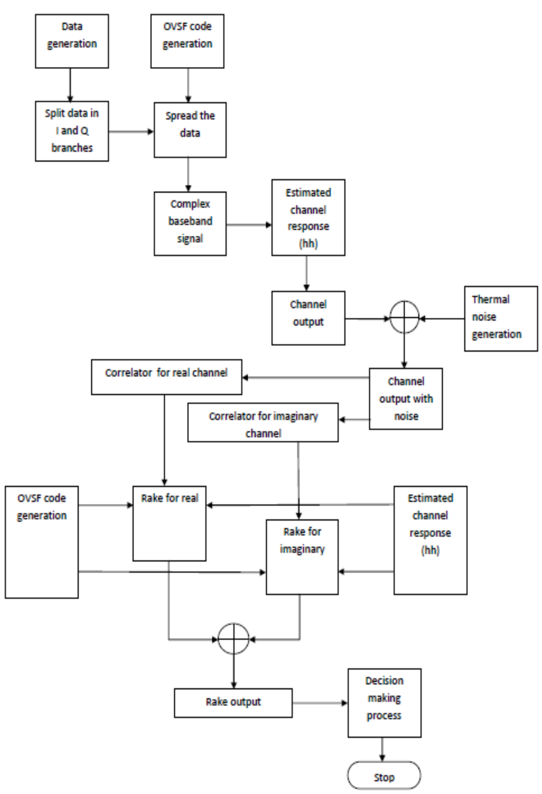

Fig. 4 Flow chart for Rake Receiver

Above figure shows code development steps for Rake receiver. Figure 4 contains some of important code blocks like Estimated channel impulse response, Correlators, Rakes, Decision making process etc.

5. Simulation Results

5.1 Simulation Setting

Channel estimation was performed using common pilot channel. For this estimation CPICH data (here twenty 1s) was used. Scrambling code with length 38400 chips per 10ms frame length[14] and Gold sequence is generated using following two polynomials (equation 3 and 4):

1. p1(x)= 1+x^3+x^25 (3)
2. p2(x)= 1+x+x^2+x^3+x^25 (4)

5.2 Channel Estimation

FIR channel (number of taps =20) has been simulated. Different types of FIR channels has been designed for different number of multipath like three multipath, five multipath, nine multipath and twenty random multipath.

At the receiver end, CPICH symbols are pilot symbols can be used for channel estimation. The advantage of using CPICH is that all the data in the frame can be used in channel estimation. Also since this is transmitted with higher power, therefore traffic channel will have the better reception at the handset.

For each independent path, the estimation channel obtained by the correlator which processed as follows

$$r_i = \sum_{l=0}^{L-1} \alpha_l \left(\sum_{k=1}^{N-1} s_{i-l}^{(k)} \right) PN_{i-l} + \sum_{l=0}^{L-1} \alpha_l PN_{i-l} \qquad (5)$$

The correlator delays signal with chip duration and calculate the correlation with PN sequence until it detects a peak in correlation function, the correlator estimates the delay and stores its value. An estimation based on CPICH is supposed to estimate αl the coefficients. The input signal at Rake Receiver is defined by

$$rr_i = \alpha_l \left(\sum_{k=1}^{N-1} s_{i-l}^{(k)} \right) + \alpha_l \qquad (6)$$

To lock the path “l”, we multiply the mentioned signal by the delayed time of PN chips. To cancel the users signals the effect of signals from users, we multiply by the orthogonal code of CPICH and we find the estimated value of αl.

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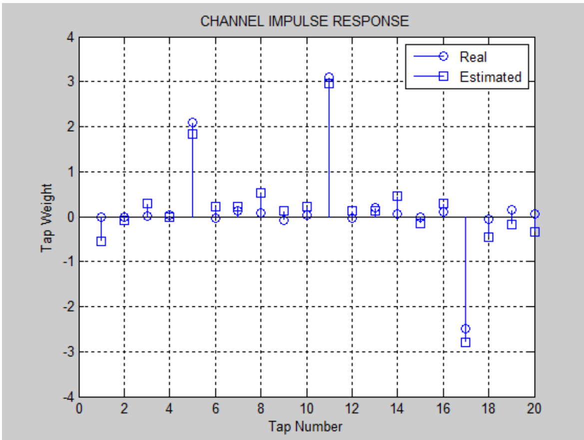

Figure 5 channel impulse response (no of multipath=3)

Figure 5 shows both real and estimated channel impulse response with SF=256 and number of multipath were 3.

We had repeated same simulation for five multipath with SF=256. Figure 6 shows results obtained.

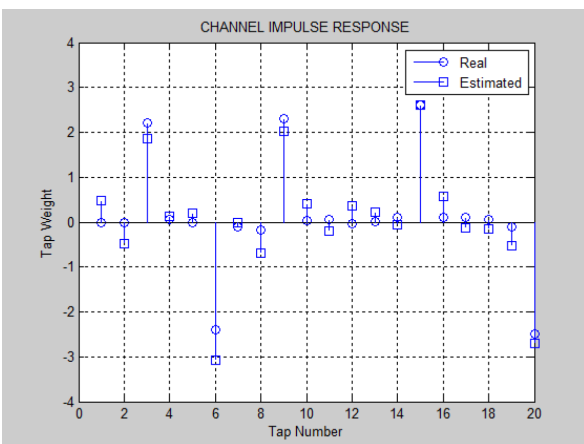

Figure 6 channel impulse response (no of multipath=5)

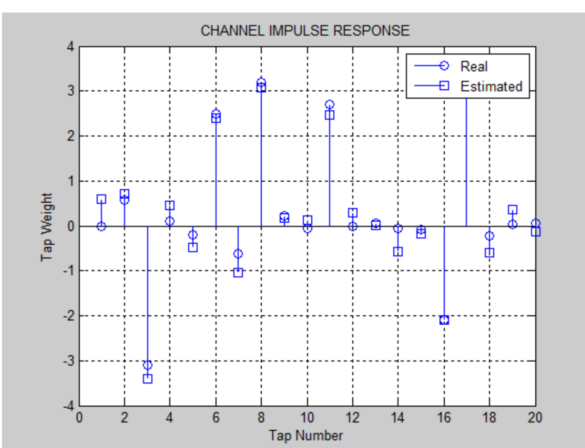

Figure 7 channel impulse response (no of multipath=9)

Figure 7 shows channel impulse responses with SF=256 and number of multipath were 9.

In fourth simulation with SF=256, we had increased number of multipath to 20. Figure 8 shows results obtained.

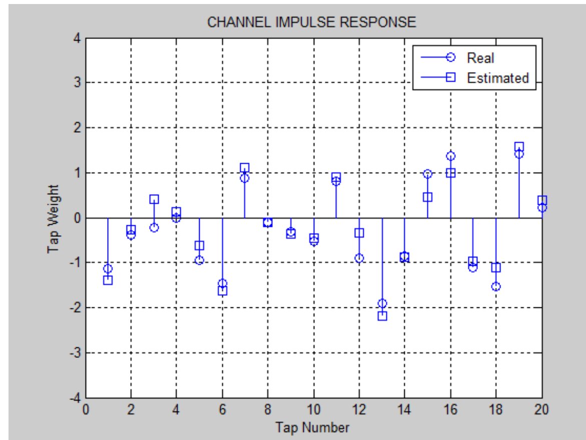

Figure 8 channel impulse response (no of multipath=20)

It is noted that number of multipath effects channel estimation.

5.3 Results for different number of Rake fingers

For this results SF=256 and three multipath channel impulse response was utilized. For number of Rake finger =1 SNR =61.1562 dB and for 20 SNR= 95.1832 dB so, there is improvement of 37.027 dB.

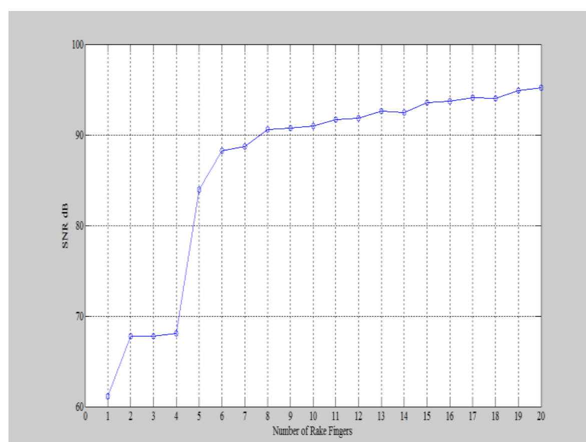

Fig. 9 SNR (dB) for different number of Rake Fingers

5.4 Results for different spreading factors

For this results number of Rake fingers = 20 and three channel impulse response was utilized. As we increased

Spreading Factor (from 4 to 512) there is also increment in SNR (from 73.3242 dB to 93.9819 dB=20.6577). Results are shown in figure 10.

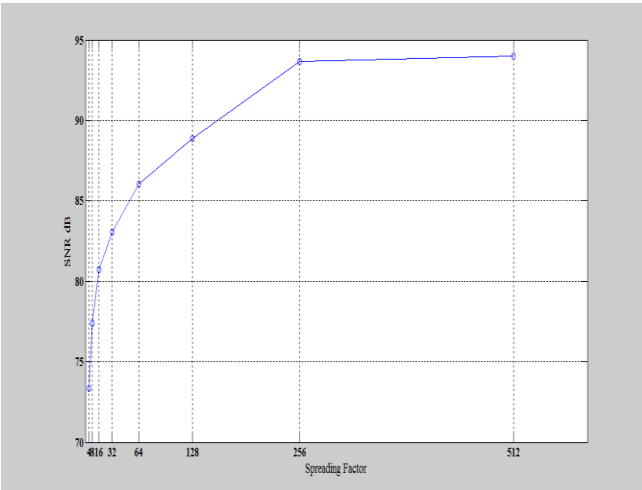

Fig. 10 SNR (dB) for different Spreading Factors

Here as we increase SF (Spreading Factor) there is decrement in data rate because data rate is inversely proportional to SF.
SF = 512/2^K, Data rate = (10*2^K bits/slot)*(15 slots/frame)*(100 frames/sec)

6. Conclusion

The performance analysis of Rake receiver has been presented in this paper. Numerical results are presented to show the channel estimation and SNR performance for downlink transmission. It is observed that increase of Rake finger from 1 to 20 gives increase of SNR by 37.027dB and increase of Spreading factor from 4 to 512 gives increase of SNR by 20.66dB. The results indicate that Rake receiver performs better against multipath power loss.

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