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Performance Evaluation of Rake Receiver in CDMA20001x Mobile Cellular Radio Network

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ABSTRACT: Code Division Multiple Access 20001x (CDMA20001x), a widely accepted third generation interface is based on Direct Sequence (DS) code Division multiple Access technology. The capacity of DS-CDMA systems is limited by distortions due to Multiple Access Interference (MAI). The phenomenon of multipath propagation has also contributed significantly towards deterioration of the quality of received signal. This paper presents the performance evaluation of Rake receiver in CDMA20001x mobile cellular radio network. Several techniques for distortions and multipath mitigation are in use, but this paper presents using the rake receiver for increasing spectrum efficiency and improving on the Bit Error Rate (BER) performance of the CDMA20001x system. Data collected were simulated in Matlab and the results show an improved BER performance of the Rake receiver in the uplink of a CDMA20001x communication system. The simulator developed can be an invaluable tool for investigating and implementation of CDMA20001x.

Keywords: **CDMA20001x, pseudo-noise code, beam forming, DOA.**

I. INTRODUCTION

Wireless communication is one of the most vibrant areas in the communication field. With the technological advancement in today's society; the ability to communicate with people on the move has evolved remarkably [1]. However, the transmission quality of the signal has deteriorated due to modernization and other man made obstacles. Because of reflections from obstacles, a radio channel can consist of many copies of the originally transmitted signals which have different amplitudes, phase and delays [2].

In CDMA20001x, Rake receivers are techniques that can be used to improve the quality of the transmitted signal in a multipath environment. CDMA1x is a channel access technique where users are separated by unique codes, which means that all users can use the same frequency and transmit at the same time [3]. The narrowband message signal is multiplied by very large bandwidth signal called the spreading signal. The spreading signal is pseudo noise code sequence that has a chip rate which is order of magnitudes greater than the data rate of the message. Each user has its own pseudorandom code word which is approximately orthogonal to all other codeword. CDMA20001x use Rake receivers to minimize communication errors resulting from multipath effects by combining them constructively to minimize interference from different directions. The Rake receiver shows real promise for increasing spectrum efficiency and improving on the Bit Error Rate (BER) performance of the communication system.

The increasing demand for mobile communication services without a corresponding increase in RF spectrum allocation motivates the need for new techniques to improve spectrum utilization. The existing frequency spectrum or radio frequency band (resource) allocated for mobile wireless communication is very scarce, costly and hence must be managed efficiency.

The most important factor in the success of cellular or mobile concept has been the relative ease with which the total system capacity can be increased. Among the many alternatives taken, the adaptive Antenna, Rake Receiver and CDMA are approaches that show real promises for increasing spectrum efficiency.

II. CDMA 20001X

Code Division Multiple Access 20001x (CDMA20001x) is one of the main technologies for implementation of third generation (3G) cellular systems.

In CDMA20001x interface, different users can simultaneously transmit at different data rates and date rates can even vary in time. The CDMA20001x physical layer has the flexibility of accommodating different service types simultaneously especially with respect to low and medium bit rates [4].

A. Conventional Beam forming

A conventional beam former or delay and sum beam former has all the weights of equal magnitudes [5]. The principle of the conventional beam former is that when an electromagnetic signal impinges upon the aperture of the antenna array, the element outputs, add together with appropriate amounts of delays, reinforce signals with respect to noise or signals arriving at different directions. The delays required depend on the physical spacing between the elements in the array. To steer the array in a particular direction, the phases are selected appropriately. In order to be able to null an interfering signal, the null steering beam former can be used to cancel a plane wave arriving from a known direction producing null in the response pattern at this direction when the number of interferers becomes large, the beam former might not be a practical approach. Beam

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steering is the simplest form of beam forming that can be achieved by the conventional beam former.

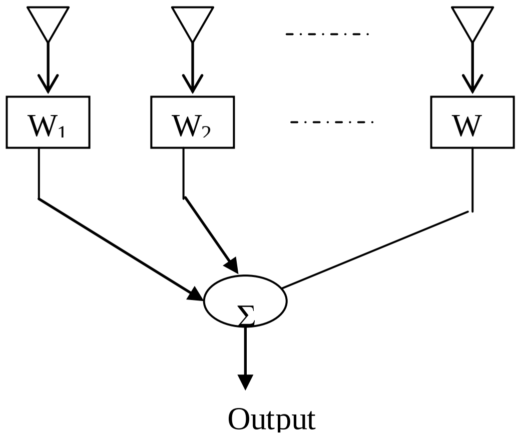

Fig 1: Conventional beamform antenna pattern

The weight of the beam former are all made equal in magnitude, where as the phase is selected to steer the main beam of the array in a particular direction

The array weights are given by [6]:

$$W_{BS} = \frac{1}{M} a(\theta_o) \quad (1)$$

Where M is the number of elements and a (θ_0) is the steering vector. In other words, the main beam is steered toward the DOA of the desired source. Thus, beam steering requires the knowledge of the desired signal location. The SNR at the output of the beam former is given by :

$$SNR_{BS} = \frac{W^H R_S W}{W^H R_N W} \quad (2)$$

In the special case where the system is dominated by uncorrelated noise

and no dominant interference exists, the output SNR thus becomes [7].

$$SNR_{BS} = \frac{\frac{1}{M^2} a^H(\theta_O) a(\theta_O) APA^H . a(\theta_O) a^H(\theta_O)}{\frac{\delta_n^2}{M^2} a^H(\theta_O) a(\theta_O)} \quad (3)$$

$$= \frac{\frac{P}{\delta_n^2}}{M} = \frac{MP}{\delta_n^2} \quad (4)$$

From equation 2,

Where $R_S = E[SS^H]$ is the desired signal's correlation matrix and $R_N = E[NN^H]$ is the noise and interference correlation matrix. If we maximize the quality $W^H R_S W$ subject to the constraint that $W^H R_N W$ = 1, then we can achieve the maximum SINR. Using the method of Lagrange multiple and setting the gradient with respect to W to zero, we then get equation (5)

$$\nabla[W^H R_S W + \lambda(1 - W^H R_N W)]$$

$$R_S W - \lambda R_N W = 0 \quad (6)$$

The results in the Eigen value problem

$$R_S W = \lambda R_N W \quad = 0 \quad (5)$$

This can be further written as

$$R_N^{-1} R_S W = \lambda W \quad (8)$$

The solution of (8) requires that W be an eigenvector of $R_N^{-1} R_S$. Hence, the eigenvector corresponding to the maximum eigen value (λ_{MAX}) would maximize the SINR and we get

$$SINR_{MAX} = \lambda_{MAX} \quad (9)$$

Therefore,

$$R_S W = \lambda_{MAX} R_N W = SINR . R_N W \quad (10)$$

Solving for the optimum weight and using the definitions of the signal correlation matrix

$$W_{OPT} = K_{SINR} R_N^{-1} A \quad (11)$$

The major disadvantage of delay- and–sum beam forming systems is the large number of sensors required to improve the SNR. Each doubling of the number of sensors will provide at most an additional 3dB increase in SNR and this is if the incoming jamming signals are completely uncorrelated between the sensors and with the desired signal. Another disadvantage is that no nulls are placed directly in jamming signal locations. The delay- and-sum seeks only to enhance the signal in the direction to which the array is currently steered. [8]

For stationary sources, it is common for the delay and –sum beam former to work in the frequency domain where a time delay is equivalent to a phase shift [9].

B. Algorithm for Conventional Beam Former

For three- element array with desired and interfering signals. The weights array for optimization are given by

$$W^H = [W_1 \ W_2 \ W_3] \quad (12)$$

Therefore, the general total array output is given as

$$y = \overline{w}^H . a = w_1 e^{-jkdsin\theta_o} + w_2 + w_3 e^{-jkdsin\theta_o} \quad (13)$$

The array output for the desired signal will be designated by y_s whereas the array output for the interfering or undesired signals will be designated by y_1 *and* y_2 . Since there are unknown weights, there must be three conditions satisfied.

Conditions: 1,2,3 are shown in y_s, y_1, y_2

$$y_s = \overline{w}^H . a_o = w_1 e^{-jkdsin\theta_o} + w_2 + w_3 e^{-jkdsin\theta_o} = 1 \quad (14)$$

$$y_1 = \overline{w}^H . a_o = w_1 e^{-jkdsin\theta_o} + w_2 + w_3 e^{-jkdsin\theta_o} = 0 \quad (15)$$

$$y_2 = \overline{w}^H . a_o = w_1 e^{-jkdsin\theta_o} + w_2 + w_3 e^{-jkdsin\theta_o} = 0 \quad (16)$$

Condition 1 demands that $y_s = 1$ for the desired signal, thus allowing the desired signal to be received without modification. Condition 2 and 3 reject the undesired interfering signal. These conditions can be recast in matrix form as

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$$\overline{w}^H - \overline{A} = U^{-T} \qquad (17)$$

where $\overline{A} = [\overline{a}_o\ \overline{a}_1\ \overline{a}_2]$ = matrix of steering vectors

$\overline{u} = [1\ 0 - - - 0] =$ carterian basis vector

One can invert the matrix to find the required complex weights $w_1, w_2\ and\ w_3$ by using

$$\overline{w}^H = u_1^{-T}.\overline{A}^{-1} \qquad (18)$$

C. *Rake Receiver*

In Code Division Multiple Access (CDMA) spread spectrum systems, the chip rate is typically much greater than the flat fading bandwidth of the channel where as conventional modulation technique require an equalizer to undo the inter symbol interference between adjacent symbols, CDMA spreading code are designed to provide very low correlation between successive chips. Thus, propagation delay spread in the radio channel merely provides multiple versions of the transmitted signal at the receiver. If these multipath components are delayed in time by more than a chip duration, they appear like uncorrelated noise at a CDMA receiver, and equalization is not required.

However, since there is useful information in the multipath components, CDMA receivers may combine the time delayed versions of the original signal transmission in order to improve the signal to noise ratio (SNR) at the receiver. A Rake Receiver does just this. It attempts to collect the time shifted versions of the original signal by providing a separate correlation receiver for each of the multipath signals [10]. Rake receiver, used specially in CDMA1x cellular systems, can combine multipath components which are time delayed versions of the original signal transmission. It is essentially a diversity receiver, where diversity is provided by the fact that multipath components are practically uncorrelated from one another when their relative propagation delays exceed a chip rate .

The Rake receiver consists of a number of branches equal to the multipath components, and each multipath branch is called a finger [11].

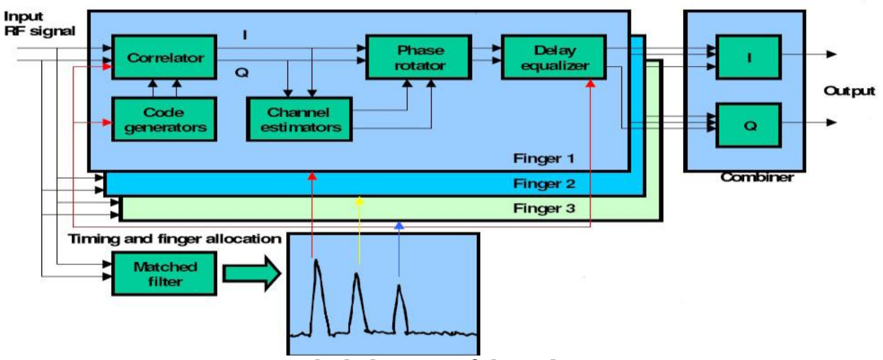

Fig 2. Block diagram of the Rake Receiver

III. RESULT AND ANALYSIS

Table 1: Simulation Parameters

Propagation environment	AWGN channel
Eb/No (in dB)	0.1-1.0
Modulation	QPSK(downlink),BPSK (uplink)
Chip rate	3.84MCPs
Spreading factor	4.256
Channel bit rate	5.76Mbps
Pulse shaping	roll off=0.22
Receiver	Rake

Eb/No (dB)	**BER (without Rake)**
0.1	0.5364
0.2	0.5278
0.3	0.5227
0.4	0.5206
0.5	0.5185
0.6	0.5149
0.7	0.5114
0.8	0.5093
0.9	0.5081
1.0	0.5057

Table 2:Result for CDMA20001X without Rake

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Table 3: Results for CDMA20001x with 1 Rake Rx.

Eb/No (dB)	**BER (Rake)**
0.1	0.489
0.2	0.480
0.3	0.4762
0.4	0.4758
0.5	0.4758
0.6	0.4730
0.7	0.4615
0.8	0.4508
0.9	0.4278
1.0	0.4124

Table 4:Results for CDMA20001x with and without Rake Receivers

Eb/No	**BER (without Rake)**	**BER(with RAKE)**	**BER(2RAKES)**
0.1	0.5364	0.489	0.00184
0.2	0.5278	0.480	0.00183
0.3	0.5227	0.4762	0.001673
0.4	0.5206	0.4758	0.001673
0.5	0.5185	0.4758	0.001673
0.6	0.5149	0.4730	0.001673
0.7	0.5114	0.4615	0.001673
0.8	0.5093	0.4508	0.001673
0.9	0.5081	0.4278	0.000418
1.0	0.5057	0.4124	0.000410

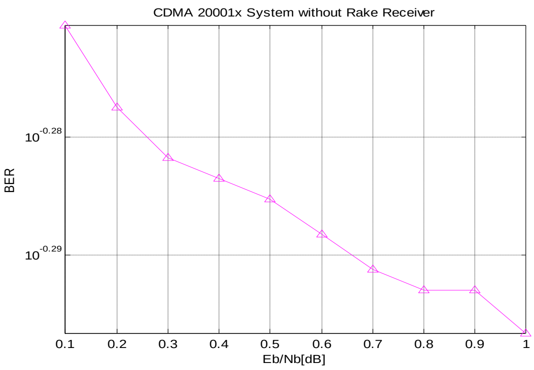

Fig 3: BER Vs Eb/No performance without Rake Receiver

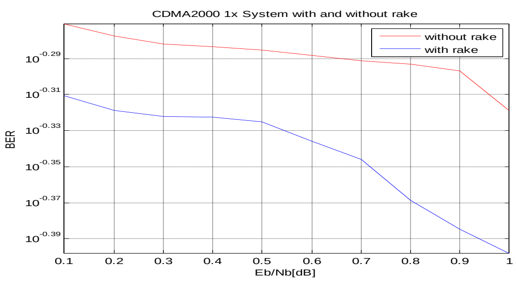

Fig 4:BER Vs Eb/No performance with 1 Rake Receiver

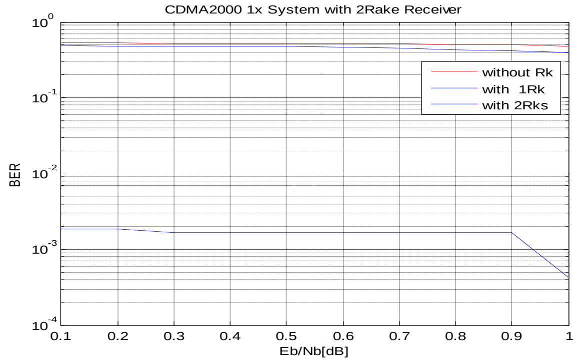

Fig 5: BER Vs Eb/No performance in presence of 2Rake Receivers

A Rake receiver is adopted in the BS as different multipath components arrive at the receiver with time delay and different directions. The diversity combining (MRC) is used to combine the output from each Rake finger.

The simulator estimates BER (Bit error Rate) as a function of channel signal to noise ratio (SNR).

IV. SUMMARY OF RESULTS

The bit error rate at uplink with presence and absence of a Rake receiver in CDMA20001x system as shown in Figure 4 and Figure 3 respectively. As expected the system is interference limited when no rake receiver is present at receiver side. We observed that without any rake receiver techniques, the BER approaches to more than 10% even though Eb/No varied from 0.1 to 1dB. This is not an acceptable performance. However the BER can be pushed back to an acceptable limit with rake receiver techniques. From Figure 4, we observed that there is a significant improvement in the BER in the case with Rake Receiver as compared to that of no Rake Receiver in which the BER does not reduce significantly even with increase in the E_b/N_o.

V. CONCLUSION

We implemented a signal simulator according to the physical layer specification of the IMT 2000 CDMA20001x system. This provides a very useful and easy way to get insight into problems in a CDMA1x system. MATLAB and SIMULINK were used as development tool. Beam forming and the Rake receiver are employed at the receiver. We investigated the Bit Error Rate (BER) in uplink. The BER depends on the channel conditions and the number of rake receiver fingers active. The simulator developed can be an invaluable tool to investigate the performance of the CDMA under various conditions.

REFERENCES

[1] Rappaport T.S. "Wireless Communication Principle and Practice", Prentice hall, 2008.

[2] Tommi Heikkila, "Rake Receiver", post graduate course in radio communications, Autumn 2004.

[3] M.Ali Akbar, Hamza Bin Tila, M. zulkifl Khalid,and Muhammad Asim Ajaz, "Bit Error Rate Improvement using ESPRIT based Beamforming and RAKE receiver'', NUST, 2002.

[4] White paper, "Basic concept of CDMA1x Radio Access Network". ERICSSON, 2004.

[5] Hiroshi Harada and Ramjee Prasad, "Simulation and software radio for mobile communications".Universal personal communications, 2002.

[6] Lee liying, ''BER performance simulation of Rake receiver for CDMA20001xsystem", University technology Malaysia, 2007.

[7] Bengt Holter and Geir E., **"The** optimal weights of a maximum ratio combiner", Norwegian University of Science and Technology, Department of Tele communication, 2009.

[8] Adrian Boukalov, Sven–Gustar Haggman, "System aspects of smart antennas technology in cellular wireless communications", Helsinki University of technology, Finland, 2000.

[9] Vikas C. Raykar, "A study of various Beam forming techniques and implementation of constrained least mean squares (LMS) algorithm for Beam forming". www. uniacs. und.edu.

[10] Frank Gross," Smart Antennas for Wireless Communication", McGraw Hill companies, 2005.

[11] Mosa A., "Introduction to CDMA Wireless Communications", Elsevier publisher, 2007.