BER Analysis to Increase Capacity of A Cellular System Using SDMA Over a Multipath Rayleigh Fading Channel

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***Abstract* --In this paper, we have presented how the capacity of cellular system can be enhanced by using Space Division Multiple Access (SDMA) with directive antenna in mobile communication systems. One of the biggest draw back of wireless environment is the limited bandwidth. However, the users sharing this limited bandwidth have been increased considerably. SDMA is a technology by which the capacity of the existing mobile communication system can economically be increased. Adaptive Antenna provides a spot beam for each users in the cells as it moves. This paper analysis the comparison of average Bit Error Rate (BER) of SDMA and Code Division Multiple Access (CDMA) technique and the way in which SDMA can be introduced to increase the capacity of a cellular system in Frequency Selective Multipath Rayleigh Fading Channel. The BER is found for a standard omni directional base station antenna, and the another set of curve is found for flat top beam having a directivity of 8 dB. We see that SDMA offers improved capacity in wireless communication system.**

***Index Terms* -- BER, Adaptive Antenna, DS-CDMA, Multipath channel , SDMA .**

INTRODUCTION

SDMA [1]-[3] with smart antennas at the base station can increase System capacity and support rate demanding services. Mobile radio communication systems are currently characterized by an ever-growing number of users, which however is Coupled with limited available resources, in particular in terms of usable frequency spectrum. The SDMA technique allows enhancing the capacity of a cellular system by exploiting spatial separation between users.

In an SDMA system, the base station does not transmit the signal throughout the area of the cell, as in the case of conventional access techniques, but rather concentrates power in the direction of the desired mobile unit, and reduces power in the directions where other units are present. The same principle is applied for reception. The SDMA technique can be integrated with different multiple access techniques (FDMA, TDMA, CDMA).

In the last couple of years there has been large activity in the field of SDMA system just applying separate antenna in a Base Station (BS) for sectoring a cell. In most of those works there have been shown the relation between average BER[4]-[5] and Signal to Noise Ratio (SNR), But in this paper the work is done on average BER analysis with the users in SDMA using adaptive antenna for mobile communications in Frequency Selective Multipath Rayleigh Fading channel.

In this paper, we study the bit error rate (BER) performance of an asynchronous DS-CDMA system and SDMA system over a frequency selective multipath Rayleigh fading channel with perfect power control. The standard Gaussian approximation (SGA) is used to evaluate the BER performance for the DS-CDMA. This approximation is the most widely cited and most widely used [6]- [9] because of its simplicity.

Section 1. presents the overview of CDMA. Section 2. gives the introduction of SDMA. The basic concept of Directive Antenna is given in section 3. In section 4. we present the system performance with using CDMA. In section 5. gives the system performance with using SDMA technique that is integrated with CDMA. In section 6. we have the Results. Section 7. gives the conclusion.

1. OVERVIEW OF CDMA

In this section we discuss an asynchronous DS-CDMA [5],[10] system for reverse link (mobile to base station) with Mc interfering cells that supports K active users. The Reverse-link System shown in Fig.1.

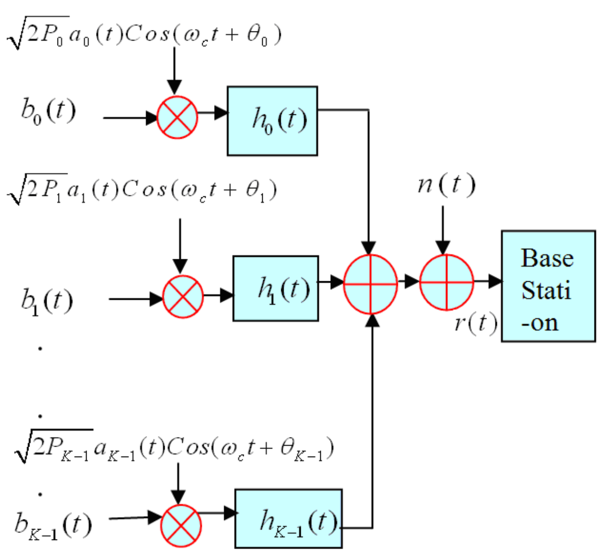

Fig.1. Reverse link system model

Let there are K active users transmitting signals in DS-CDMA system. Each of them transmitting a signal which is described by [5]

$$S_k(t-\tau_k) = \sqrt{2P_k}\, b_k(t-\tau_k) a_k(t-\tau_k) Cos(\omega_c t + \theta_k) \quad (1)$$

Where $b_k(t)$ is binary data sequence, $a_k(t)$ is a pseudorandom sequence, P_k is the power of the transmitted signal, ω_c is the carrier angular frequency, τ_k is the time delay that accounts for the lack of synchronisation between the transmitters and θ_k is the phase angle of the kth carrier. The kth user's data signal is a sequence of unit amplitude rectangular pulse of duration Tb, taking values {-1,+1}.If Tc is the chip period and there are Nc chips per bit thus Nc = Tb / Tc is the spreading factor for user k. Let the desired user is k=0 and all other users contribute to MAI. We assume that channel $h_k(t)$ is multipath Rayleigh frequency selective fading channel. The delay difference between any two different paths is larger than the chip duration Tc. The complex low pass equivalent impulse response of the channel is given by

$$h_k(t) = \sum_{l_k=1}^{L_k} \alpha_{k,l_k} e^{j\phi_{k,l_k}} \delta(t-\tau_{k,l_k}) \quad (2)$$

Where ϕ_{k,l_k} is the phase of the multipath component, τ_{k,l_k} is the path delay, and L_k is the number of multipath components. α_{k,l_k} is magnitude of the l^{th} multipath with Rayleigh distribution. The received signal at the input of the receiver is given by

$$r(t) = \sum_{k=0}^{K-1} \sum_{l_k=1}^{L_k} \sqrt{2P_k}\, \alpha_{k,l_k} b_k(t-\tau_{k,l_k}) \times a_k(t) Cos(t-\tau_{k,l_k}) Cos(\omega_c t + \phi_{k,l_k}) + n(t) \quad (3)$$

Where $n(t)$ is Additive White Gaussian Noise (AWGN) with a two sided power spectral density of $N_0/2$. Where N_0 is the noise power spectral density measured in watts/hertz (joules).

2. OVERVIEW OF SDMA

In SDMA a number of users share the same available resources and are distinguished only in the spatial dimension. In traditional cellular systems the base station radiate the signal in all direction to cover the entire area of the cell, due to this we have both a waste of power and the transmission, in the directions where there are no mobile terminals to reach, of a signal which will be seen as interfering for co-channel cells, i.e. those cells using the same group of radio channels. Analogously, in reception, the antenna picks up signals coming from all directions, including noise and interference. These considerations have lead to the development of the SDMA technique, which is based on deriving and exploiting information on the spatial position of mobile terminals. In particular, the radiation pattern of the base station, both in transmission and reception is adapted to each different user so as to obtain the highest gain in the direction of the mobile user. Thus SDMA is recognized as one of the most useful techniques for improving the capacity of cellular systems. This technique allows different users to be served on the same frequency channel at the same time thus improving the spectral efficiency.

3. DIRECTIVE ANTENNA

This section illustrate how directive antenna can improve the reverse link in a single-cell CDMA system. Fig .2. shows three possible base station antenna configurations.

The omnidirectional receiver antenna will detect signal from all users in the system and thus will receive the greatest amount of noise. The sectored antenna will divide the received noise in to smaller values and will increase the number of users in CDMA system.

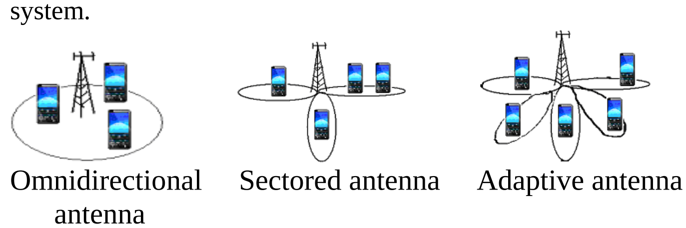

Fig.2. Base Station Antenna Configurations.

Adaptive antenna provides a spot beam for each user and base station tracks each user in the cell as it moves. Assume that beam pattern G(ϕ) is formed such that the pattern has maximum gain in the direction of desired user. It can be seen that the probability of bit error is depend on the beam pattern of a receiver, and there is considerable improvement that is achieved using high gain adaptive antennas at the base station. In this paper we find the probability of error for a flat top beam (a beam with constant gain over a specific angular region) having a directivity of about 8 dB. In typical cellular installations, D ranges between 3dB to10 dB. As the antenna beam pattern is made narrower, D increases, and the received interference decreases proportionally.

4. SYSTEM PERFORMANCE WITH USING CDMA -

For CDMA operating in an Frequency selective Rayleigh Fading and Additive White Gaussian Noise (AWGN) channel, with perfect power control with interference from adjacent cells & with omni directional antennas used at the base station, the average Bit Error Rate, P_e can be found from the Standard Gaussian Approximation as [11]

$$P_e = \frac{1}{2} - \frac{1}{2\sqrt{1 + \frac{N_0}{2E_b} + \frac{2}{3N_c}\left[(1 + \frac{M_c}{5})LK - 1\right]}} \qquad (4)$$

5. SYSTEM PERFORMANCE WITH USING SDMA –

In SDMA technique we use adaptive antenna at base station which has directivity D. In this paper SDMA technique is integrated with Code Division Multiple Access (CDMA) technique. The average Bit Error Rate, $P_e^{'}$ can be given as

$$P_e^{'} = \frac{1}{2} - \frac{1}{2\sqrt{1 + \frac{N_0}{2E_b} + \frac{2}{3DN_c}\left[(1 + \frac{M_c}{5})LK - 1\right]}} \qquad (5)$$

6. RESULTS

6.1 . BER AS A FUNCTION OF NUMBER OF INTERFERING CELLS (Mc)-

Fig.3 shows the comparison between CDMA and SDMA. Here BER is taken as a function of the number of interfering cells (Mc). In this the number of multipaths L=10, the number of interfering cells Mc = [1,4,6], the spreading factor Nc = 84, CDMA system using omni directional base station antenna has directivity D= 0dB, SDMA system using adaptive base station antenna has directivity D = 8 dB, signal to noise ratio Eb/N0= 20 dB. At the BER value of 10^{-1}, and Mc = 4, flat top beam having directivity 8 dB will support 25 users, whereas the omni-directional antenna will support only 5 users.

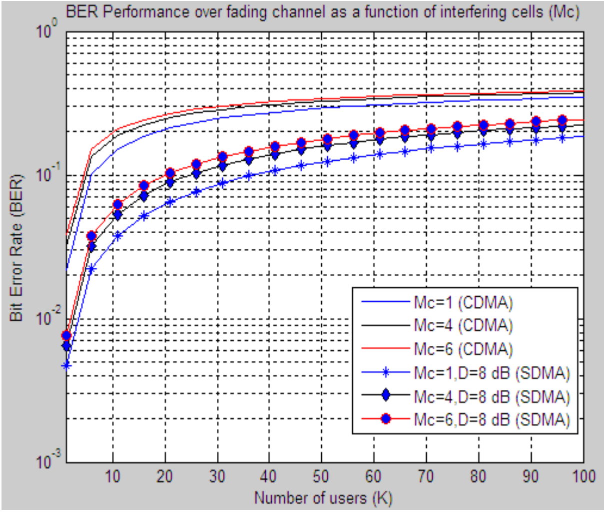

Fig.3 BER as a function of interfering cells (Mc)

6.2 . BER AS A FUNCTION OF NUMBER OF MULTI PATHS (L) –

Fig.4 shows the comparison between CDMA and SDMA. Here BER is taken as a function of the number of multipaths (L). In this the number of multipaths L= [3,5,10], the number of interfering cells Mc=4, the spreading factor Nc=84, adaptive base station antenna has directivity D= 8dB, signal to noise ratio Eb/N0 = 20dB. At the BER value of 10^{-1}, and L=5, Adaptive antenna having directivity D=8dB will support 50 users, whereas the omni-directional antenna will support only 8 users. Thus we see that using SDMA technique capacity of the communication system will increase.

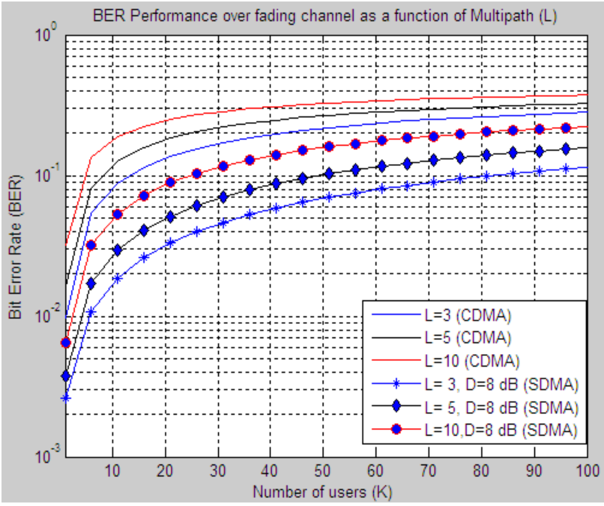

Fig.4 BER as a function of multipaths (L) .

6.3 . BER AS A FUNCTION OF SPREADING FACTOR (Nc) –

Fig.5 shows the comparison between CDMA and SDMA. Here BER is taken as a function of the spreading factor (Nc). In this the number of multipaths L=10, the number of interfering cells Mc=4, the spreading factor Nc= [32, 84, 128], adaptive base station antenna has directivity D = 8 dB, signal to noise ratio Eb/N0 = 20 dB. At the BER value of 10^{-1}, and Nc= 84, Adaptive antenna having directivity 8dB will support 25 users, whereas the omni-directional antenna will support only 5 users. Thus we can say that capacity of wireless communication system will increase by using SDMA technique.

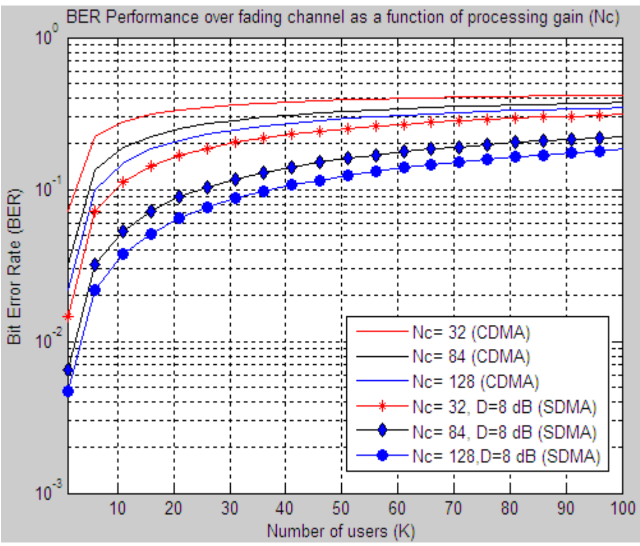

Fig.5 BER as a function of Spreading Factor (Nc)

6.4. BER AS A FUNCTION OF SINGAL TO NOISE RATIO (Eb/N0) –

Fig.6 shows the comparison between CDMA and SDMA. Here BER is taken as a function of Signal to Noise Ratio (Eb/N0). In this the number of multipaths L=10, the number of interfering cells Mc=4, the spreading factor Nc=84, adaptive base station antenna having directivity D=8 dB, number of users K=7. At the BER value of $10^{-0.8}$, Adaptive antenna with directivity 8 dB has 8 dB advantage as compared to omni-directional antenna.

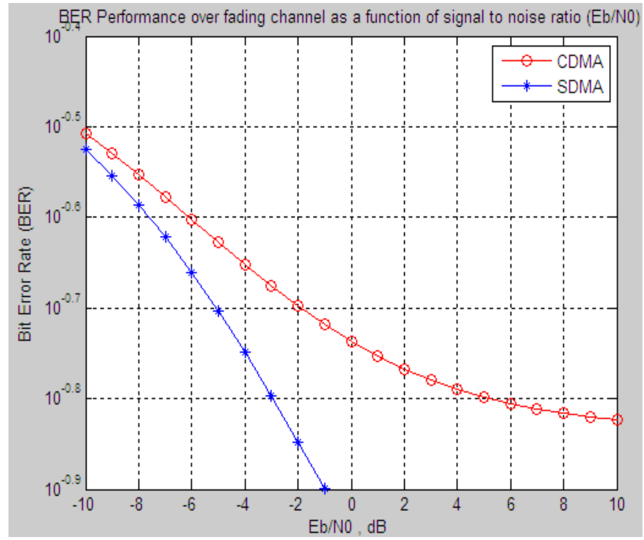

Fig.6 BER as a function of signal to noise ratio (Eb/N0).

7. CONCLUSION

For the figures 3,4,5, one set of probability of error is found for a standard omni directional base station antenna, and another set of curve is found for a flat top beam (a constant gain over a specific angular region) having a directivity of 8 dB. At the BER value of 10^{-1}, Adaptive antenna having directivity 8 dB will support the number of users that are greater than the number of users which are supported by omni-directional antenna. This increase the number of user is roughly equal to the directivity offered by the flat top beam system, and illustrates the promise SDMA offers for improving capacity in wireless communication system. Here we consider the channel is frequency selective Rayleigh fading channel.

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