

PERFORMANCE ANALYSIS OF
A WIRELESS COMMUNICATION SYSTEM WITH
SMART ANTENNA

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DECLARATION

We, Andre Sarker and Hamim Al-ahsan hereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researcher are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

for Andre
12/8/10
Signature of
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Abstract

Analysis will be carried out for wireless communication links considering an smart antenna to combat the effect of multi path fading. The beam forming of the smart antennae will be optimized to have the highest signal to noise ratio(SNR) at the receivers output in presence of fading. The analysis will be carried out to find out the SNR and BER performance. Results will be evaluated by numeric computation of various beam forming techniques and optimum system design parameters will be determined.

Objective

Smart antennas are a modern technology for wireless systems that use a fixed set of antenna elements. Using smart antenna the performance of a particular system can be improved as the signals from the antenna elements are combined using a signal processor, processed, and then is fed to the output to get the optimized desired signal. This thesis intends to explore this technology comprehensively, focusing on the beam forming mechanism and criteria. Moreover the objective of this thesis is also to investigate the effect of beam forming on CDMA System

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Introduction

Modern communication system has many attributes. Some of these attributes are exploited and implemented to enhance the convenience. However some of the capabilities are constrained by the lack of technology and they are rarely brought out of the laboratory. For instance factors like noise, multi-path reception and fading and other factors are huge constrains to modern wireless communication. Due to this, wireless communication is suffering from less number of channel in a specific cell, interference, high SNR, lack of control channels etc and it has been a constant effort of the engineers and scientists to do away with this sort of limitation.. They are in constant search for better DSP(digital signal processing) schemes, smarter digital protocols, efficient algorithms and obviously hi-tech equipments such as antennas which would calibrate the existing systems such as CDMA, MC-CDMA, FDMA etc to a higher degree of performance.

Antenna happens to be the most significant part of a wireless communication system. Both transmission and receptions are dependent on the types and efficiency of antennae. The antennas have their individual directions constant that they can only receive from or transmit to that direction. However signals come from all the directions but due to the directional limitations, antennas can not intercept all of the signals together and this leads to the inefficiency of the system. This calls for compensations and takes the form of installations of multiple antennae which in turn adds to the cost of the existing system. For instance, the installation of multiple GSM antennae in the BTS and base stations is a very common scenario. Still when the cost is considered with the in-capabilities of overcoming the mentioned constrains, a huge improvement is desired. Consequently “Smart Antennae” happens to be a very promising solution.

This paper happens to explore various aspect of smart antenna. It conspires of a literature about the system and analysis of various aspects. Special focus is given on beam forming

mechanisms and criteria. Evaluation of those criteria will be carried out in terms of numeric computation in terms of parameters such as weight, interference, bandwidth, noise.. Moreover, a study on implementation of this smart antenna system on Code Division Multiple Access that mainly focuses on modification of existing SNR and BER criteria, when smart antenna system is implemented on it. For scope of simplicity of these deductions several assumptions were considered on numeric computations and those will be discussed in details.

CHAPTER 1

Introduction to Smart Antenna

1.1 What is a smart antenna?

To understand the smart antennae let us go in the navigation system of a bat. Bat which happens to be a nocturnal creature, is incapable of vision and it steers itself through out its flight by “hearing’ that is by sound wave. Suppose a bat is to overcome some obstacle. In order to do so, it sends a high frequency signal towards the obstacle, which is in turn reflected and received by the auditory sensor, the ear. The brain will interpret the signal by adding extra information and the bat is capable of sensing the obstacle. Now lets say the bat has encountered another entity. The ear can receive that too and the brain is actually capable of filtering out the priority i.e. which one to confront at first.

Smart antennae are actually capable of such function. By using many antennas instead of two ears and a digital signal processor instead of brain, the smart antenna systems work in a similar way. It receives signal from all direction. Once the signal is received the processing algorithm adds extra information to it making it optimized and that signal contains the highest power. Also it can choose between the signals i.e. which signal to receive. This criterion makes it an ideal solution for compensating factors like delay spread, co-channel interference, multi path fading and system complexity.

In general smart antenna consists of a uniform linear antenna array for which the current amplitudes are adjusted by a set of complex weights using an adaptive beam forming algorithm. The adaptive beam forming algorithm optimizes the array output beam pattern such that maximum radiated power is produced in the directions of desired mobile users and deep nulls are generated in the directions of undesired signals representing co-

channel interference from mobile users in adjacent cells. Prior to adaptive beam forming, the directions of users and interferes must be obtained using a direction-of arrival estimation algorithm. This adaptive algorithm is embedded in the beam-forming module. The block diagram representation of a generalized smart antenna system is shown in the diagram below.

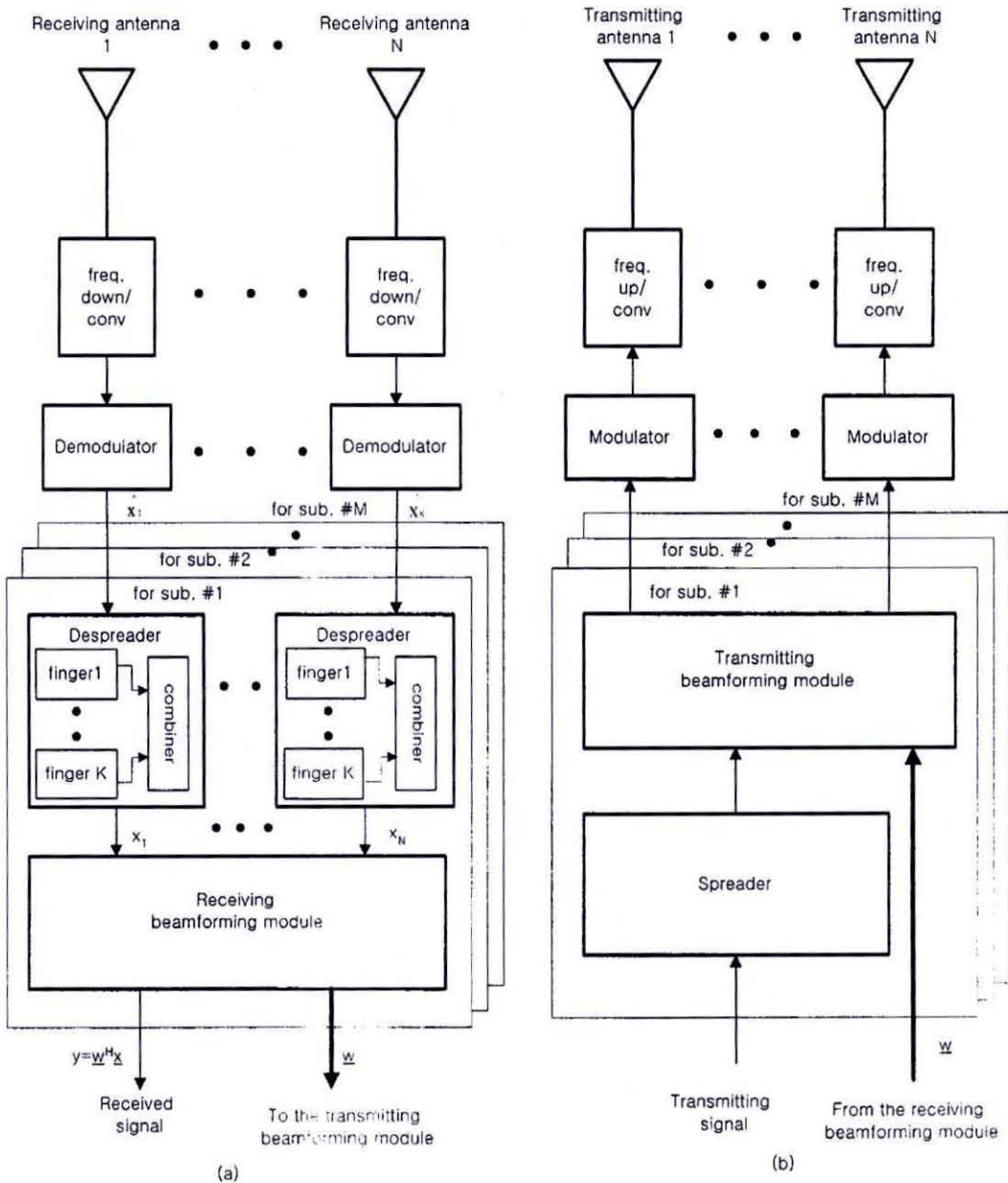


Fig.1.1. Block Representation of a smart antennae system

1.2 Why smart antennae?

The most challenging matter of wireless communication is the cell capacity. As the user is increasing the allocated bandwidth to a certain service providers is failing to support this huge number of user. Smart antennae when used appropriately, is capable of increasing cell capacity and spectral efficiency and improves signal quality by electronic compensation methods(feedback mechanism).the smart antennae has a mechanism of forming beams in some directions and voids in other, which accounts for the fact that it can decide the desired signal. By this criterion the smart antenna system also decreases delay spreads, multipath fading, co-channel interference, system complexities and bit error rate. In transmission modes, the smart antennae focus energy in specific direction which results in the reduction of multi path reflection and delay spreads. In receiving mode the smart antennae can compensate for the faded signal by adding extra signal from other clusters. Beside it increases spectral efficiency by canceling delayed signal.

Now, in order to perform these automated functions, the antennae array has to be equipped with prior knowledge of the type of signal and the direction of its source to achieve its desired objectives. There are many ways and algorithms to do these i.e. to update the antennae by the whereabouts of the signal source, speed of convergence and divergence and processing time

How smart antennae can reduce delay spread and co-channel interference?

Delay spread takes place when desired signal, arriving from different direction becomes delayed due to different direction traveled.. This delay spread would be reduced by using smart antenna arrays that are capable of forming beam in certain directions and null in other hence canceling the arrived signal with delay

Another important feature of the smart antenna happens to be co-channel interference minimization by forming a directive beam in the direction of the desired signal and nullity in the direction of the other receiver. Co-channel interference in the receiver side

is reduced by knowing the directional location of the signal source and the interference cancellation is utilized.

1.3 Types of Smart antenna

Smart antenna systems are categorized into two types: (i) Switched beam (ii) Adaptive array.

The switch beam method.

Switched beam system is a modified version of cell sectoring. In which each sectorized cell is composed of three 120-degree macro-sectors. Here, the macro-sectors are further sub-divided into micro-sectors. The system assigns a certain number of predefined beam patterns with the greatest gain. Usually the processor of the system makes a choice so as to prioritize them during operation. When a mobile user arrives in the macro cell in which the smart antennae system is deployed, the smart antenna chooses the beam with greatest gain and uses that to monitor the signal strength and executes the communication process. It, however, may switch to other micro cells for compensation if the received signal is not adequate. This method tends to increase the capacity from 20 to 200 percent depending on the circumstantial scenario.

However there are some drawbacks in this method. Since the signal is pre-set, the signal intensity varies as the mobile unit roams in the micro cell. As the unit goes at the edge of the beam, the signal quality degrades rapidly before it can switch to other micro cell. This might give a delayed hand off situation compared to the other existing system. Moreover the switch beam method cannot choose between the desired signals. To compensate this method another method is used which is called adaptive array method

Adaptive array method

This is somewhat of a more advanced method. This method can customize the beam pattern according to the registry of the location of the mobile unit. As the mobile unit inside a cell the advanced processor of the antennae is constantly updated about the weights of the signal and then it is multiplied to the receiving or transmitting array element of the system. Since the system can renovate signal pattern according to the mobile unit, it can directly focus on the unit and hence it can enhance the signal capacity of the system. Another method for increasing capacity is the ability of choosing and canceling signal. It performs this by directing the main lobes of the beam pattern directly to the mobile unit and null to the other signal. This accounts for the fact that smart antennae can choose between the signal and cancel out the others. This is a great mechanism to increase the networking capacity of the system.

1.4 Comparing Switched beam method with Adaptive array method

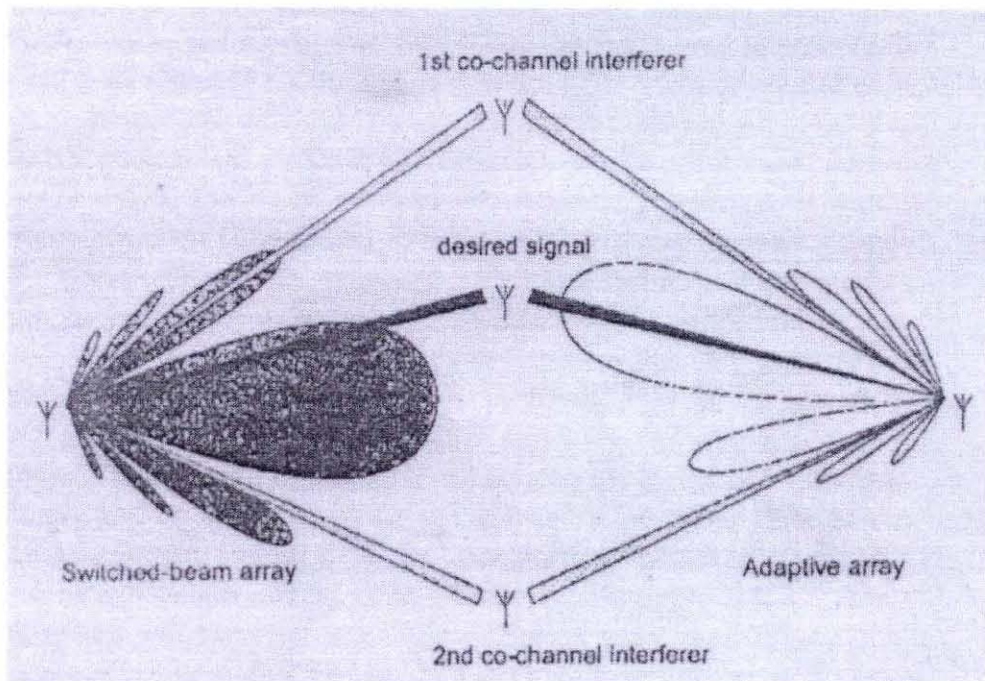


Fig.1.2. The beam forming lobes and nulls that switched-beam(left) and adaptive array(right) systems might choose for identical user signals and co-channel interferers.

Hence, we can conclude that the adaptive system offers optimal gain, while at the same time identifying, tracking and minimizing interfering signals. In other words, adaptive system provides substantial performance advantages and flexibility over the passive switch-beam system. Fig2 above shows that the beam patterns of the systems, where the switch beam is shown on the left and the adaptive array on the right. Both systems direct their major lobe in the general direction of the signal of interest, but the adaptive system chose a more accurate placement. Moreover the interfering signals receive maximum suppression, whereas in switched beam, the interfering signals arrive at places of the lower gain outside the main lobe.

Beam forming

2.1 Introduction

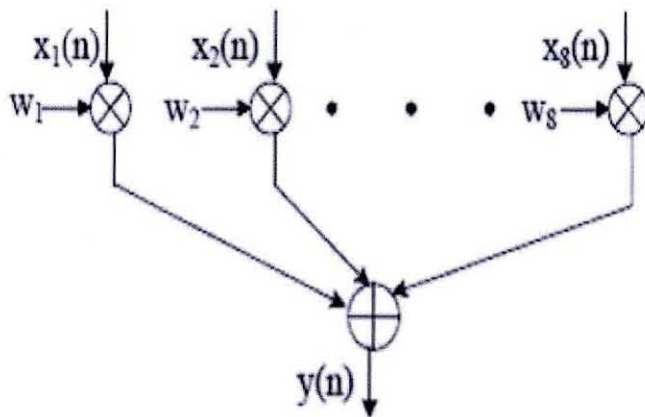


Fig 2.1. The block diagram of a beam forming scheme

Beam forming is an advanced signal processing method which when applied to the antennae array (both transmitter and receiver) is capable of controlling the directionality and sensitivity of a particular radiation pattern. A smart antenna follows some specific methods during beam formation. The block diagram above represents the method of beam formation.

A simple beam forming mechanism involves the multiplication of all the array outputs with a similar gain. This scheme provide the largest output SNR provided that there is nothing that tends to jam the signal. The fact that the smart antennae can direct its null in the direction of unwanted signal and cancel those, makes the system appropriate to low level interference cancellation but this scheme becomes vulnerable when strong level of

interference is concerned. Then the efficiency is increased by adjusting the gain with which the array outputs are multiplied. There are actually a couple of sophisticated schemes in order to achieve these which are left for further research.

2.2 Signal model:

Considering an array antenna of L isotropic elements, as shown in Fig3 below and assuming that the array is receiving M uncorrelated sinusoidal point sources, of

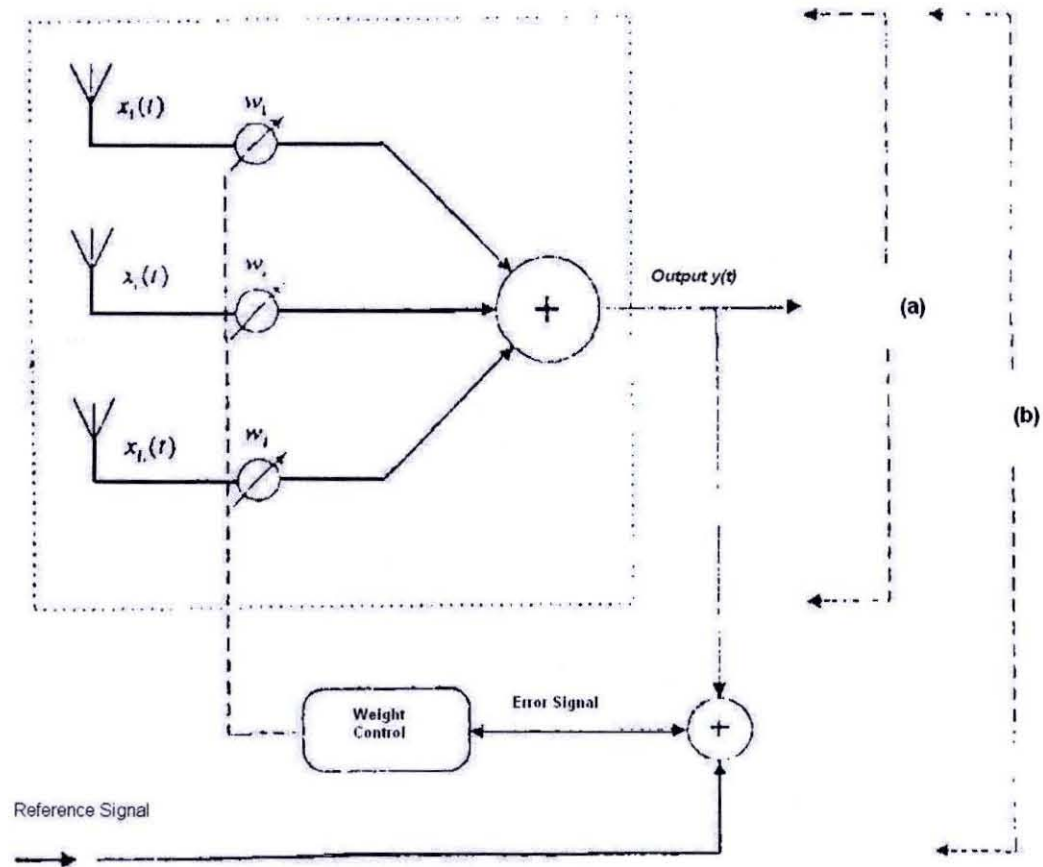


Fig.2.2. The structure of a narrow-band beam-former (a) without and (b) with a reference signal

frequency f_0 . A plane wave, radiated from the i th source direction (φ_i, θ_i) , arrives at the i th element of the array after time

$$\tau_l(\varphi_i, \theta_i) = \frac{\bar{r}_l \cdot \hat{a}(\varphi_i, \theta_i)}{c} \quad (2.1)$$

where \bar{r}_l is the position vector of the l th element, $\hat{a}(\varphi_i, \theta_i)$ is the unit vector in the direction (φ_i, θ_i) , and c is the speed of propagation of the plane wave front. For a linear equi-spaced array, aligned with the x -axis such that the first element is situated at the origin, this becomes

$$\tau_l(\theta_i) = \frac{d}{c} (l-1) \cos \theta_i, \quad (2.2)$$

where d is the inter-element distance. The signal induced on the reference element due to the i th source is normally expressed in complex notation as

$$m_i(t) \exp(j2\pi f_0 t) \quad (2.3)$$

Assuming that the plane wave on the l th element arrives $\tau_l(\varphi_i, \theta_i)$ seconds before it arrives at the reference element, the signal induced on the l th element due to the i th source can be expressed as

$$m_i(t) \exp\{j2\pi f_0 [t + \tau_l(\varphi_i, \theta_i)]\} \quad (2.4)$$

Assuming the signal is narrow enough for modulating function to stay almost constant during $\tau_l(\varphi_i, \theta_i)$ seconds, that is, the approximation

$$m_i(t) = m_i[t + \tau_l(\varphi_i, \theta_i)] \text{ holds. } \theta_i, \varphi_i$$

Let x_l denote the total signal induced due to all all M directional sources and background noise on the l th element. Then, it is given by

$$x_l = \sum_{i=1}^M m_i(t) \exp\{j2\pi f_0 [t + \tau_l(\varphi_i, \theta_i)]\} + n_l(t) \quad (2.5)$$

where $n_l(t)$ is the random-noise component on the l th element, which includes background noise and electronic noise generated in the l th channel. It is assumed to be temporally white, with zero mean and variance equal to σ_n^2 .

Consider a narrow-band beam-former, shown in the figure a, where signals from each element are multiplied by a complex weight, and summed the array output. It follows from the figure that an expression for the array output can be given by

$$y(t) = \sum_{l=1}^L w_l^* x_l(t) \quad (2.6)$$

where $*$ represents complex conjugate.

2.3 SNR analysis

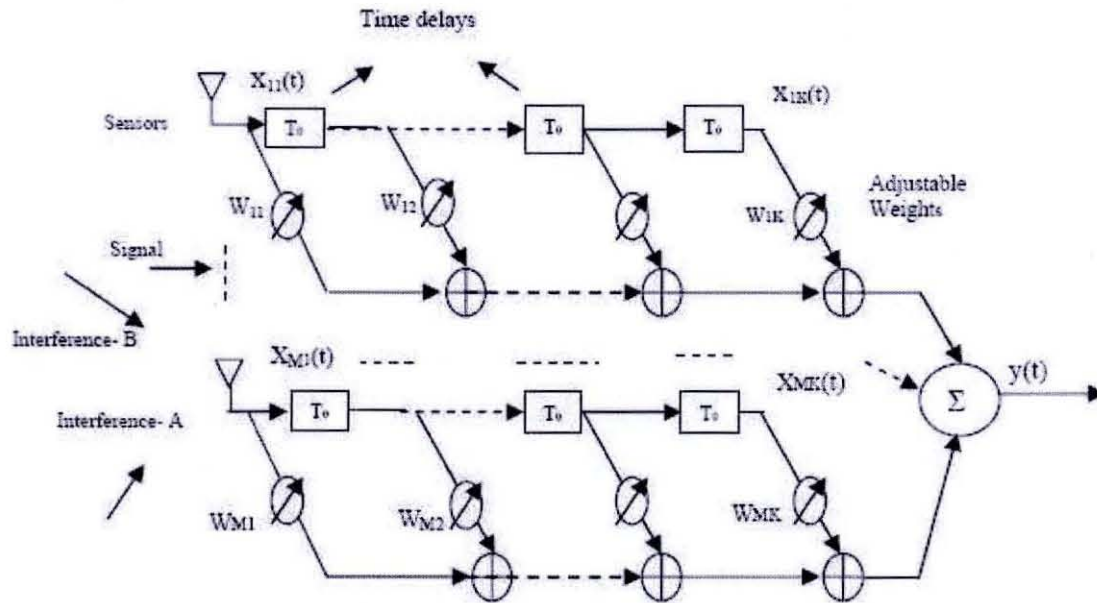


Fig 2.3 Smart antenna for interference mitigation

We consider a linear array of M elements as shown in Fig.4. We assume elements are omni directional and one wavelength apart. Each element is followed by K taps and a delay of T_0 seconds between taps. The continuous time signal received by the m -th sensor at the k -th tap is designated as $x_{mk}(t)$. The output of the first tap behind each element is the signal itself with no delay. These signals are multiplied by w_{mk} real weights and then combined to produce the array output $y(t)$. Let X_m and W_m be the column vectors containing the signals and weights at the k taps behind element m then,

$$X_m = [x_{m1}(t) \ x_{m2}(t) \ \dots \ x_{mK}(t)]^T \quad (2.7)$$

$$W_m = [w_{m1} \ w_{m2} \ \dots \ w_{mK}]^T \quad (2.8)$$

The subscript T denotes transpose. The array receives a desired signal interference signals and an uncorrelated thermal noise. The signal $x_{mk}(t)$ may be written as

$$x_{mk}(t) = d_{mk}(t) + i_{mk}(t) + n_{mk}(t) \quad (2.9)$$

where $d_{mk}(t)$, $i_{mk}(t)$ and $n_{mk}(t)$ are the desired, interference and noise components.

Let X and W are the total signal and weight vectors for the entire array are

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_M \end{bmatrix} \quad (2.10)$$

$$W = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_M \end{bmatrix} \quad (2.11)$$

The element signal vector X_m and the total signal vector X may be split in a similar way as (2.9)

$$X_m = X_{dm} + X_{im} + X_{nm}, \quad (2.12)$$

$$X = X_d + X_i + X_n. \quad (2.13)$$

Suppose the desired signal arrives from angle θ_d , $d(t)$ is the waveform on element 1, then the desired signal at an arbitrary tap is

$$d_{mk}(t) = d(t - [k-1]T_0 - [m-1]T_d) \quad (2.14)$$

where T_d is the desired signal spatial propagation delay between elements,

$$T_d = \frac{d}{c} \sin \theta_d, \quad (2.15)$$

d is the distance between elements and c is the speed of light. Next, the interference signal arrives from angle θ_i and produce waveform $i(t)$ on element 1. The interference signal at an arbitrary tap is then

$$i_{mk}(t) = i(t - [k-1]T_0 - [m-1]T_i), \quad (2.16)$$

$$T_i = \frac{d}{c} \sin \theta_i \quad (2.17)$$

Thus the output signal $y(t)$ is considered to be

$$y(t) = W^T X = W^T (X_d + X_i + X_n) \quad (2.18)$$

Using equation (2.18) the expected power of the array is

$$E[y^2(t)] = E[W^T X X^T W] = W^T R W, \quad (2.19)$$

where $R = E[XX^T]$ is the covariance matrix of the received signal. We are interested in finding the optimal weights of the antenna such that it maintains specified look direction frequency response and cancels the interference. To keep this condition on the array we define constraint matrix C of the $MK \times K$ dimension. This constraint matrix makes the

weights on the j^{th} vertical column of taps to a chosen number f_i , is expressed by $C^T W = F$ where

$$C = \begin{bmatrix} I \\ I \end{bmatrix}, \quad \text{and} \quad F = \begin{bmatrix} f_1 \\ f_k \end{bmatrix} \quad (2.20)$$

I is the $K \times K$ identity matrix and F specifies the frequency response of the beam former in the look direction. The beam-forming problem can be formulated as follows

$$\min_W W^T R W \quad (2.21a)$$

$$\text{subject to } C^T W = F, \quad (2.21b)$$

The solution to the above problem can be established by adjoining the constraint to the cost function by a J -dimensional vector of undetermined Lagrange multipliers λ as

$$H(w) = \frac{1}{2} W^T R W + \lambda^T (C^T W - F), \quad (2.22)$$

Taking gradient of (2.22) with respect to W and equating it to zero we can obtain optimal weights as

$$W_{opt} = R^{-1} C (C^T R^{-1} C)^{-1} F \quad (2.23)$$

R is the sum of desired, interference, and thermal noise terms,

$$R = R_d + R_i + R_n, \quad (2.24)$$

R_d can be represented in a partitioned form as

$$R_d = E[X_d^* X_d^T] = \begin{pmatrix} R_{d_{11}} & \dots & R_{d_{1M}} \\ \vdots & \ddots & \vdots \\ R_{d_{M1}} & \dots & R_{d_{MM}} \end{pmatrix} \quad (2.25)$$

where each submatrix R_d is a $K \times K$ covariance matrix associated with a pair of element signal vectors X_{d_m} and X_{d_n}

$$R_{d_{mn}} = E[X_{d_m}^* X_{d_n}^T] \quad (2.26)$$

$R_{d_{mn}}$ may be found by substituting $d_{mk}(t)$ of (2.14) into (2.26). The jk^{th} term of $R_{d_{mn}}$ is

$$[R_{d_{mn}}]_{jk} = R_d[(j-k)T_0 + (m-n)T_d], \quad (2.27)$$

$R_d(\tau) = E[d^*(t)d(t+\tau)]$ is the auto correlation term of $d(t)$ can also be given by

$$\begin{aligned} R_d(\tau) &= \frac{1}{2} \int_{-\infty}^{\infty} \Gamma^2(\omega) e^{j\omega\tau} d\omega \\ &= \frac{1}{2\pi I_0^3} \int_{-\infty}^{\infty} \omega^4 \exp(-\frac{1}{I_0}(\omega^2 - j\omega\tau I_0)) d\omega, \end{aligned}$$

using the result of

$$\begin{aligned} E[x^4] &= E[\{(x - \mu) + \mu\}^4] \\ &= E[(x - \mu)^4] + 4\mu E[(x - \mu)^3] \end{aligned}$$

$$+6\mu 2E[(x - \mu)^2] \\ +4\mu 3E[(x - \mu)] + \mu^4$$

where $\mu = E[x]$

$R_d(\tau)$ is calculated as

$$R_d(\tau) = \frac{\exp(-\frac{1}{4}I_0\tau^2)}{8\sqrt{\pi}} \left[\frac{3}{\sqrt{I_0}} - 3\tau^2\sqrt{I_0} + \tau^4\frac{(I_0)^{\frac{3}{2}}}{4} \right] \quad (2.28)$$

where $I_0 = 16\pi\Delta f^2$

$R_d(0) = \frac{3}{32\pi\Delta f^2}$ gives average power per element of the pulses with power spectral density of $S_d(\omega)$.

$$S_d(\omega) = Ft\{R_d(\tau)\} \quad (2.29)$$

where Ft stands for Fourier transform of $R_d(\tau)$.

Hence, the signal power is

$$P_{sig} = \int_{-\infty}^{\infty} |S_d(\omega)|^2 d\omega \quad (2.30)$$

$$P_n = \frac{N_0}{2} BW \quad (2.31)$$

where $\frac{N_0}{2}$ is the noise power spectral density and BW is the bandwidth of the desired signal.

From these formulas we can calculate the output SNR. Finally, the output SNR is given by

$$SNR = \frac{P_{sig}}{P_n} \quad (2.32)$$

$$\left(\frac{S}{N}\right)_{dB} = 10 \log_{10}(SNR) \quad (2.33)$$

2.4 Further Beam-forming techniques

Conventional beam-former: This is the simplest form of beam former in which all the weights are of equal magnitudes and it has unity response in the direction of the beam, i.e. the mean output power of the processor is same as the source power

Null steering beam-former: This can cancel a plane wave arriving from a known direction creating a null in the response pattern in that respective direction. Therefore the technique assists in multiple interference cancellation.

Optimal beam-former: The method is irrespective of direction and power levels of interferers. In this method the weights are computed assuming all sources are interference. Thus minimizes the total output noise, keeping the output signal constant.

Broadband beam forming schemes: Where the signal bandwidth increases a narrow beam-forming scheme cannot perform well. This is where broadband beam-forming is used.

Frequency domain beam forming scheme: here the broadband signals from elements is converted to frequency domain using FFT and each frequency is processed by a narrow band processor structure. The weighted signals from the elements are combined to produce the output.

Digital beam forming: The weighted signals from each elements are sampled and stored and beams are formed by the summation of appropriate samples so that the required is included in the process. Here the array signals must be sampled at much higher rates than that required by the Nyquist Criteria to re construct the wave form back from the samples

CHAPTER 3

Implementation of Beam forming in CDMA System

3.1 Background

Code division multiple access or CDMA system is one of the primitive and also traditional standards used in communication links. Standards like this actually built the base of the wireless communications and admittedly these are standards that other systems such as TDMA, FDMA are inspired from. For simplicity and world wide acceptability this systems became popular not for voice communication only but also for data communications such as in Wi Fi and Wi-max systems. However that lead to a intense use of it. As the number of user increased the systems was facing various constrains and eventually became more vulnerable to inference and noises. As a result other technologies outsmarted CDMA. However spontaneous modifications are constantly be carried out in other to combat the backwardness of the design implementations. Now in the modern era the CDMA system is merged with most advanced technologies so as to receive and transmit with maximum efficiency.

3.2 Introduction

The following block diagram represents a CDMA system

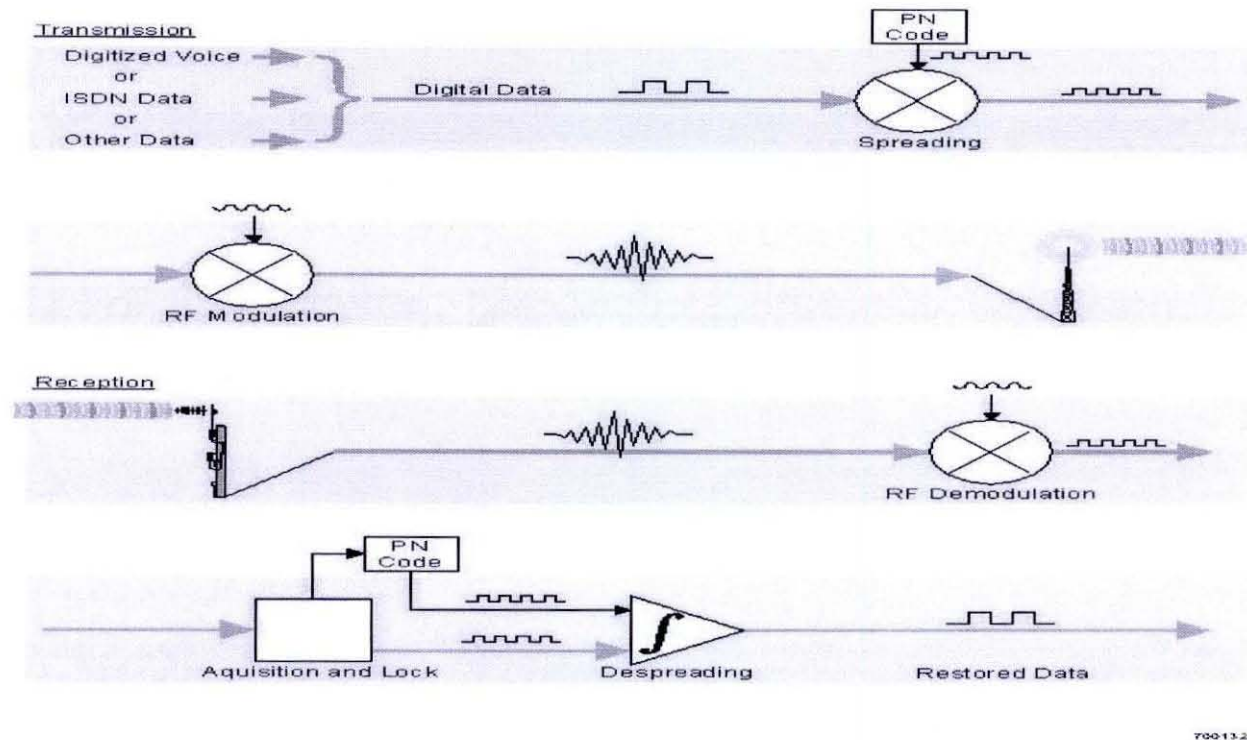
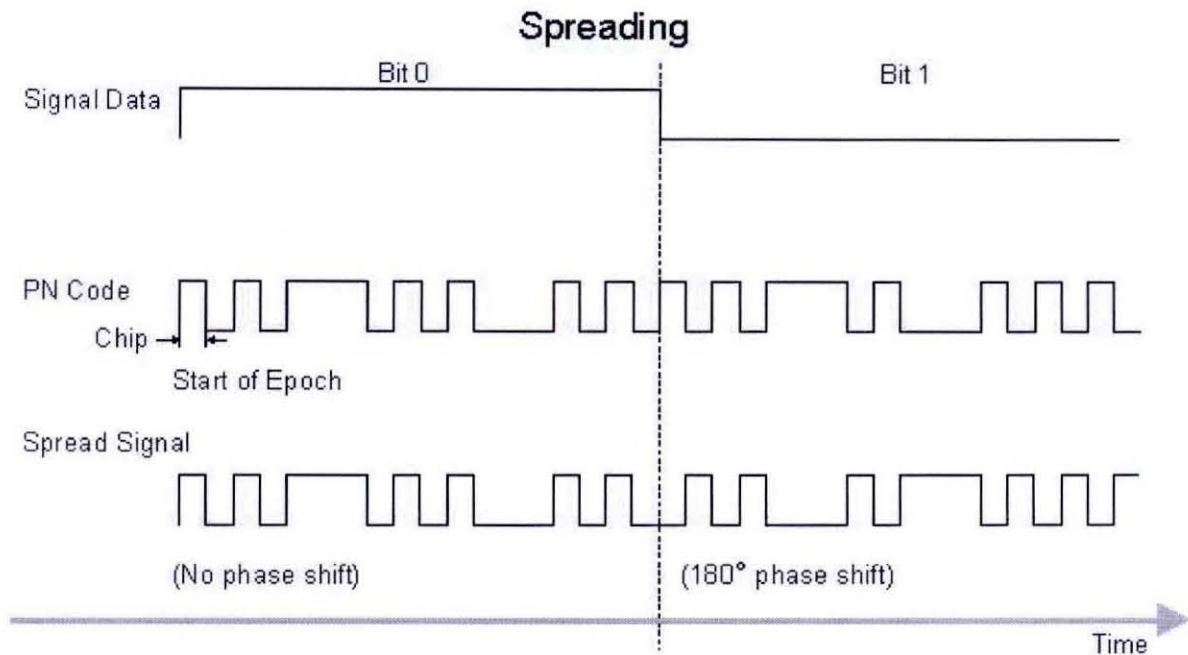


Fig 3.1. Representation of a simple CDMA system

As shown in the block diagram above the, the system involve multiplying the digitized digital signal with a series of random codes. The codes in turn are the are quantized values of very small square pulse the multiplication process is known as spreading. Later the spread signal is multiplied with a signal of very high frequency which is normally know as modulation. In the reception side the modulated signal is demodulated and de-spread thus extracting the original digital SIGNAL over reception side.

3.3 Spreading

The following diagram shows the spreading procedure



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Fig.3.2. Spreading sequence

As mentioned in the earlier section, the digital signal is multiplied with quantized value of short square pulses commonly known as chips and the corresponding quantized bits are known as codes. The chips are generated in random that accounts for the uniqueness of every signal.

3.4 De-spreading

This is the method of extracting the multiplied code or chips from the transmitted signal. What happens is the signal is multiplied with the conjugate of the previously multiplied code at the receiver's end

3.5 Implementation of Beam Forming

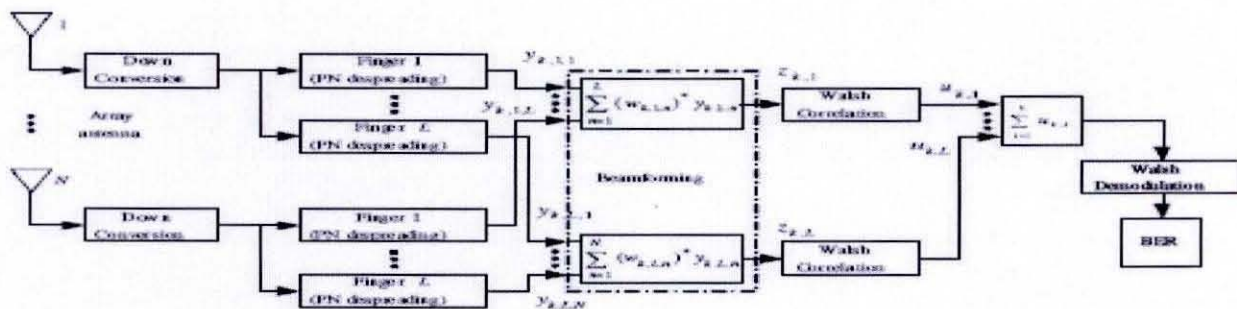


Fig.3.3. Modification by applying beam forming

The above diagram shows a reception side of a CDMA system merged with the beam forming algorithm. As shown in the figure, before the beam forming block, the system is a simple CDMA reception side. The PN de-spreader extracts all the multiplied codes in the signal. The main smart phenomenon occurs in the beam forming block. as discussed in the beam forming section the beam former is already fed with a reference signal which is considered to be the most optimum. Now as being shown in the figure the signals from different channels are fed into the beam forming block.. then it is being multiplied with optimum weight matrix (shown in the Beam forming section) until the most optimum signal is achieved. Then it is fed in the demodulating section and to the signal processor. If compared with the statistics of other systems it will be seen that the system has a better BER and SNR performance that those do not degrade with the increasing number of users

3.6 SNR Calculation for smart antenna 3-G CDMA system

$$\rho = \frac{\gamma}{\frac{1}{N} + \frac{2\gamma}{3N_c} [(L-1) + \alpha_0(K - \kappa - 1) + \upsilon \kappa L]} \quad (3.1)$$

where average $\frac{E_b}{N_0}$ of each multipath is $\gamma = \frac{\Omega E_s}{L N_0} = \log_2(M) \frac{\Omega E_b}{L N_0}$

υ = Correction factor for in-beam interferer

$\Omega_{\kappa,l}$ = Power of the l th path of the κ th user.

L = Number of multipaths per user

E_s = Signal energy

E_b = Bit energy

N_0 = Noise power spectral density

K = Number of users

N = Number of antenna elements

3.7 BER analysis of Smart Antenna

For the case of Rayleigh fading, the mean BER for a conventional one-dimensional Rake receiver (i.e., single antenna beam forming) with L -fold multipath diversity is given by

$$P_b^{1-D} = \frac{M/2}{M-1} \sum_{m=1}^{M-1} \binom{M-1}{m} \frac{(-1)^{m+1}}{(1+m+m\rho)^L} \sum_{l=0}^{m(L-1)} C_l(m) \binom{L+l-1}{l} \left(\frac{1+\rho}{1+m+m\rho} \right)^l \quad (3.2)$$

where, $\rho = \frac{\Omega E_s}{L 2\sigma_v^2} = \frac{\gamma}{1 + \frac{2}{2N_c} \gamma(KL-1)}$

$\Omega_{\kappa,l}$ = Power of the l th path of the κ th user

N_c = Spreading gain, considered to be 256 for an un-coded IS-CDMA system(2G) with alphabet size $M=64$

$$C_l(m) = \begin{cases} \frac{1}{l} \sum_{q=1}^l \binom{l}{q} [(m+l)q-1] C_{l-q}(m); l \leq L-1, \\ \frac{1}{l} \sum_{q=1}^{L-1} \binom{l}{q} [(m+l)q-1] C_{l-q}(m); l \geq L-1. \end{cases}$$

Using the above model, the average bit error probability of a 2-Dimensional RAKE receiver is given by,

$$P_b^{2-D} = \sum_{\kappa=0}^{K-1} \chi \xi^{\kappa} \binom{K-1}{\kappa} P_b^{1-D} \quad (3.3)$$

where P_b^{1-D} is independent of number of antenna elements since ($N=1$) and the mean average BER for 1-D antenna receiver is considered 0.00197305166(refer to the table below)

Eb/No (dB)	SNR (dB)	Drops	Total bits	Total Err.	Mean BER
0	-22.321	50	3.6e+006	36359	1.0100e-002
5	-17.321	50	3.6e+006	2805	7.7917e-004
10	-12.321	50	3.6e+006	466	1.2944e-004
15	-7.3215	50	3.6e+006	260	7.2222e-005
20	-2.3215	50	3.6e+006	199	5.5278e-005
25	+2.6785	50	3.6e+006	188	5.2222e-005

χ and the probability of an in-bean interferer ξ id defined as,

$$\xi = \frac{(2\theta_{BW})}{\Delta\theta}, \quad \chi = (1 - \xi)^{K - \kappa - 1}$$

where κ denotes the number of in-beam interferers, $(K - \kappa - 1)$ is the number of out-of-beam interferers, $\Delta\theta = 120^\circ$ is the total coverage angle of the sector and $2\theta_{BW}$ is the total beamwidth towards the desired user.

The optimized values of equivalent beam forming parameters collected during the thesis are shown below in the table.

Table 1: Equivalent beam forming parameters

Number of antenna elements N 4 6 8	4	6	8
Attenuation α_o (dB)	-12	-14	-16
Beamwidth $2\theta_{BW}$ (degs.)	30	20	15

CHAPTER 4

SIMULATIONS

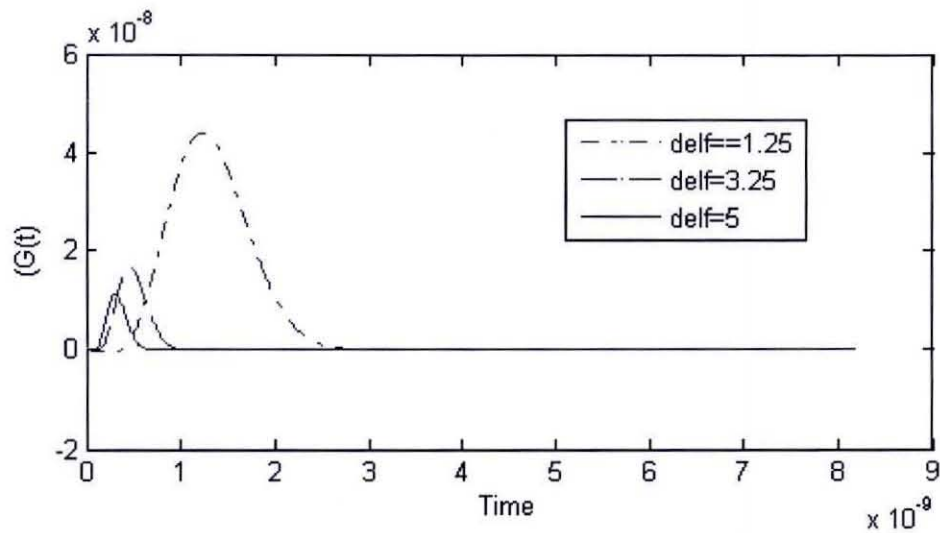


Fig.4.1. Time response curve

A time response curve is plotted for the auto correlation term used in the eqn(16) for different bandwidth. One desired source and two interferers were introduced by (i.e taking into consideration the other two values of delf) All sources are assumed to have equal powers. The desired signal and interfering waveforms are shown in fig.1.

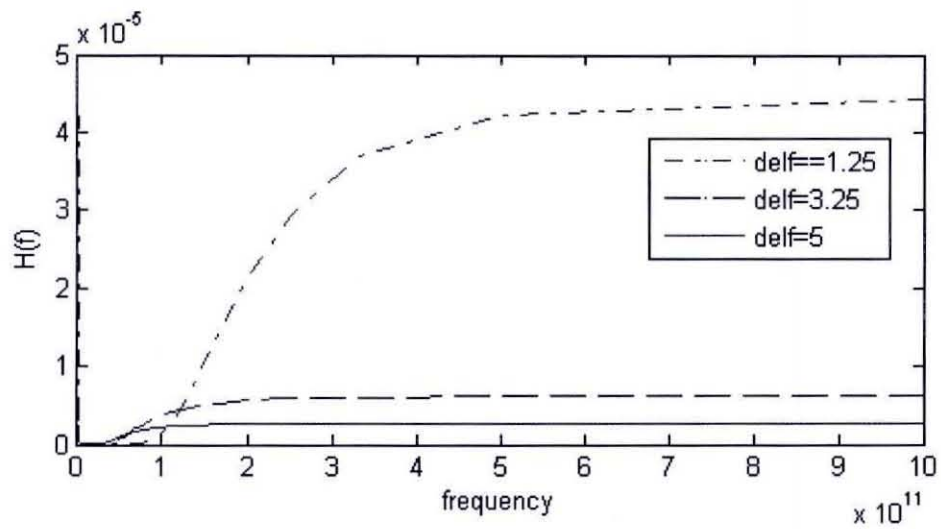


Fig.4.2.Frequency response curve

Fig. shows the frequency response curve(amplitude spectra). Here we see that amplitude of the desired signal is the highest which assures the fact that the look-direction has achieved the strongest signal.

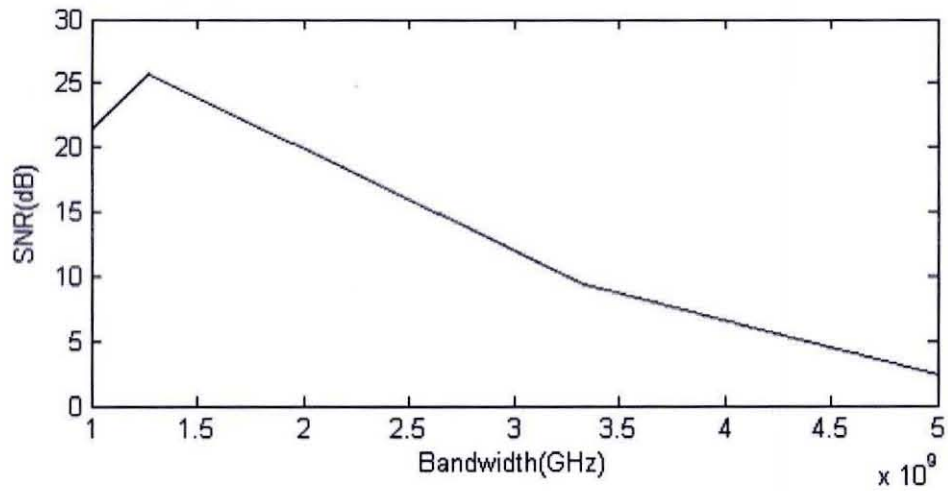


Fig.4.3.SNR Vs Bandwidth

SNR versus bandwidth of the desired signal shows, how interference increases with bandwidth. The interfering signals of respective bandwidths 3.25GHz and 5GHz have lower SNR than the desired signal of bandwidth 1.25GHz. This shows that SNR decreases with increase in bandwidth.

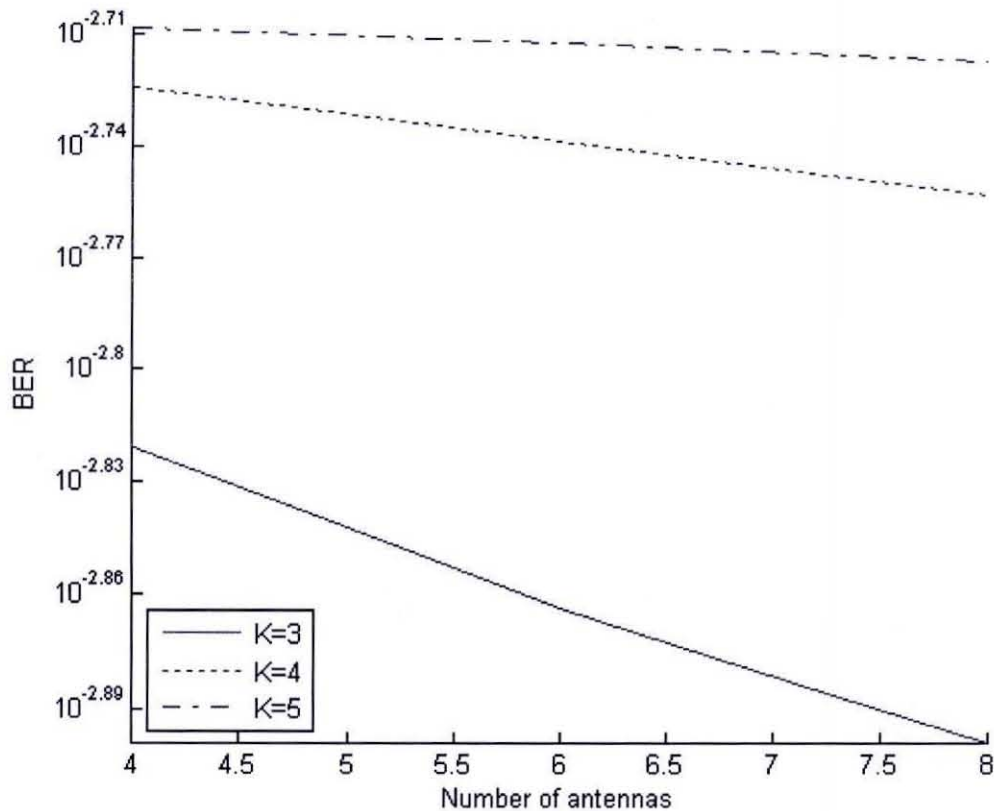


Fig.4.4.BER Vs Number of antennas

Fig:12 BER Vs Number of antennas is plotted for different users. From this figure it can be seen that beam forming improves the performance of the system. That is the mean BER of the signal improves as the number of antenna increases. For K=3 the BER increases in a much higher rate than when K=4 or 5.(K=number of users) This figure also shows that as the number of users increases the performance of the system gradually deteriorates. This is to be expected as CDMA systems are interference limited systems.

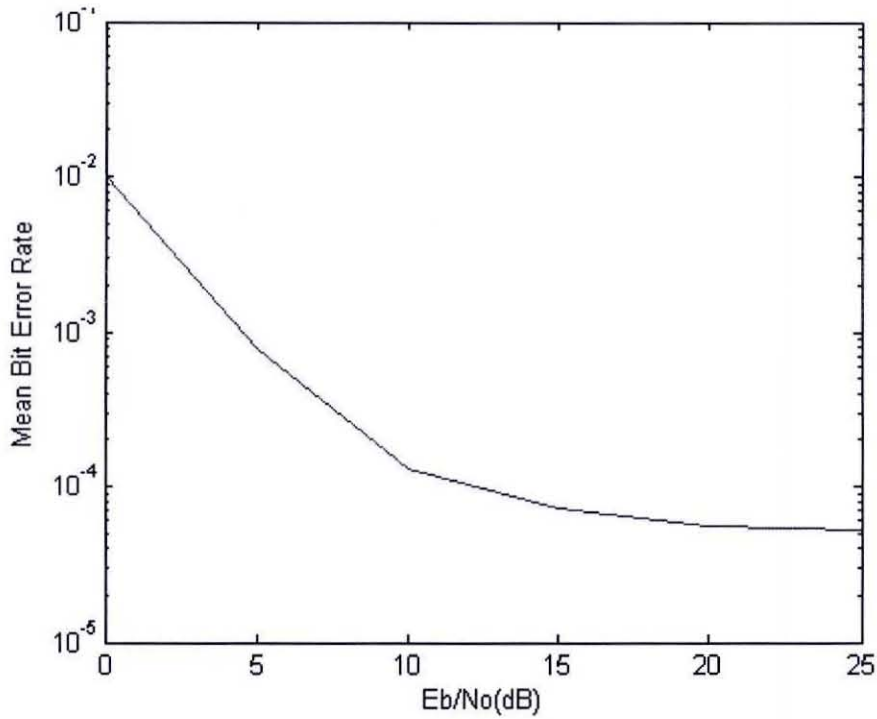


Fig 4.5. Mean BER vs. E_b/N_0 (dB)

Fig.4.5 shows the Mean BER vs. E_b/N_0 (dB) for $N=6$ antennas, $K=1$ user with single path . The performance of the system increases as E_b/N_0 increases. We know that SNIR is a function of E_b/N_0 [eqn(-)]. Therefore increasing number of antenna elements increases SNIR and so increases E_b/N_0 hence decreases BER increasing the performance of the system as shown in the fig.

Future scope

Smart antenna is indeed a very vast topic and myriad scopes are there to executes researches. This paper is rather an introductory concept about the smart antenna where only the primary aspects are discussed. Focus was given on the beam forming and it's implementations on CDMA. However smart antenna has many other feature with are worthy of being a topic of research. Topics such as

1. Adaptive Algorithm
2. Diversity
3. Switch Beam method
4. Adaptive method

And of course all the features can be applied in all the existing standards. So those can be subjected to investigations.

Therefore we would try to investigate all these feature step by step

Conclusion

No matter how much we talk about the glory of wireless communications we just cannot agree that this types of communications are utterly perfect. Although this type of communication can deliver a much higher efficiency including high data rates there are certain systematic degradation as the application tends to increase which contributes to inefficiency. However this constant effort are being made to improve the systems. This paper explores all the attributes which tends be one of those efforts.

Many important aspects of this advanced system was discussed in this paper such as types and criteria of smart antenna more r explains the advent of the system. The beam forming of the system was comprehensively analyzed with numerical computations where many aspects by which a smart antenna system tend to enhance the performance of the system, is reveal. Moreover, a research of how a CDMA system would work with this beam forming, is also shown.

So we can conclude that this paper gives a legitimate idea about smart antenna and it is capable of inducing interest of further research about the respective matter

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