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Performance Evaluation of Broad Band CDMA Signal using Beam forming Antenna Technology for next Next Generation Communications

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ABSTRACT

In order to accommodate various multimedia services, next generation wireless networks are characterized by very high transmission rates. Thus, in such systems and networks, the received signal is not only limited by noise like Additive White Gaussian noise (AWGN) but especially with increasing data transmission rate by the Intersymbol Symbol Interference (ISI) due to time dispersion of channel. A number of techniques such as rake receiver in CDMA systems and equalizers in GSM systems have been proposed to combat the effect of fading so as to improve the performance of wireless communication network. In this paper we evolve the performance of uncoded uplink transmission in broadband CDMA using beam forming technique under multipath conditions. The beam-former has been implemented using Transport Delay Line (TDL) filters. An expression for the optimal weights of a TDL based beam former has been derived. A carrier frequency of 2 Ghz has been used in this work as they are useful for next generation wireless systems. Simulation results show that TDL beamformer can reduce the multipath fading and Multiple Access Interferance (MAI). It has been shown that if SNR (related with Variance of the channel) is maintained at 10 db and if a 3 ray based beamformer having 3 antennas with 3 taps is used, the Error Rate of 0.1 was found without using channel coding.

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1. INTRODUCTION

In the telecommunication market most of the traffic is changing from speech oriented Communication to multimedia Communications. Thus the actual communication system 3G needs to evolve to be able to handle this change. The next generation of communication system 4G and 5G (recently proposed) can be defined as the total convergence of wireless mobile and wireless access communications that permits to handle the various multimedia applications. Furthermore, nowadays most of the users equipped with a mobile device want to enjoy Internet and all its multimedia applications. However those types of applications, such as high-definition television, require a higher data rate than the one needed by standard data or voice traffic. In order to optimize the transmission to achieve a higher data rate, several techniques can be applied either at the transmitter or receiver side. Nowadays the most challenging techniques are beam forming and multiple-inputs-multiple-outputs. Moreover, the multimedia traffic is usually requesting multicast services for a better optimization of the resources i.e. the users are served as part of a group instead as a unique user.

The need of a better wireless communication, in terms of higher data rate, fewer dropped calls, QoS and network capacity, brought the scientist to focus on different approach for the communications organization. The number of transmitter/receiver antennas is one of the parameters which has been analyzed over time. Usually the Multiple input/ Multiple output system that uses multiple antenna arrays at both transmitter and receiver side promises a better spectral efficiency and a more reliable wireless connection.

One of the system which is using multiple antennas for the transmission is the Beamforming. The vector addition of the fields radiated by the individual elements of an antennas array permits to obtain the total field of the array. To obtain very directive patterns, it is necessary that the field from the elements of the array interfere constructively in the desired directions and destructively in the remaining space. To shape the overall pattern of the antenna, supposing an array of identical elements, there are five controls that can be used to shape the overall pattern of the array. These are:

1. The geometrical configuration of the overall array (linear, circular, rectangular, spherical, etc.)
2. The relative displacement between the elements
3. The excitation amplitude of the individual elements
4. The excitation phase of the individual elements
5. The relative pattern of the individual elements

In this paper we propose a beam former based CDMA system transmission over Additive white Gaussian Noise (AWGN) channel. The performance of the proposed system has been evaluated. The mathematical model for the calculation of tap gains in case of beam former has also been addressed. The paper organization is divided into following sections.

2. SYSTEM MODEL

2.1. Transmitted Signal

Assume that there are K users in a broadband CDMA system. Let G be the processing gain or equivalently the spreading factor of CDMA. Let Ck= (COk, C1k,...........CkG- 1) be the CDMA code for user k , k ∈{1,...,K}. Assume that Binary Phase Shift Keying (BPSK) is used as a digital modulation technique. The ith symbol transmitted from user k is denoted by ak [i], i∈{0,1...}. It is assumed that ak [i], i∈{1,-1}. The baseband pulse for BPSK is denoted by p(t). Let Tb and Tc indicate the bit and chip periods respectively. The combined baseband CDMA signal from all users is given by

$$\text{mb(t)} = \sum_{k=1}^{K}\sum_{I=0}^{\infty}\sum_{g=0}^{G-1} aK[i]c_g^k \;\; P(t-g\,Tc-iTb) \tag{1}$$

The corresponding passband signal with carrier frequency fc is given as

$$\text{mp(t)} = \sqrt{2}\ \text{mb (t)}\ cos(2\pi fct) \tag{2}$$

2.2. Multipath Fading Channel Model

When a passband signal mp(t) is sent through a multipath fading channel, multiple copies of the original signal will be received at the receiver due to the presence of reflecting objects and scatters in the channel as shown in Figure 1.

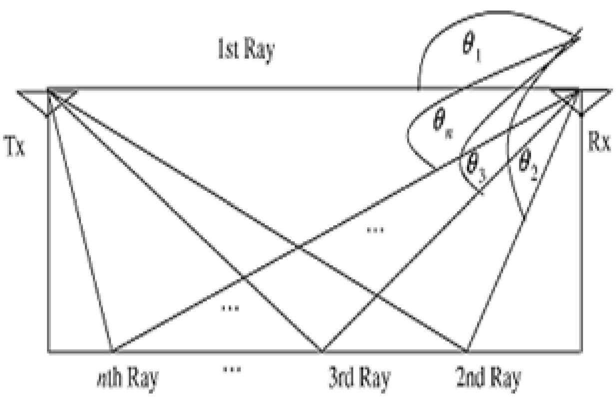

Figure 1. Multipath Fading Channel Model

These effects result in multiple versions of the transmitted signal that arrive at the receiving antenna, displaced with respect to one another in time and spatial orientation. The amplitudes and phases of the different multipath components cause fluctuations in signal strength, thereby introducing multipath fading. In this work it has been assumed that the signal components reflected and scattered by the objects are independent of each other. The amplitudes and phases of these independent multipath signals can be time varying. As the variations of amplitudes and phases are of random nature, the multipath fading channel is best described in statistical terms with random and time- variant characteristics. In the proposed work, it is assumed that the channel is a Linear Time Invariant (LTI) channel due to slow fading assumption. The slow fading channel has been mathematically modelled as

1. The gain parameter γ1, γ2, γn Where √ (γ12 +γ22 +...+γn2) =1,
2. The angle of incident θ1, θ2,............. θn,
3. (3) The absolute delays of linear array elements with spacing d, t1, t2,......... tn where t1 = $\frac{dsin\theta_1}{c}$, t2 = $\frac{dsin\theta_2}{c}$……………., tn = $\frac{dsin\theta_n}{c}$,
   Where c is the velocity of light,
4. The relative delays of the multipath signal with respect to direct path (i.e. line- of- sight) signal are denoted by t11, t12,.........t1n.
   The LTI channel response of antenna 1 is modelled based on the above mentioned parameter as follows:

$$hn(t) = \sum_{path=1}^{1} \gamma path\ \delta(\tau - \tau 1path) \quad (3)$$

Where (.) is the unit impulse function

2.3. Received Signals

Consider a receiver with a linear array of L antennas with spacing d. Let *xl(t)* be received signal at antenna *l, l∈{1,..., L}*. Assume that there is an Additive White Gaussian Noise (AWGN) process *nl*(t) at antenna *l*. The received combined signals at antenna *l* can be defined as

$$Xl(t) = \sqrt{2\gamma 1}\ mb\ (t - (l-1)t1)\ cos(2\pi fc(t- (l-1)t1)+$$
$$\sqrt{2\gamma 2}mb(T - t12 - (l-1)t2)\ cos(2\pi fc(T- t12- (l-1)t2) +,.....+$$
$$\sqrt{2\gamma n}\ mb(t- t1n- (l-1)tn)\ cos(2\pi fc(T-t1n - (l- 1)tn) + nl(t). \quad (4)$$

2.4. TDL Beamformer

In a TDL beamformer, there are L antennas each of which is equipped with J taps separated by delay TD. Let wij*, l∈{1,.........L}, j∈{1,.........J}, denote the weight for the signal on antenna l at tap j. The first tap output corresponds to the received signal without delay, while the jth tap output corresponds to the signal delayed by (j – 1)TD. The output y(t) of a TDL beamformer is given by

$$y(t) = \sum_{l=1}^{L} \sum_{j=1}^{J} Xl\ (t - (j-1)TD)Wij^* \quad (5)$$

for conveience, the vectors w and x(t) are defined by

$$w= [w1T...........wLT],\ where\ wl= [wl1...........wlj]T \quad (6)$$

$$x(t)= [x1T(t),...........xLT(t)]T,\ where\ xl =[xl(t),.......xl(t- (j-1)TD)]T \quad (7)$$

from the definitions in (6) and (7), the beamformer output y(t) can be expressed concisely as

$$y(t) = w^\dagger x(t). \quad (8)$$

where xT and w† denote the transpose of x(t)and conjugate transpose of w

The optimal tap weights w of a TDL beamformer, denoted by wopt , can be found using the Wiener Hop equations and is expressed as

$$w_{opt} = R^{-1}p \quad (9)$$

where $R= E[X(t)X\dagger(t)]$ is the LJ X LJ covariance matrix of the received signal vector $X(t)$

$$\mathbf{R}=\begin{bmatrix} \begin{bmatrix} r_{11}(0) & \cdots & r_{11}(J-1) \\ \cdots & r_{11}(0) & \cdots \\ r_{11}(-J+1) & \cdots & r_{11}(0) \end{bmatrix} & \cdots & \begin{bmatrix} r_{1L}(0) & \cdots & r_{1L}(J-1) \\ \cdots & r_{1L}(0) & \cdots \\ r_{1L}(-J+1) & \cdots & r_{1L}(0) \end{bmatrix} \\ & & \vdots \\ \cdots & \cdots & \vdots \\ & & \vdots \\ \begin{bmatrix} r_{L1}(0) & \cdots & r_{L1}(J-1) \\ \cdots & r_{L1}(0) & \cdots \\ r_{L1}(-J+1) & \cdots & r_{L1}(0) \end{bmatrix} & \cdots & \begin{bmatrix} r_{LL}(0) & \cdots & r_{LL}(J-1) \\ \cdots & r_{L1}(0) & \cdots \\ r_{LL}(-J+1) & \cdots & r_{LL}(0) \end{bmatrix} \end{bmatrix}$$

And **p** = $E[X(t)d^*(t)]$ *is the* LJ *x 1* correlation vector of X(t) and d(t) is the reference signal. In computing wopt in (9), it is assumed that reference signal d(t) is known to the receiver. Hence the value of p is known and is expressed as

P= [[p11(0)..........p1j(1-j)].........[pL1(0)........pLJ (1- J)]]T

2.5. Derivation of Optimal TDL weights for CDMA based Systems

The analytical expression for the optimal weight wopt of a TDL beam-former used in a broadband CDMA system has been derived in this section. First, the correlation function of the signals received at two different antenna- tap values (l, j) and (l', j') can be expressed as

$$\varphi ll'(\Delta)= E[xl(t-(j-1)TD)xl'(t-(j'-1)TD)]$$

$$\text{Where } \Delta = (j-j')TD \quad = [\gamma 1\,\gamma 1\,\phi m_p m_p(\Delta_{11}) + \gamma 1\,\gamma 2\,\phi m_p\, m_p(\Delta_{12}) + \gamma 1\,\gamma 3\,\phi mp\, mp(\Delta_{13}) + \ldots\ldots\ldots \gamma 1\,\gamma n\,\phi mp\, mp(\Delta 1_n) + \gamma 2\,\gamma 1\,\phi m_p\, m_p(\Delta_{21}) + \gamma 2\,\gamma 2\,\phi m_p\, m_p(\Delta_{22}) + \gamma 2\,\gamma 3\,\phi m_p\, m_p(\Delta_{23}) + \ldots\ldots\ldots + \gamma_2\,\gamma_n\,\phi m_p\, m_p(\Delta_{2n}) + \ldots\ldots\ldots\, \gamma n\,\gamma 1 + \phi m_p\, m_p(\Delta_{n1}) + \gamma n\,\gamma_2\,\phi m_p\, m_p(\Delta_{n2}) + \gamma_n\,\gamma_3\,\phi m_p\, m_p(\Delta_{n3}) \ldots\ldots\ldots\, \gamma_n\,\gamma_n\,\phi mp\, m_p(\Delta_{mn}) \tag{10}$$

Where $\Delta 11 = [(l-1)t_1 + t_{11} + jT_D - (l'-1)t_1 - t_{11} - j'T_D]$

$\Delta 12 = [(l-1)t_2 + t_{12} + jT_D - (l'-1)t_1 - t11 - j'T_D]$

$\Delta 13 = [(l-1)t_3 + t_{12} + jT_D - (l'-1)t1 - t_{11} - j'T_D]$

.

.

$\Delta 1n = [(l-1)tn + t1n + jT_D - (l'-1)t1 - t11 - j'T_D]$

$\Delta_{12} = [(l-1)t_2 + t_{11} + jT_D - (l'-1)t1 - t11 - j'T_D]$

$\Delta_{22} = [(l-1)t_2 + t_{12} + jT_D - (l'-1)t_1 - t_{11} - j'T_D]$

$\Delta_{23} = [(l-1)t_2 + t_{13} + jT_D - (l'-1)t_1 - t_{11} - j'T_D]$

.

.

$\Delta 2n = [(l-1)tn + t1n + jT_D - (l'-1)t_2 - t_{12} - j'T_D]$

.

.

$\Delta 1n = [(l-1)t_1 + t_{11} + jT_D - (l'-1)t_1 - t1n - j'T_D]$

$\Delta 2n = [(l-1)t_2 + t1_2 + jT_D - (l'-1)t1 - t1n - j'T_D]$

$\Delta 3n = [(l-1)t3 + t1_3 + jT_D - (l'-1)tn - t1n - j'T_D]$

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$$\Delta nn = [(l-1)tn + t1n + jT_D - (l'-1)tn - t1n - j'T_D]$$
$$\text{Where } t_{11} = t_{12} =, \ldots\ldots, = t_{nn} = 0 \tag{11}$$
$$t_{12} = t_{21}, t_{13}, \ldots\ldots\ldots, t_{1n} = t_{n1}$$

The autocorrelation function of the passband signal $\phi_{mp}\ m_p$ (.) can be described in terms of the autocorrelation of the baseband signal $\phi_{mb}\ m_b$ (.) as follows and is shown in Figure 16

$$\phi_{mp\ mp}(\Delta) = E[\, m_P(T)\, m_P(T+\Delta)]$$
$$= E[m_b(T)\, m_b(T+\Delta)]\cos(2\pi fc\,\Delta)t$$
$$= \phi mb\ mb(\Delta)\cos(2\pi fc\,\Delta)t \qquad (12)$$

In case of narrowband systems, it is assumed that $m_b(t)$ is approximately equal $m_b(t+\Delta)$, yielding ϕmb $m_b(\Delta) = E[\, m_b(T+\Delta)]$ approximately equls to $E[M_b^2(t)]$, which states that the $\phi mb\ mb\ (\Delta)$ is approximately equal to the base band signal power. Since this approximation is not valid for a broadband system. A new expression for $\phi mbmb$ (Δ) has been given in this paper. For statistically independent transmitted symbols, the following conditions are

$$E[A^k[i]\, A^{k'}[i'] = \{\ 1,\ k = k' \text{ and } i = i' \qquad (13)$$

$$0, \text{ otherwise}$$

Another assumption is that different chip values of CDMA codes are statistically independent. This assumption allows computing the approximated expression for ϕmb mb (Δ). With the assumption, the property in (3.13) can be extended to the following statement:

$$E[Cg^k A^k[i] Cg^{'k'} A^{k'}[i'] = \{\ 1,\ k = k' \text{ and } i = i',\ \text{and } g = g' \qquad (14)$$

$$0, \text{ otherwise}$$

From (1) and (14). We can write ϕmb mb(Δ) as

$$\phi m_b\, m_b(\Delta) = E[m_b(T)\, m_b(T+\Delta)]$$

$$= E\left[\left(\sum_{k=1}^{K}\sum_{i=1}^{\infty}\sum_{g'=0}^{G-1} c_g^k A^k[i] p(t - gT_c - iT_b)\right) \times \left(\sum_{k'=1}^{K}\sum_{i'=1}^{\infty}\sum_{g'=0}^{G-1} c_{g'}^{k'} A^{k'}[i'] p(t - g'T_c - i'T_b + \Delta)\right)\right] \qquad (15)$$

$$= E\left[\left(\sum_{k=1}^{K}\sum_{i=1}^{\infty}\sum_{g'=0}^{G-1} c_g^k A^k[i] p(t - gT_c - iT_b)\right) \times \left(\sum_{k'=1}^{K}\sum_{i'=1}^{\infty}\sum_{g'=0}^{G-1} c_{g'}^{k'} A^{k'}[i'] p(t - g'T_c - i'T_b + \Delta)\right)\right]$$

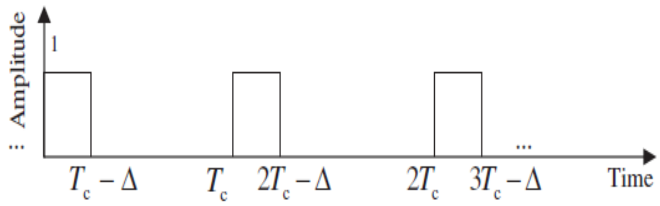

Figure. 2

The ϕ (t, Δ) function defined by equation 16 is illustrate in Figure 2

$$\varphi(t,\Delta) = \sum_{i=1}^{\infty}\sum_{g=0}^{G-1} p(t - gT_c - iT_b)\, p(t - gT_c - iT_b + \Delta) \qquad (16)$$

Note that ϕ (t, Δ) is periodic with period TC and ϕ (t, Δ) = 0 if Δ > TC. Since ϕ (t, Δ) is time dependant, for the TDL weight computation, the time average value of ϕ (t, Δ) can be used. This averaging is similar to the process of computing autocorrelation of cyclostationary process. The time average value of ϕ (t, Δ) over a single period is computed as follows.

$$\overline{\varphi}(\Delta) = \frac{1}{T_c}\int_0^{T_c} \varphi(t,\Delta)dt = \begin{cases} 1-\dfrac{\Delta}{T_c}, & |\Delta| \le T_c \\ 0, & \text{otherwise} \end{cases} \tag{17}$$

By setting ϕ *(t, Δ)=* ϕ *(Δ)* and using (10), (11), (12), (15), (16), and (17), we can compute the optimal TDL weights in (9) for broadband CDMA system.

3. BROAD BAND CDMA SIGNAL TRANSMISSION AND RECEPTION USING TDL BEAM FORMING TECHNIQUE

The schematic of the proposed technique for the broadband CDMA transmission and reception using beam forming antenna technology is shown in Figure 3 and the implementation is shown in figure 4. In figure 4,the implementations of subsystems are shown in figures 4, 5 and 6 respectively.

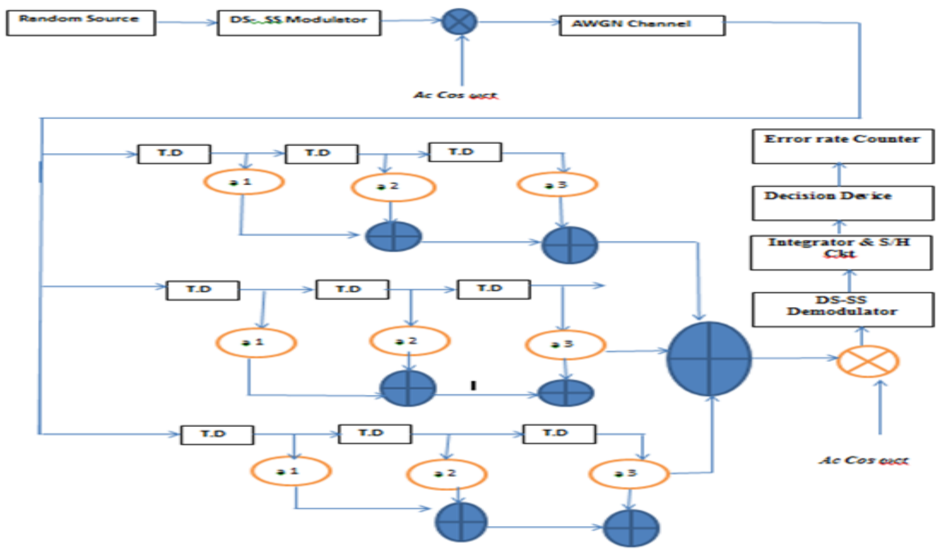

Figure 3. Shows Schematic of the Proposed Scheme

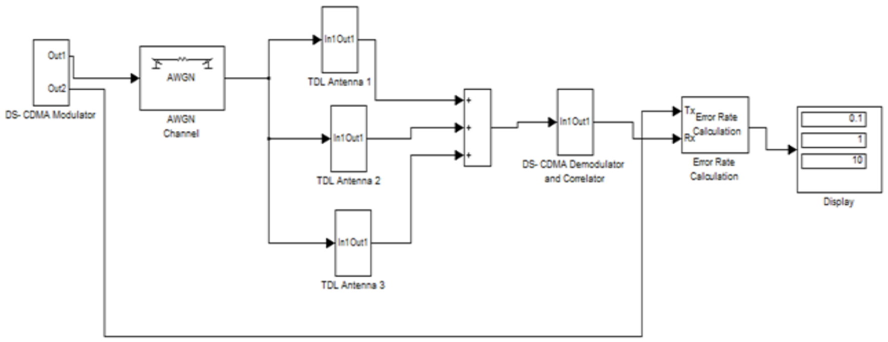

Figure 4. Implementation of Proposed Schem

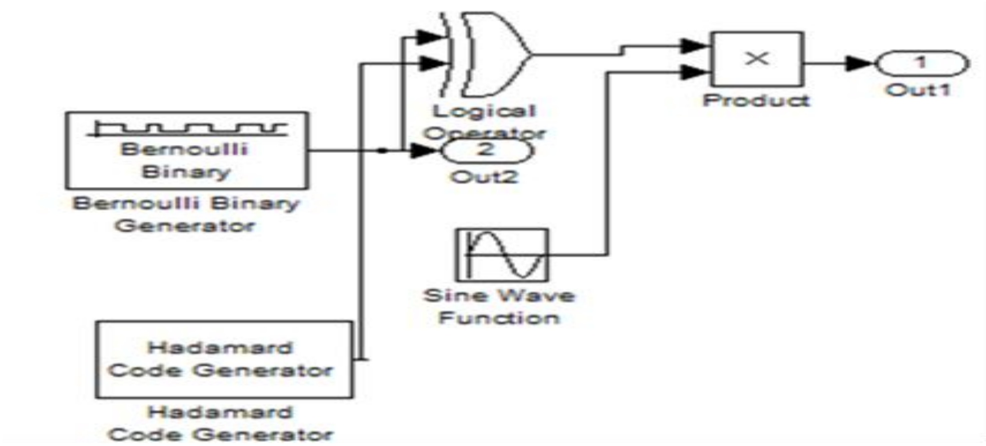

Figure 5. DS- CDMA Modulator

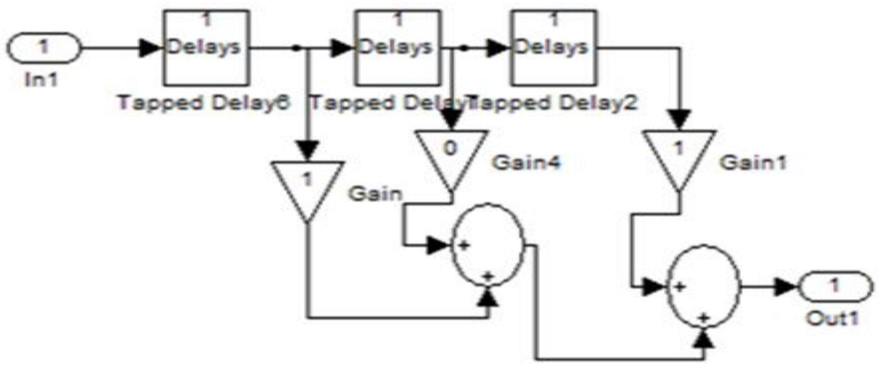

Figure 6. DTL Antenna Implementation

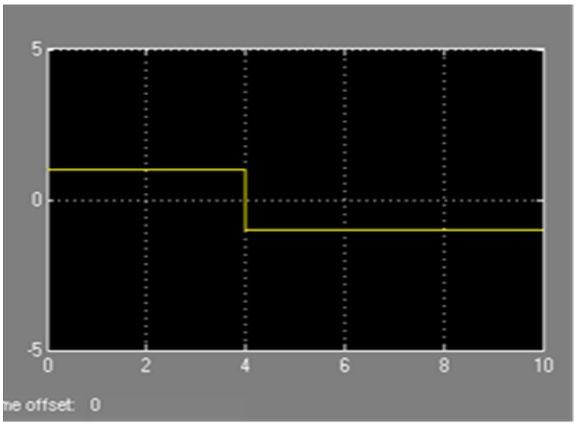

Figure 8. Waveforn of BRG at Transmiting end

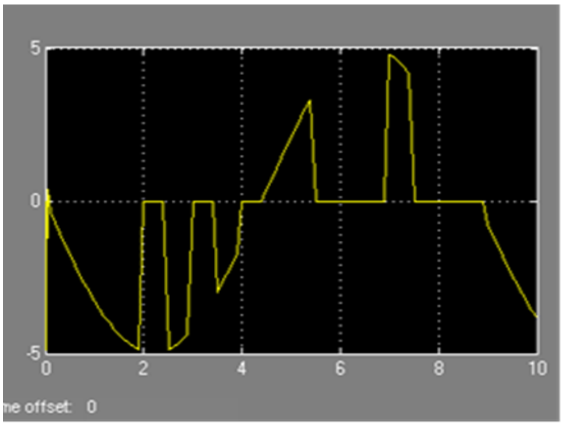

Figure 9. Waveform of Transmiting signal

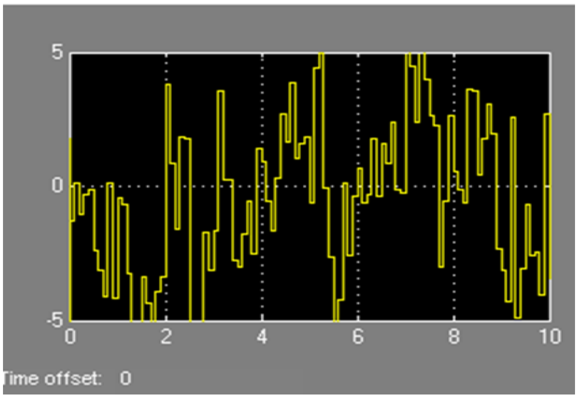

Figure 10. Waveform of Transmitting signal over AWGN channel

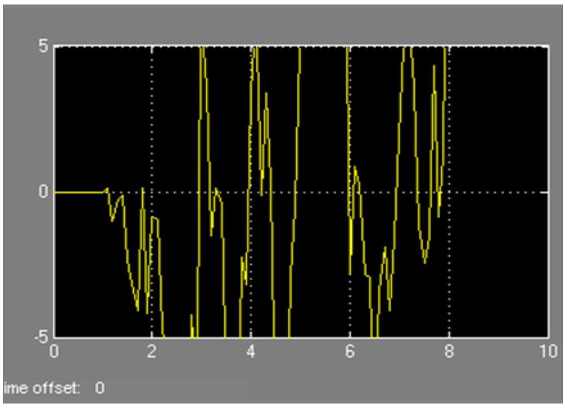

Figure 11. Waveform of combiner formed by Beam forming Antenna

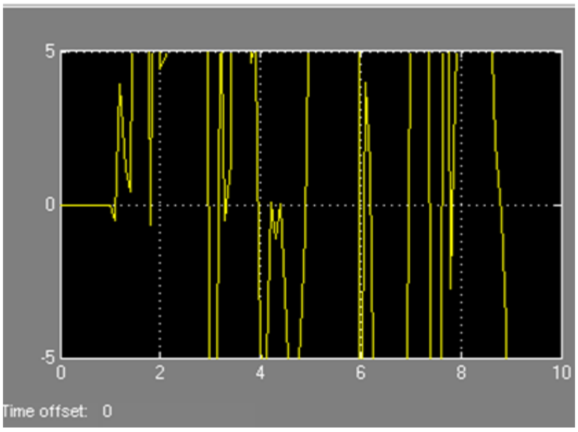

Figure.12. Waveform of demodulating signal

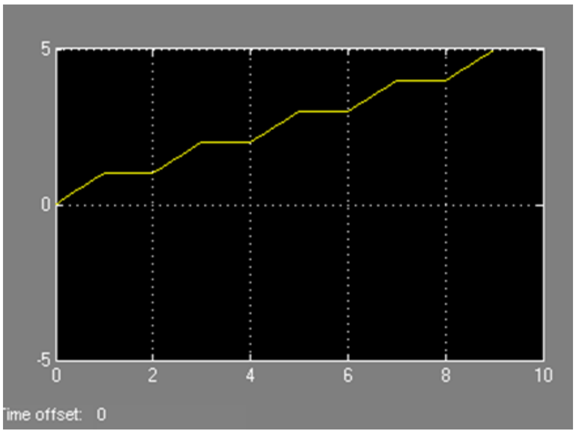

Figure.13. Waveform of Integrator at receiving end

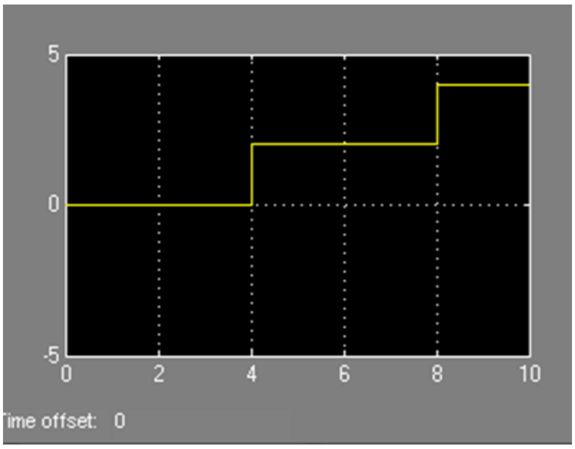

Figure 14. Waveform of Sample and Hold Circuit

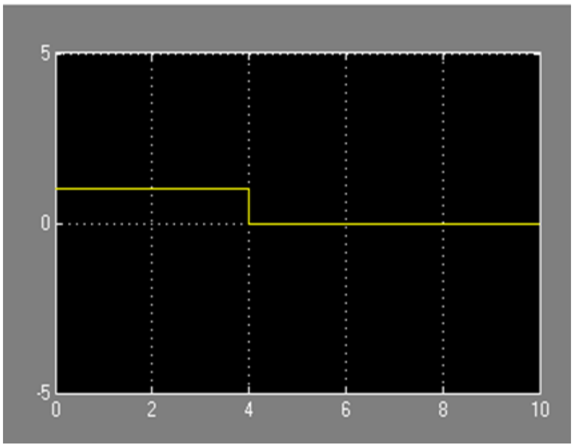

Figure 15. Waveform of Threshold Circuit

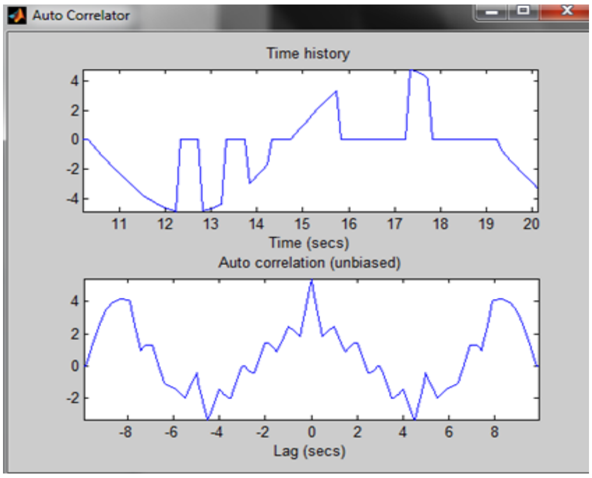

Figure 16. Auto-correlation of Pass band signal

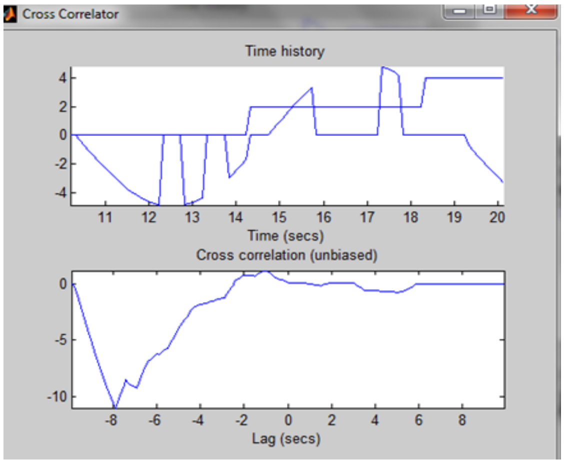

Figure 17. Cross-correlation of Pass band signal and Received signal

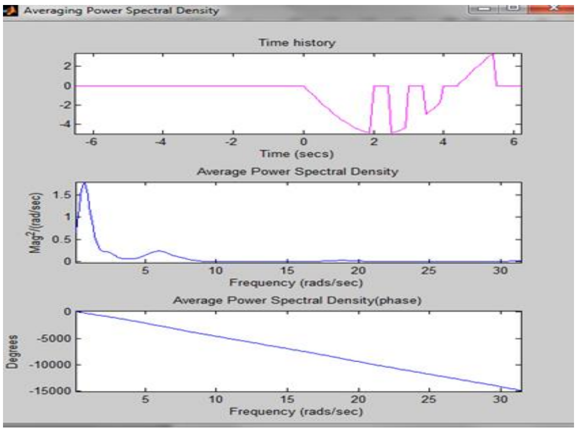

Figure 18. Average Power Spectral Density of Pass band signal and Received signal

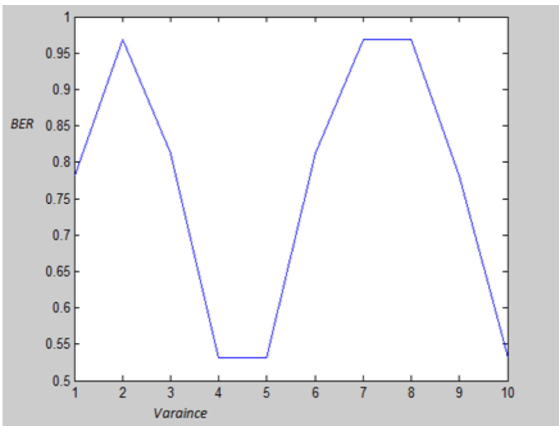

Figure 19. Plot between Variance of AWGN channel and BER of the proposed Technique

In the proposed technique, a Bernoulli Binary Generator (BRG) has been taken as information source. The BRG generates a random binary number. The carrier frequency is set to 2 GHz, the transmission bandwidth is 100 MHz. The bandwidth values are based on the IMT- 2000 standard. The data rete is 200 kbps. The CDMA processing gain is 512. Hadmarad code sequence is used as CDMA pseudo-noise code of length 256 as is used in CDMA mobile communications. The outputs of BRG (as binary information source) and Hadamard code sequence are modulo- 2- added with X-OR gate to get the Direct Sequence Spread Spectrum (DS-SS) signal. The output of the X-OR gate is multiplied with carrier frequency generated by sinusoidal oscillator having frequency 2 GHz so as to generate the pass band signal which has been transmitted through Additive White Gaussian Noise (AWGN) channel. The AWGN channel adds white Gaussian noise to the real or complex input signal. Assuming nominal impedance of the channel to be 1 ohm, the transmitted signal has been received by beam forming antenna consisting of three elements implemented by using Transport Delay elements. The tap gain has been computed using Equation 9. The weighted sum of TDL antenna array signals are combined at the combiner. The output of the combiner is first demodulated using a local oscillator operating at the carrier frequency fc. The demodulated output is then de-spread using the CDMA code (same Hadamard code used at the transmitting end) for the desired user. The resultant output is then passed through a integrator followed by sample and hold circuit which takes the samples at every bit period Tb and the sampled output is passed through the threshold decision device. The performance of the proposed system has been verified by computing the bit error rate using Error Rate Calculation counter which computes the error rate of the received data by comparing it with delayed version of the transmitted data. The error counter specifies the three element vector consisting of the error rate, followed by the number of errors detected and the total number of symbols compared. It has been observed that bit error rate varies in accordance with the variation of variance of the Additive White Gaussian (AWGN) Channel, which has been plotted in the graph 19. The error rate has been found 0.1, which is quite satisfactory. The waveforms obtained at various points, which includes auto- correlation, cross-correlation and power spectral density are shown in Figures 8 to 19 respectively. An observation of the resultant waveforms proves the efficacy of the proposed system. Moreover, the transmitted and received signal (after demodulation) is same in frequency and phase.

4. CONCLUSION

The performance of Transport delay Line (TDL) beam-former in broadband CDMA over the Additive White Gaussian Noise channel has been investigated in this chapter. The beam forming method of receiving signal from multiple paths has been found efficient to combat and minimise the effect of phase and amplitude distortion due to frequency selective fading nature of the channel. Optima values of TDL weights have been derived and used to minimise the effect of channel distortion, MAI interference and multipath fading. In this scheme three antennas with nine taps have been used to simulate the antenna array. Monte Carlo Simulation has been performed by using random data generated from Barnauli Random generator. Hadmarad codes have been used as spreading code. The simulation was done at a carrier frequency of 2 Ghz which makes the proposed scheme compatible with IMT 2000 standard. The efficacy of the system has been checked by verifying the waveforms obtained at various points and with the calculation of bit error rate. The error rate has been found 0.1 with out using channel coding which means out of ten frames transmitted at the transmitting end only one bit error was obtained which is quite satisfactory. From the analytical as well as simulation results, it has been found that the proposed scheme finds a range of applications in mobile broad band communications to minimise the bit error rate in a multipath environment. The performance would further increase by using standard channel coding techniques.

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