ISSN:0975-9646

Design of DFE Based MIMO Communication System for Mobile Moving with High Velocity

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Abstract – **Reliability, high quality, and efficient data rate communication for high speed mobile is the growing research in recent years. In this paper time dispersive and frequency dispersive effects on signal is analyzed. Then a decision feedback equalizer is proposed whose weights are periodically updated using LMS algorithm depending upon the statistical parameters of fading channel. In order to combat the effect of fading a MIMO wireless communication technique is used. Finally the performance of the system under high time dispersive and frequency dispersive channel is analyzed while the velocity of the mobile is taken as high as 250km/hr.**

Keywords **– MIMO System, Fading, Diversity, DFE, LMS Algorithm.**

I. INTRODUCTION

Reliable high data communication over wireless channel is highly demandable and challenging. Considerable research has been done in last decades in the area of wireless communication. The mobile broadband wireless access (MBWA-IEEE802.20) standard describes a reliable communication for data rate up to 1Mbps at a mobile speed of 250km/hr which is close to the standards of 4G[1]. The bottleneck of reliable high data rate communication is that when mobile is moving at very high velocity, the signal strength and phase alters quite randomly due to high time dispersive and frequency dispersive channel.

Diversity is one of the important aspect in wireless communication. The most suitable method to overcome the above mentioned problem is to use space diversity. Space diversity exploits the random nature of radio propagation by finding independent but highly uncorrelated signal path for communication .The idea behind this is, if there are number of independent paths then the probability of getting at least one strong signal, is more [2].

$$P_r\left[\sigma_1,\sigma_{2,\ldots\ldots\ldots},\sigma_m\le\sigma\right]=\left(1-e^{-\sigma/E}\right)^N=P_N(\sigma) \qquad \ldots (1)$$

where σ_1, σ_2 ,……….., σ_m =instantaneous SNR of each independent path..

σ=specific SNR threshold below which call will drop.

E =average SNR

N=Number of independent path.

The uncorrelated path can be obtained by using more than one transmitting antenna and more than one receiving antenna. If the antenna separations are more than half of the wavelength then the received signal is highly uncorrelated[3]. In this work the time dispersive and frequency dispersive effects of channel on signal is analyzed. Then the improvement of bit error rate (BER) performance is observed by using multiple inputs and multiple output (MIMO) antenna system. Then a MIMO based communication system using decision feedback equalizer is proposed whose weights are periodically updated by using LMS algorithm, depending on statistical parameters of channel like rms delay spread, coherence time and coherence bandwidth.

II. STATISTICAL PARAMETERS OF FADING CHANNEL

Statistical parameters are most important for accuracy and efficacy of the system. The mean excess delay and rms delay spread are the statistical parameters which grossly quantity the multi-path channel used. The mean excess delay and rms delay spread parameters give a mathematical insight to the time dispersive properties of multi-path channel. The mean excess delay is the first moment of power delay profile and is defined as

$$\overline{\tau} = \frac{\sum_K P(\tau_k)\tau_k}{\sum_K P(\tau_k)} \qquad \ldots \qquad (2)$$

The rms delay spread is the square root of the second central moment of the power delay profile is given by

$$\sigma_\tau = \sqrt{\overline{\tau}^2 - (\overline{\tau})^2} \quad \ldots \quad (3)$$

III. MULTIPLE INPUT MULTIPLE OUTPUT (MIMO) SYSTEM

A communication system characterized by use of Nt transmitting antenna and Nr receiving antenna (Nt &Nr >1) is generally called as multiple input multiple output (MIMO) system. The equivalent low pass channel impulse response between j^{th} transmitting antenna and i^{th} receiving antenna is $h_{ji}(\tau:t)$ where 'τ' is the delay variable and 't' is the time variable [[5]-[9]].

The random time-varying channel is characterized by Nt X Nr matrix

$$H(\tau;t) = \begin{bmatrix} h_{11}(\tau;t) & h_{12}(\tau;t) & \cdots & h_{1NT}(\tau;t) \\ h_{21}(\tau;t) & h_{22}(\tau;t) & \cdots & h_{2NT}(\tau;t) \\ \vdots & \vdots & \cdots & \vdots \\ h_{NR1}(\tau;t) & h_{NR2}(\tau;t) & \cdots & h_{NRNT}(\tau;t) \end{bmatrix} \ldots (4)$$

If a signal Xj(t) is transmitted from j^{th} transmitting antenna, then the signal received at i^{th} receiving antenna in absence of noise is given by

$$r_i(t) = \sum_{j=1}^{NT} \int_{-\infty}^{\infty} h_{ij}(\tau;t) * X_j(t-\tau)d\tau$$

$$= \sum_{j=1}^{NT} \int_{-\infty}^{\infty} h_{ij}(\tau;t) * X_j(\tau)d\tau \quad \ldots \quad (5)$$

where j=1,2,3…Nt

$$\Rightarrow r_i(t) = H(\tau;t) * X(\tau) \quad \ldots \quad (6)$$

Considering additive noise at the i^{th} receiving antenna the received signal i^{th} receiving antenna is

$$r_i(t) = \sum_{j=1}^{NT} \int_{-\infty}^{\infty} h_{ij}(\tau;t) * S_j(t-\tau)d\tau + \eta_i(t) \ \ldots \ (7)$$

IV. DECISION FEEDBACK EQUALIZATION (DFE)

It is a non-linear type equalizer consisting of two filters - feed forward and feedback filter. The input to the feed forward filter is the received signal sequence while the sequences of decisions on previously detected symbols are the input to the feedback filter. In real time communication, the length of training sequence plays a vital role on system performance. Decision feedback equalizer is an excellent equalizer structure which provides almost same result comparison to linear equalizer with lesser training sequence. The feedback filter used in DFE removes that part of ISI from present estimated symbol caused by previously detected symbols.

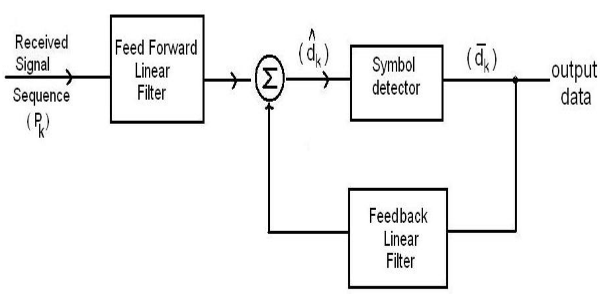

Fig: 1 Decision Feedback Equalizer

If the equalizer has (N_1+1) forward weights and N_2 feed back weights then

$$\hat{d}_k = \sum_{j=-N_1}^{0} W_j r_{k-j} + \sum_{j=1}^{N_2} W_j \bar{d}_{k-j} \left\{ \bar{d}_{k-1}, \bar{d}_{k-2}, \ldots\ldots\ldots\ldots \bar{d}_{k-N_2} \right\} \ldots (8)$$

where $\hat{d}_k$ is the estimate of the k^{th} transmitted symbol. W_j are the weights of the filter { $\bar{d}_{k-j}$ } where j=1,2….N_2 are the previously detected symbols The weight updating of DFE is done mostly on Mean-Square-Error (MSE) criterion. In this criterion the weight of equalizer are adjusted to minimize the means square value of error.

$$J = E\left|\in_k\right|^2 = E\left|d_k - \hat{d}_k\right|^2 \quad \ldots \quad (9)$$

where d_k is the information symbol transmitted in k^{th} signaling interval and $\hat{d}_k$ is the estimated symbol [4][5].

V. SIMULATION RESULT

In this section the performance of MIMO wireless communication system is analyzed using DFE (Decision Feedback Equalizer) while the velocity of the receiver is about 250km/hour. Initially the dispersive property of fading channel and the analysis of various aspects of MIMO channel is followed. The SNR~BER performance of DFE based systems is evaluated and obtained graphically, where the equalizer weights are updated using LMS algorithm periodically depending upon the statistical parameters of fading channel. Various factors are summarized along with their result as follows.

A. Dispersive effect of fading channel

Fig-2 shows the time dispersive and frequency dispersive effect of channel on signal. For frequency dispersive channel a Doppler shift of 200Hz (about 250Km/hour for 900Mhz frequency) and for time dispersive channel three multi path delay components of path delays of 0,65ms and 130ms with average path gain of 0dB, -1dB and -1.5dB respectively are introduced.

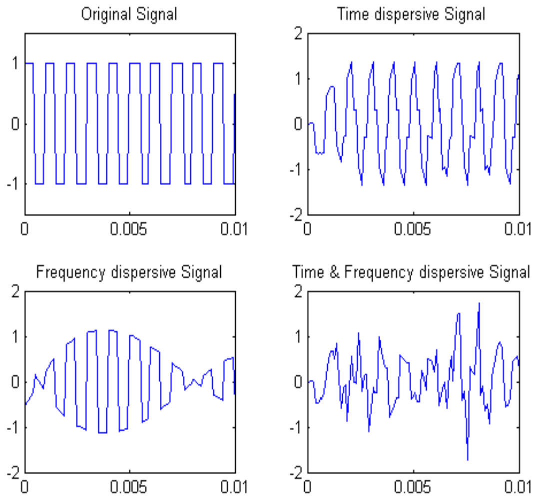

Fig-2: Dispersive effect of fading channel

B. Fading envelop of the channel and Eigen value analysis

Fig-3 and fig-4 shows fading envelop and the Eigen value analysis of correlation matrix of MIMO channel respectively with N_R=2 and N_T=1, 2, 3, 4.which shows that with the increase of the number of antenna the fading nature of the channel mitigates and the Eigen value spread also decreases which improves the convergence rate of the gradient-based LMS algorithm.

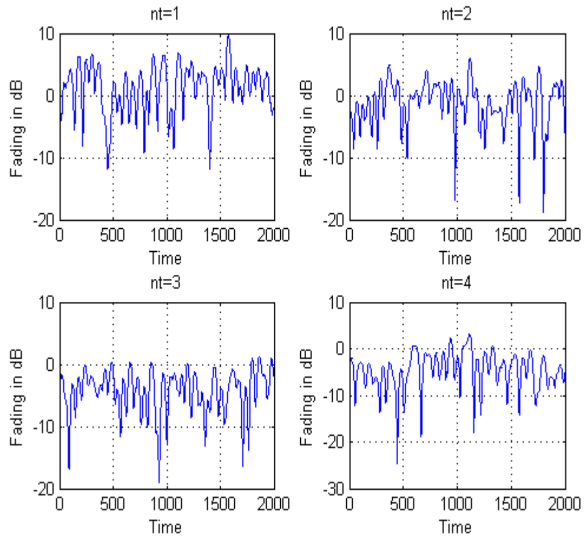

Fig-3 Fading envelop of MIMO channel

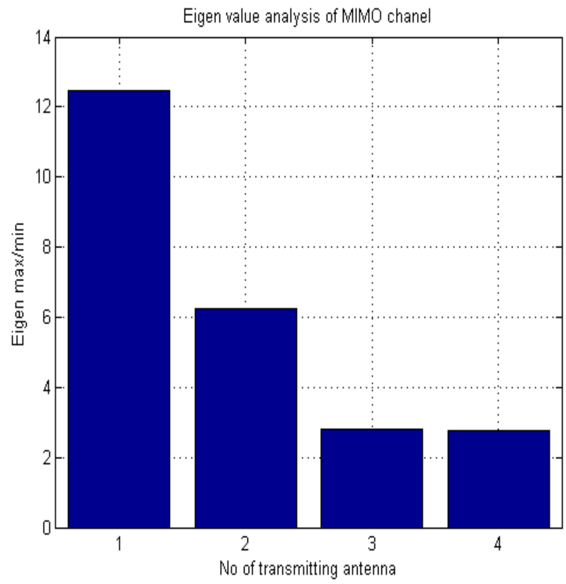

Fig-4 Eigen value analysis of MIMO channel

C. Noise analysis of MIMO systems

Fig-5 shows BER (bit error rate) performance of MIMO systems in presence of noise with N_R=2 and N_T=1,2,3,4.

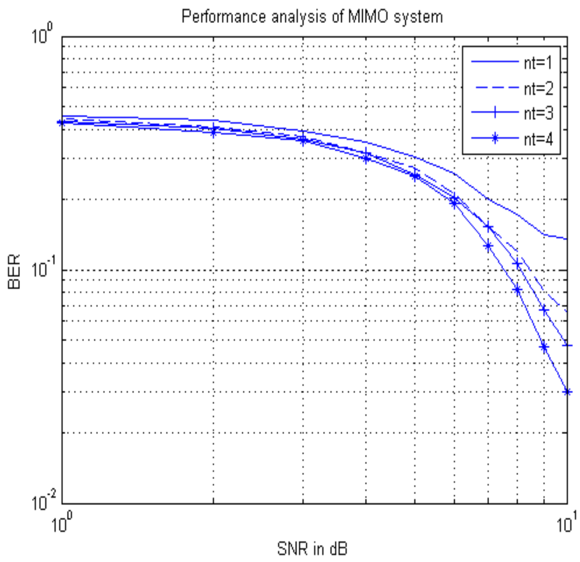

Fig-5 Noise analysis of MIMO systems

D. Bit error rate (BER) performance of MIMO wireless system with Decision feedback Equalizer (DFE)

Fig-7 presents a computer simulation of bit error rate(BER) performance of MIMO wireless system with Decision feedback equalizer (DFE) whose weights are updated using statistical parameters of fading channel

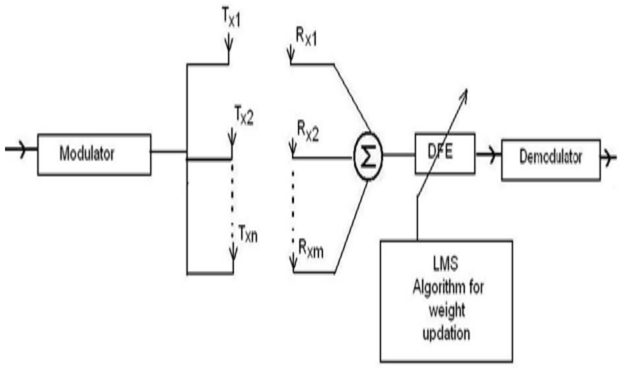

Fig-6: DFE based MIMO Communication system

In this simulation the information bits are QAM modulated and passed through a high time dispersive and frequency dispersive channel using multiple input multiple output (MIMO) scheme with $N_T=2, N_R=1,2,3$ by taking the receiver velocity as approx. 250Km/hour at signal frequency of 900MHz and three multipath components arriving at the receiver of path delays of 0,250 µs and 300µs with average path gains of 0dB,-2dB,-3dB respectively. The received signal is passed through a decision feedback equalizer in order to nullify the adverse effect of channel. The equalizer has 4 feed forward weights and 2 feedback weights where the weights are updated by LMS algorithm with step size of 0 .01.

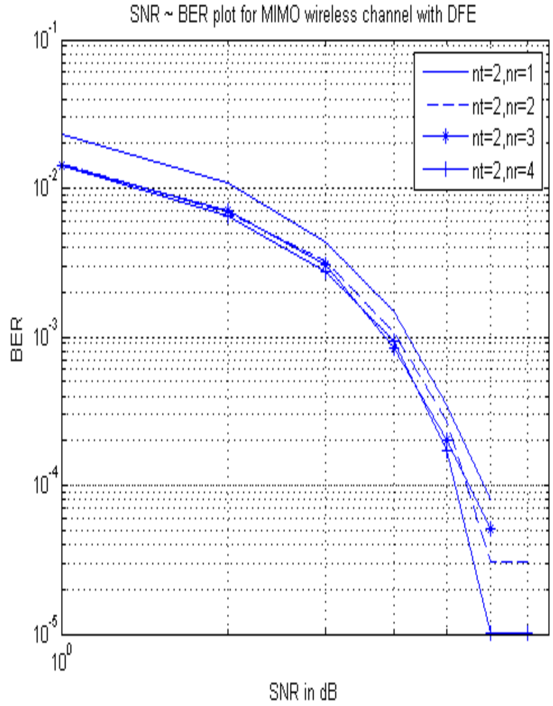

Fig-7 SNR ~ BER plot for MIMO wireless channel with DFE

VI. CONCLUSION

It is observed from the simulation that when the receiver velocity is about 250 km/hr, which is close to the standards of IEEE 802.20, the bit error rate (BER) performance of the system is quite satisfactory in presence of a Decision feed back equalizer with proper weight optimization. At the receiver bit error rate falls below 10^{-3} at SNR value of 4dB and 10^{-4} at SNR value of 6dB and the spectrum of MIMO channel response is flatter than individual path response. Finally the paper concludes that as the number of antenna increases the noise performance of the system improves also it concludes that the improvement is marginal comparing the performance of the systems with $n_t=2$ and $n_r=2$ hence it is advisable not to increase the number of receiving antenna more than two that increases the system cost which dominates the improvement of noise performance .The system performance further will be improved by using efficient error correction codes, OFDM and different spread spectrum techniques which will allow the future researcher to go forward.

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