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Improved TMSE with imperfect CSI in MU-MIMO

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Abstract: Although tremendous progress has been made in the past years on MU-MIMO systems, there still exist a number of problems. We believe that the most important one is related to the channel state information (CSI). In wireless communications "Evaluation of Imperfect CSI Criterion in Multi User MIMO Transceiver System" is still area of concern. Multiple transmit and receive antennas can be used to form multiple-input multiple-output (MIMO) channels to increase the capacity by a factor of the minimum number of transmit and receive antennas. In this paper, we propose a novel joint linear transceiver design for single-user multiple-input, multiple-output (SU-MIMO) systems and Multi-user multiple-input, multiple-output (MU-MIMO) systems employing improper signal constellations. A novel contribution in this paper is to derive a closed-form optimum linear pre coder and decoder for both the downlink and uplink MU-MIMO systems with improper modulation by solving the non convex optimization problem under total power constraint. The simulation results show that the performance of the proposed design is improved over the previous design.

Keywords: Channel State Information (CSI) ; Minimum Mean Square Error (MMSE) ; Single-User Multiple-Input Multiple-Output (SU-MIMO) ; Multi-User MIMO(MU-MIMO) ; Channel State Information Transmitter (CSIT) ; Channel State Information Receiver (CSIR) ; Signal-to-Noise Ratio (SNR) ; Bit Error Rate (BER) ;

I. INTRODUCTION

The scarcity of wireless bandwidth prompts the need for spectrally efficient methods. Using multiple transmit and receive antennas is an effective means to increase spectral efficiency. Recently, there has been considerable research in exploiting the space dimension through transmit diversity, space-time coding, and spatial multiplexing for multiple input multiple output (MIMO) systems that employ multiple transmit and/or receive antennas. In particular, spatial multiplexing can be used to transmit multiple data streams that can be separated using receiver signal processing.

Spatial multiplexing can significantly benefit from transmit pre coding when channel information is available at the transmitter side. In such cases, designing the appropriate pre coding strategy has been studied under a variety of system objectives. All of these studies, as with most of the MIMO system analysis, have been done for a single-user system that transmits multiple data streams. In the case of a multiuser MIMO system where users' transmissions interfere with each other, the system objectives should be optimized jointly for all users given the channels of all users. Thus, optimal designs of single-user systems are not directly applicable. In this context, optimum or near-optimum transmit strategies that maximize the information theoretic sum capacity of vector multiple access channels have been investigated.

A recent reference considers optimum transmit strategies relevant for a multicarrier scenario. Joint transmitter and receiver design is an effective interference management technique for multiuser systems. In particular, signature sequence optimization in CDMA systems, which aims to determine optimum transmitter sets to enhance the performance of the overall system, has been investigated for several channel models. Optimum CDMA signature sequence sets are identified, and iterative algorithms that converge to the optimum signature sequence set are proposed. For multipath CDMA systems, jointly optimum transmission schemes are investigated, and iterative algorithms to find the optimum signature sets are proposed.

An important strategy is to form use of the feedback info obtainable at the transmitter, the spatial multiplexing are often considerably like pre coder once the CSI is accessible at the transmitter. A joint pre coder and equalizer style for downlink MU-MIMO wireless communication is taken into account. A joint pre coder and decoder improvement technique is taken into account for transmission MU-MIMO systems with imperfect CSI at each the transmitter and receiver. The imperfect CSI considers the impact of the channel estimation error and channel correlations at the transmitter for transmission, and therefore the receiver for downlink. each the transmit and receive correlation info area unit thought of. just in case of correct modulation schemes, the transmitted image sequence is a correct complex random method (i.e., E[s j sTj] = 0). Samples of correct advanced modulation schemes area unit phase-shift keying (PSK) and construction AM (QAM) ones.

In explicit, recovery of the transmitted symbols is primarily based on each real and unreal half of the

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received signal. As such, the standard transceiver design supported proper modulation schemes is optimum. However, in several cases of sensible interest, the image sequence is AN improper random method (i.e., E[s j sTj] _= 0). The simplest examples of improper modulations area unit all real-valued ones. Once real- valued modulations area unit thought of, a common assumption is that the base band channel impulse response (CIR) and the additive noise area unit conjointly real valued and the recovery of the transmitted symbols is primarily based on solely real half of the received signal.

Our aim in this work is to design algorithms that converge to the optimum transmitters (pre coders) and receivers (decoders) for all users in a multiuser MIMO system when users transmit possibly multiple data streams. The channels are assumed to be flat and known at the receiver side, and we assume that there exists an error-free and low-delay feedback channel to each user. The transmitters and receivers are assumed to be linear for all users. A multiuser MIMO system can be viewed as a MIMO system with a channel matrix that consists of the channel gains of all transmitter-receiver pairs of all users where each user's symbols can be pre coded only by that user's transmitter antennas. We work with a system-wide performance measure for the joint optimization of transmitters and receivers, namely, the system-wide mean squared error (MSE). In contrast to receiver optimization for fixed transmitters, optimization of the individual MSEs is not equivalent to total MSE optimization. However, one can construct iterative algorithms for the cases where users transmit single or multiple symbols that monotonically decrease the total MSE under the given system constraints.

We projected a joint linear pre coder and decoder styles for downlink MU-MIMO systems with improper constellations beneath imperfect CSI, and show that the existing joint linear pre coder and decoder styles for downlink MU-MIMO systems are suboptimum for systems using improper modulation. The projected joint linear pre coding/decoding styles ar extended for the case of transmission MU-MIMO systems beneath imperfect CSI. A minimum TMSE design is formulated as a non convex optimization problem under a complete transmit power constraint and also the closed-form optimum linear pre coder and decoder for both the downlink and uplink MU-MIMO systems with improper modulation are determined by solving this non convex optimization problem.

II. JOINT LINEAR PRECODER AND DECODER

The Pre coded signals from all users are simultaneously transmitted across slowly-varying flat Rayleigh fading channels. The downlink channels to user j are collectively represented in matrix Hi. The conventional downlink transceiver design is formulated as a problem of minimizing the total mean squared error (TMSE) under the total transmits power constraint. The main objective of downlink MU-MIMO transceiver design is to find a pair of precoding matrix, (Fi), and decoding matrix, (Gi), to minimize E[ke(DL)k 2] subject to the total BS transmit power constraint. That is, the improved TMSE design for downlink MU-MIMO systems employing improper modulations. In both cases, the linear pre coder and decoder designs are accomplished with an iterative procedure. Significant performance gains of the proposed designs over other designs in terms of the system's BER was thoroughly demonstrated with simulation results.

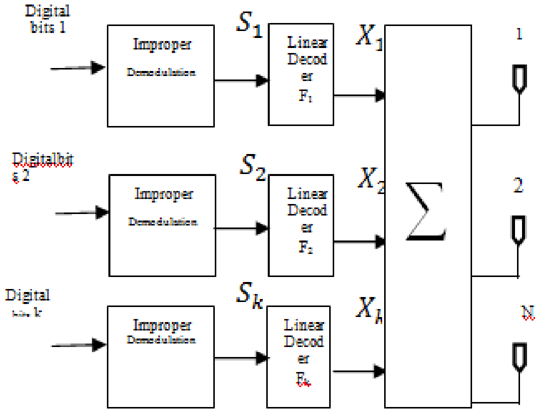

Fig 1: Transmitter in Multi user MIMO system.

A generic MIMO communication system model is shown in Fig. 1. The input bit streams are coded and modulated to generate symbol streams. The latter are then passed through the linear precoder which is optimized for a fixed and known channel. The precoder is a matrix with complex elements and can add redundancy to the input symbol streams to improve system performance (as will be explained later). The precoder output is launched into the MIMO channel through transmit antennas.

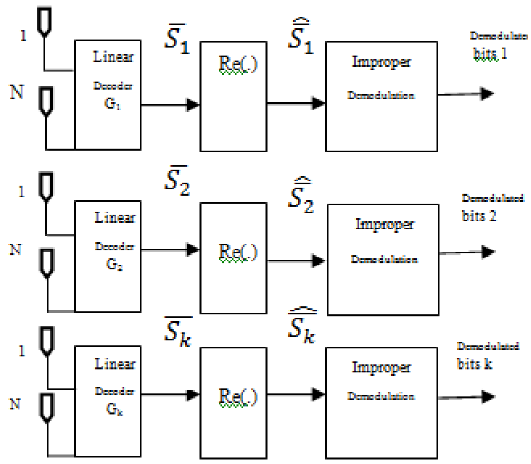

Figure 2: Receiver in Multi user MIMO system.

The signal is received by receive antennas and processed by the linear decoder, which is optimized for the fixed and known channel. The linear decoder also operates in the complex field and removes any redundancy that has been introduced by the precoder. In the present paper, we will focus on the boxed section of the communication system shown in Fig. 1, i.e., we will not consider coding and modulation design, but instead focus only on the design of the linear precoder and decoder.

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This section incorporates the joint linear precoder and decoder style for downlink MU-MIMO systems, that minimizes the TMSE beneath a constraint on total transmit power. It take into account a downlink MU-MIMO systems as delineated in Fig. one with NT transmit antennas transmits to K users every equipped with NR, j receive antennas at the same time over the same physical resources, wherever j = one, K. The user j has B j information streams that square measure denoted by B j × 1(B j ≤ min (NT, NR, j)) and therefore the total range of the transmit information streams is B = Kj=1 B j. The precoding matrix for the jth user is denoted as F j, j = 1, K with matrix size NT × B j. The information vectors square measure assumed to possess a similar statistics, output type jth precoder square measure painted as x j = F j s j .

The info symbols square measure assumed to be unrelated and have zero mean and unit energy, i.e., E[s j s Hj] = IB, j . The signal when the precoder satisfies the following total transmit power constraint:1

$$E\,[\|x\|^2] = \sum_{j=1}^{k}\left\|F_j s_j\right\|^2 = \sum_{j=1}^{k} Tr F_j F_j^H = P_T \quad \text{.......... (1)}$$

The Precoded signals are transmitted across a slowly-varying flat Lord Rayleigh attenuation channels. The signal received at the antennas of user i is given by [15,19], yi(DL) = Hi[Kj=1 F j s j]+ ni(DL) with matrix size NR,i × 1. and therefore the received vector is fed to the decoder Gi, i = 1, . . . , K which is a Bi × NR,i matrix. Then the resultant vector from output of decoder will be written as:

$$r_i^{(DL)} = G_i H_i^{(DL)}\left[\sum_{j=1}^{k} F_j s_j\right] + G_i n_i^{(DL)} \quad \text{..........(2)}$$

Where the NR,i × 1 vector ni(DL) represents spatially and temporally additive white Gaussian noise (AWGN) of zero mean and variance (σn(DL))2. The conventional downlink transceiver problem is formulated as minimizing the TMSE under the total transmit power constraint specified by (1):. In case of improper modulations, the same conventional optimization approach is failed to provide an optimum performance with improper modulations techniques such as BPSK and M-ASK, since the conventional optimization method produce a complex-values filter output.

$$\epsilon_i^{(DL)} = E\,[\,\left\|r_i^{(DL)} - S_i\right\|^2] \quad \text{. ....(3)}$$

$$= E\left[\left\|G_i Hi^{(DL)}\left[\sum_{j=1}^{k} F_{j=1} s_j\right] + G_i n_i^{(DL)} - s_i\right\|\right]^2 \quad \text{.........(4)}$$

The decision of a system with improper constellation is based on only real part of the output. And it is pointed out in [20], in which a novel linear transceiver strategy for SU-MIMO systems with improper constellations is proposed. In this paper, the same strategy is extended to the case of both downlink and uplink MU-MIMO systems with imperfect CSI.

A. DOWNLINK

For the case of imperfect CSI, the estimated channel information is not the same as the instantaneous channel information, where the case of perfect CSI it is same. So that the downlink MU-MIMO transceiver design under perfect CSI is no longer optimum for the systems operating with estimated channel information. The impulse response respective downlink users are represented as follows

$$H_j^{(DL)} = \begin{bmatrix} h_{1,1}^{(DL)} h_{1,2}^{(DL)} \dots\ h_{1,N_T}^{(DL)} \\ h_{2,1}^{(DL)} h_{2,2}^{(DL)} \dots\ h_{2,N_T}^{(DL)} \\ \cdot \\ \cdot \\ \cdot \\ h_{N_R,j,1}^{(DL)} h_{N_R,j,2}^{(DL)} \dots\ h_{N_R,j,N_T}^{(DL)} \end{bmatrix} \quad \text{.......... (5)}$$

We have used the channel model in [22], channel of the jth user is denoted as H(DL) j = RR1/,2j Hw(DL, j)RT1/2, where Hw(DL, j) is a spatially white matrix whose entries are independent and identically distributed (i.i.d.) Nc(0, 1) and j = 1, . . . , K. The matrices RT and RR, j represent the normalized transmit and receive correlations (i.e., with unit diagonal entries), respectively. Both RT and RR, j are assumed to be full-rank and known to both the transmitter and the receiver. In general feedback information are not perfect due to feedback delays and errors, transmitter can only get an erroneous estimate Hˆ (DL) j of the true channel H(jDL). When the channel is spatially correlated, the jth user channel error model can be written a

$$H_j^{(DL)} = \widehat{H}_j^{(DL)} + E_j^{(DL)} \quad \text{......... (6)}$$

$$H_j^{(DL)} = R_{R,j}^{1/2}\widehat{H}_{w,j}^{(DL)} R_T^{1/2} + R_{e,R,j}^{1/2} E_{w,j}^{(DL)} R_T^{(1/2)} \quad \text{......... (7)}$$

Information theory highlights some key aspects of MU-MIMO systems over SU-MIMO systems. The MU-MIMO systems can offers some significant advantages for capacity gain in terms of data rate over SU-MIMO systems and also it can provide advantages by supporting more number of users.

Firstly, it is well known that when the channel matrix is full rank, the capacity gain of SU-MIMO systems is scaled by min{ NT, NR} at high Signal-to-noise ratio (SNR), where NT and NR are the number of antennas at the transmitter and the receiver, respectively.

$$e^{(DL)} = \hat{r}_i^{(DL)} - s_i \quad \text{.......... (8)}$$

The TMSE function for joint transceiver design can be evaluated for improper modulation as follows

$$E\left[\left\|e^{(DL)}\right\|^2\right] = E\left[\left\|\widehat{r}_i^{(DL)} - s_i\right\|^2\right] \quad \text{.......... (9)}$$

Substitute the value of rˆ(DL) i in (9), we get

$$E\left[\left\|e^{(DL)}\right\|^2\right] = E$$

$$\left[\left\|\Re\left(G_i\left(\widehat{H}_i^{(DL)} + E_i^{(DL)}\left[\sum_{j=1}^{k} F_{j=1} s_j + G_i n_i^{(DL)} - s_i\right]\right)\right)\right\|^2\right] \quad \text{.......... (10)}$$

From the assumptions on the statistics of the channel, noise and data, one has E[sisiH] = E[sisiT] = IBi , E[ni(DL)(ni(DL)) H] = (σn(,DLi))2INT and E[ni(DL)] = E[ni(DL)(ni(DL)) T] = E[(ni(DL))∗(ni(DL)) H] = 0. Using these facts and after some manipulations (10) can be simplified to

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$$\mathrm{E}\left[\left\|e^{(DL)}\right\|^2\right]$$

$$r\left\{\begin{array}{c} 0.25G_i\widehat{H}_i^{(DL)}\left[\sum_{j=1}^{k}F_jF_j^{\mathcal{H}}\right]\left(\widehat{H}_i^{(DL)}\right)^{\mathcal{H}}G_i^{\mathcal{H}} \\ +0.25G_i\widehat{H}_i^{(DL)}\left[\sum_{j=1}^{k}F_jF_j^{\mathcal{T}}\right]\left(\widehat{H}_i^{(DL)}\right)^{\mathcal{T}}G_i^{\mathcal{T}} \\ +0.25R_{e,R,i}G_i^{\mathcal{H}}\left[\sum_{j=1}^{k}\left(Tr\left(R_TF_jF_j^{\mathcal{H}}\right)\right)\right]\sigma^2{}_{ce,i} \\ +0.25G_i\widehat{H}_i^{(DL)}\left[\sum_{j=1}^{k}F_jF_j^{\mathcal{T}}\right]\left(\widehat{H}_i^{(DL)}\right)^{\mathcal{T}}G_i^{\mathcal{T}} \end{array}\right\} \qquad 11)$$

Initialize F z, z = 1, . . . , K, is chosen from the Bz × Bz upper sub-matrix of Fz is a scaled identity, while all the other remaining entries of Fz are zero. The joint design is formulated into an optimization problem, and the optimum closed-form precoder and decoder are derived under both the scenario of perfect and imperfect CSI. A Joint Optimization of Precoder and Decoder in Multiuser MIMO Systems under perfect CSI is also proposed in our previous work . In general, the wireless channels are time-varying. As such, obtaining the channel information at both the transmitter and receiver can be difficult. Usually the obtained channel information is not the same as the instantaneous channel information.

B. UPLINK

The channel matrix between the jth user and the BS in uplink contains the impulse response h(UL) and it can be represented by Each of the transmitter is equipped with NT, j antennas and the receiver is equipped with NR. Linear precoder of the user j at MS is denoted as V j, j = 1, . . . , K with matrix size NT, j × B j and the decoder at BS to received the signal from ith user is represented as Wi, i = 1, . . . , K. Data vectors are assumed to have the same statistics, output form jth precoder is represented as x j = V j s j. The signal after the precoder satisfies the power constraint specified as in (1). The proposed TMSE matrix for user i is defined by

$$\mathrm{E}\left[\left\|\mathrm{e}^{(\mathrm{UL})}\right\|^2\right] = \mathrm{E}\left[\left\|\Re\left(\mathrm{W_i}\left[\sum_{j=1}^{K}\left(\widehat{\mathrm{H}}_j^{(\mathrm{UL})} + \mathrm{E}_j^{(\mathrm{UL})}\right)\mathrm{V_j s_j}\right] + \mathrm{W_i n_i^{(UL)}}\right) - \mathrm{s_i}\right\|^2\right]$$

$$\begin{aligned} = \mathrm{Tr}\Bigg\{ & 0.25\mathrm{W_i}\left[\sum_{j=1}^{K}\hat{\mathrm{H}}_j^{(\mathrm{UL})}\mathrm{V_j}\mathrm{V_j^{\mathcal{H}}}(\hat{\mathrm{H}}_j^{(\mathrm{UL})})^{\mathcal{H}}\right]\mathrm{W_i^{\mathcal{H}}} \\ & + 0.25\mathrm{W_i}\left[\sum_{j=1}^{K}\hat{\mathrm{H}}_j^{(\mathrm{UL})}\mathrm{V_j}\mathrm{V_j^{\mathcal{T}}}\left(\hat{\mathrm{H}}_j^{(\mathrm{UL})}\right)^{\mathcal{T}}\right]\mathrm{W_i^{\mathcal{T}}} - 0.5\,\mathrm{W_i}\left[\sum_{j=1}^{K}\hat{\mathrm{H}}_j^{(\mathrm{UL})}\mathrm{V_j}\right] \\ & + 0.25\,\mathrm{W_i}\,\mathrm{R_{e,R,j}}\mathrm{W_i^{\mathcal{H}}}\,\mathrm{Tr}\left(\left[\sum_{j=1}^{K}\mathrm{V_j}\mathrm{V_j^{\mathcal{H}}}\right]\right)\sigma_{\mathrm{ce,i}}^2 \\ & + 0.25\mathrm{W_i}\mathrm{W_i^{\mathcal{H}}}\left(\sigma_n^{(\mathrm{UL})}\right)^2 \\ & + 0.25\mathrm{W_i^*}\left[\sum_{j=1}^{K}\left(\hat{\mathrm{H}}_j^{(\mathrm{UL})}\right)^*\mathrm{V_j^*}\mathrm{V_j^{\mathcal{H}}}\left(\hat{\mathrm{H}}_j^{(\mathrm{UL})}\right)^{\mathcal{H}}\right]\mathrm{W_i^{\mathcal{H}}} \\ & + 0.25\mathrm{W_i^*}\left[\sum_{j=1}^{K}\left(\hat{\mathrm{H}}_j^{(\mathrm{UL})}\right)^*\mathrm{V_i^*}\mathrm{V_i^{\mathcal{T}}}\left(\hat{\mathrm{H}}_j^{(\mathrm{UL})}\right)^{\mathcal{T}}\right]\mathrm{W_i^{\mathcal{T}}} - 0.5\mathrm{W_i^*}\left[\sum_{j=1}^{K}\left(\hat{\mathrm{H}}_j^{(\mathrm{UL})}\right)^*\mathrm{V_j^*}\right] \\ & + 0.25\mathrm{W_i^*}\mathrm{R_{e,R,j}^*}\mathrm{W_i^{\mathcal{T}}} \times \left\{\mathrm{Tr}\left(\mathrm{R_{T_i}}\left[\sum_{j=1}^{K}\mathrm{V_i}\mathrm{V_i^{\mathcal{H}}}\right]\right)\right\}^*\sigma_{\mathrm{ce,i}}^2 \\ & + 0.25\mathrm{W_i^*}\mathrm{W_i^{\mathcal{T}}}\left(\sigma_n^{(\mathrm{UL})}\right)^2 - 0.5\left[\sum_{j=1}^{K}\mathrm{V_j^{\mathcal{H}}}\left(\hat{\mathrm{H}}_j^{(\mathrm{UL})}\right)^{\mathcal{H}}\right]\mathrm{W_i^{\mathcal{H}}} \\ & - 0.5\left[\sum_{j=1}^{K}\mathrm{V_j^{\mathcal{T}}}\left(\hat{\mathrm{H}}_j^{(\mathrm{UL})}\right)^{\mathcal{T}}\right]\mathrm{W_i^{\mathcal{T}}} + \mathrm{I_{B_i}}\Bigg\} \end{aligned}$$

………… (12)

The performance of the proposed joint transceiver design is compared with the novel linear precoding scheme in [18] for MU-MIMO systems employing the improper constellation. This comparison is to illustrate the benefit of performing decoder optimization in MU-MIMO systems which is not considered in [18].

The proposed joint linear transceiver is also compared with the previously-designed joint linear transceiver strategy in [19], but without taking into account specific property of improper modulations.

IV. RESULTS

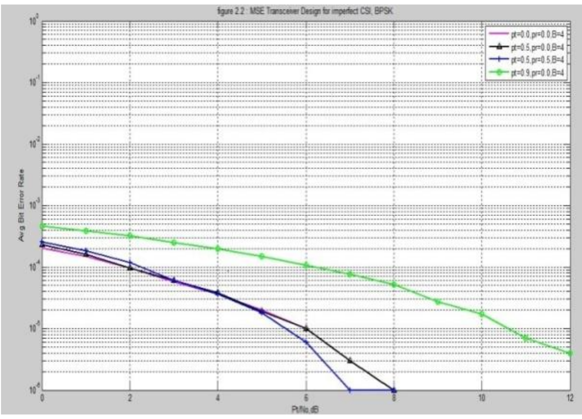

FIG3: SU-MIMO MSE transceiver design for IMPERFECT CSI, BPSK

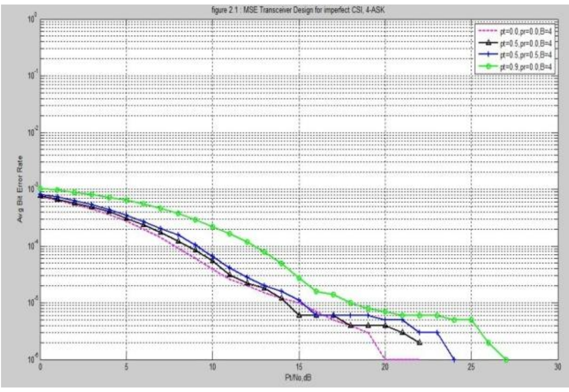

FIG 4: SU-MIMO MSE transceiver design for imperfect CSI, 4-ASK

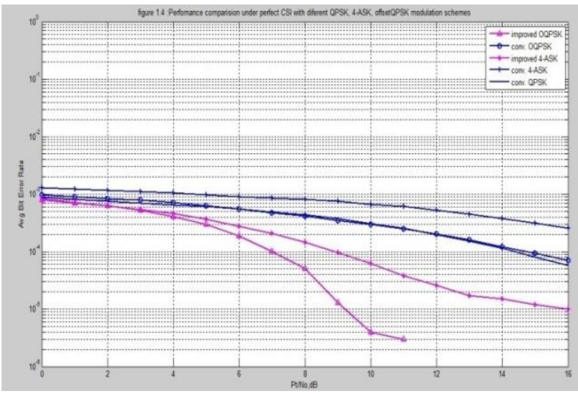

FIG 5: SU-MIMO Performance comparison under perfect CSI with different QPSK, 4-ASK, offset QPSK modulation

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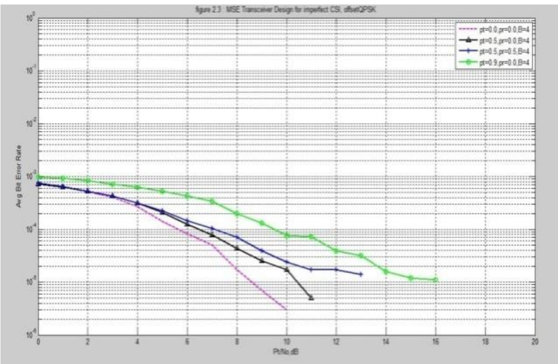

FIG 6: MU-MIMO MSE Transceiver Design for Imperfect CSI, OFFSETQPSK

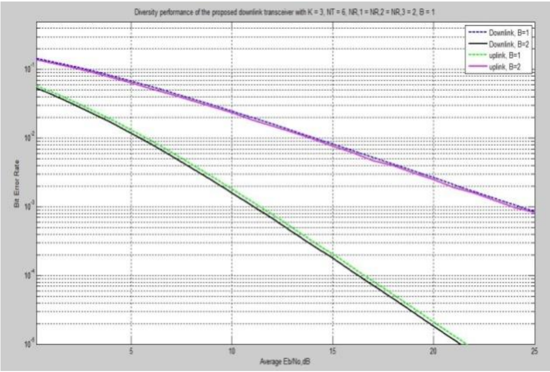

FIG 7: MU-MIMODiversity performance of proposed Down -link transciever with $K=3, N_T=6, N_{R1}=N_{R2}=N_{R3}=2, B=2$

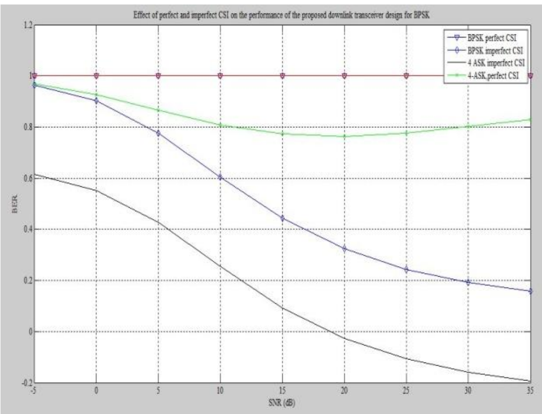

FIG 8**:** Effect of perfect & imperfect CSI on performance of proposed downlink transceiver design for BPSK and 4-ASK in MU-MIMO

V. CONCLUSION

In wireless communications “Evaluation of Imperfect CSI Criterion in Multi User MIMO Transceiver System” is still area of concern. Although so many algorithms proposed in the literature to tackle this issue of “Multi User MIMO Transceiver System”. Both the transmission and downlink MU-MIMO systems, that is utilized with improper constellations like binary section shift-keying and M-ary amplitude shift-keying area unit thought of. A minimum TMSE style is developed as a nonconvex improvement downside below a complete transmit power constraint and therefore the closed-form optimum linear pre coder and decoder for each the downlink and transmission MU-MIMO systems with improper modulation area unit determined by finding this nonconvex improvement downside. a completely unique contribution during this paper is to derive a closed-form optimum linear pre coder and decoder for each the downlink and transmission MU-MIMO systems with improper modulation by finding the nonconvex improvement downside below total power constraint.

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