Channel Estimation of massive MIMO Using Code Shift Keying Pilot Symbols (CSK-PS)

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Abstract: The increasing demand for bandwidth by mobile users in wireless communication becomes a challenging issue to the research community. Several theories and models have been proposed to mitigate this issue. The most effective and commonly used approach to resolve the demand shortage of bandwidth is the massive Multi-Input and Multi-Output (MIMO) approach in which the number of transmitting and receiving antennas is placed at the base station (BS) to fulfill the issue of bandwidth. However, this technique suffers from various issues in estimating the channel due to interference, beamforming, and pilot contamination. In this paper, a novel channel estimation technique is being proposed using Code Shifting Keying symbols as pilot signals (CSK-PS) to minimize the pilot contamination. These signals are used as reference signals and the received signal is detected. The presented approach reduces the interference (pilot contamination) and improves the channel estimation in massive MIMO networks by using the modified expected propagation estimation method (MEPE). The presented approach is validated using mat-lab.

Index Terms: Massive MIMO, Pilot symbols, code shift keying, channel estimation, mat-lab

1. Introduction

Wireless communication gains importance around the globe due to numerous applications in the field of communication engineering (i.e., Wi-Fi, T.V remote control, security systems, cell phones, etc.). The tremendous increase of mobile users in the field of wireless communication has made the network connection greedy to bandwidth and thirsty to the channel estimation. Various approaches and techniques have already been proposed to alleviate these issues in computer networks [1,2,3,4]. All these approaches either improve the bandwidth by optimizing the size of the buffer or by optimizing the network parameters (i.e., queuing delay, prorogation delay, energy, and traffic intensity) for the fourth generation. As a result of which bandwidth can be utilized efficiently but cannot be increased. In the fifth generation and beyond networks the issue of bandwidth and channel estimation has been mitigated by the use of massive MIMO [5,6,7]. In massive MIMO networks numbers of transmitting and receiving antennas are placed at the base station (BS) to resolve the bandwidth problem in the network. No doubt this network improves the bandwidth up to a certain extent but gave birth to other issues in the network (i.e., Pilot contamination, beamforming, and interference). So, estimation of the channel now becomes the new challenge to the research society.

Few models and techniques have been proposed to overcome the challenge of channel estimation such as Panos N. Alevizos et al and Chen, X et al [8, 9], however, both the two approaches fail to overcome the pilot contamination problem within the network. Thus, may not be the optimum solution to the network. In [10] the authors discussed the traffic management technique for 5G systems by employing 5Ge base-station which is e-commerce-oriented and using queuing technique based on multi-pipeline. Viacheslav al [11, 12] presented mathematical models for the application of 5G for evaluation of different parameters for session interaction and discussed various functional scenarios in IoT systems. Hence the network needs some novel approach to diminish the challenge of pilot contamination.

The following highlights the main aspects of the proposed approach:

- Obtaining random and orthogonal Pilot sequences by CSK technique to mitigate pilot contamination.
- Optimized channel estimation using MEPE method by using the obtained pilot sequences as reference signals.

- Better performance of the proposed technique when SNR is high.

In this paper an approach using Code Shift Keying Pilot Symbols (CSK-PS) is being presented, that reduces the pilot contamination problem as CSK method generates orthogonal signals for given symbol and also optimizes the estimation of the channel using MEPE for Massive MIMO systems. This channel estimation technique uses matrix of correlation and it is most suitable for imperfect channel state information (CSI) as in practice there is no perfect CSI availability. This estimation is better than Minimum Mean Square Error (MMSE) and Expected propagation (EP) technique as in MMSE Symbol error rate (SER) is more at higher Signal to noise ratio (SNR) (as large numbers of antennas are present) and EP technique requires perfect CSI for estimation which is impractical. In this paper an approach using Code Shift Keying Pilot Symbols (CSK-PS) is being presented, that not only reduces the pilot contamination problem but also optimizes the estimation of the channel using MEPE for Massive MIMO systems.

The remainder of the paper is organized as follows. Section 2 describes the works done in the similar lines of the paper. In section 3 we represent the model, which describes the development and implementation of the proposed approach. Section 4 presents, the simulation results of the proposed system and Section 5 summarizes the development of proposed system and future prospective.

2. Related Work

Xin Su et al [13] proposed a model in which the author tries to reduce the feedback that can enhance the channel estimation. In this method more focus was given towards the transmission of the downlink in massive MIMO networks, here the authors design the codebook in which multiple code words have been allotted to both the transmitter and the receiver. Every codeword in trans-receiver represents a state that can optimize the channel information by minimizing the interference using the pre coding technique. However, the presented approach increases the complexity and enhances the delay so may not be the optimum solution in real-time problems. Mohammad Ghasemi et al [14] proposed an algorithm to reduce the pilot contamination problem in massive MIMO using a linear zero-forcing algorithm, however, this algorithm may not give the optimum solution of channel estimation as it is independent of the channel state information.

Wu, Y et al [15] proposed Distributed Non-Orthogonal design for massive MIMO systems in which the authors optimize the bandwidth, but non-orthogonal signals resulted in interference and degrade the performance of the network. Chataut, R.and Akl, R [16] proposed a technique in which the authors reuse the pilot by sensing the user environment. On the other hand, this approach maximizes the delay due to the fact of continuous monitoring of the user conditions for the channel, so may not be the optimum in real-time applications. Moqbel and Wangdong [17] suggested an approach to estimate the channel using Least Square (LS) and Minimum Mean Square Error (MMSE) Algorithm, however, this algorithm improves the mathematical complexity and reduces the throughput of the network between end-users. Wu [18] provided a design using a cyclic shift pilot scheme to enhance the channel estimation property. But this scheme used a table-driven mechanism and improves the delay, therefore may not be optimum for massive MIMO networks. Olabode Idowu-Bismark et al [19] proposed a new novel methodology for achieving high channel capacity in massive MIMO systems for wireless backhauling and proposed generalized spatial modulation aided hybrid beam forming (GSMA-HBF) for high energy efficiency. Author in [20], proposed support detection algorithm for efficient channel estimation for 5G technology using massive MIMO systems and SD algorithm channel estimation divided into sub issues. Nirmalkumar S et al [21] proposed smart MIMO channel estimation in downlink 4G systems and proposed closed loop spatial multiplexing (CLSM) for better performance in ANN networks.

In [22,23,24] the authors discussed a method to reduce the pilot contamination by using the improvised soft pilot reuse (SPR) technique and Weighted-Graph-Coloring-Based Pilot Decontamination (WGCB-PD). However, the combination of these two methods is complex and increases the delay as each of them has its disadvantages. The SPR scheme has to calculate the coefficient of large-scale fading of each user which may not be appropriate as in 5G network real time application as huge numbers of users communicate and calculating the coefficient for each user increases the delay. The improvised version of SPR may not remove the pilot contamination completely. In WGCB-PD calculation of potential pilot contamination between two users may be complex for a large number of users. Peng et al. [25] briefly discussed the effect of pilot contamination on channel estimation. Matta JCP and Siddiah P [26] presented a modified OMP algorithm with reduced feedback, in which authors tried to optimize the feedback to estimate the channel.

This paper presents a solution to the pilot contamination by the use of code shift keying pilot symbols (CSK-PS) which produces orthogonal signals in a wide range such that, if reused, the interference is negligible. This method improves the performance of the system and helps to find the channel matrix elements to improve the channel estimation and minimize the complexity and delay, therefore can be used to mitigate the pilot contamination crisis in the massive MIMO system.

3. Proposed Approach

Code shift keying is M-array orthogonal signaling, a spread spectrum technique that is used to generate the cyclically shifted symbols in a digital signal [27]. FIn this approach code shift, the keying technique is employed to generate the pilot sequence using binary hex codes to reduce pilot contamination. Many sequences can be generated with different combinations of hex codes such that the new orthogonal sequence will not interfere with any of the previously generated sequences (the distance will be far enough even if the sequence is reused). Conventionally CSK symbols are generated using the pseudo-random (PR) sequence but it might be difficult to generate the same PR sequence at the receiver. To improve the synchronization binary hex code with Differential Manchester (DM) line coding is used in this approach. The symbols in CSK are generated using base symbol B_s which on cyclic shift gives the sequence of symbols i.e. S_s which is multiplied by the conventional Pilot sequence to generate the pilot sequence of the proposed approach.

A. Generation of B_s and S_s Symbols

In the presented approach B_s is considered as 0 0 0 1 (randomly from binary hex codes), however, one can use any other digital bits to generate one's desired symbols. The number of bits represented by B_s is 4 and hence the chip size is also 4. The number shifts Q that can be given to B_s can be represented as

$$Q = 2^R \tag{1}$$

$$R = \log_2(Q) \tag{2}$$

Where R is the bits per CSK symbol to be transmitted

Different B_s sequence has a period length of D_l, which spans over F chips. The sequence S_s can be formed by concatenating all the combinations of B_s (considering only the first 4-bits as chip size is 4). To make the symbol more compact differential Manchester line coding is used to generate B_s and S_s as continuous 0's and 1's occurs when a cyclic shift to the code is performed. Hence $S_s(t)$ can be represented by

$$S_s(t) = \sum_{i=0}^{M-1} M_l(i).rect(\frac{t-iC_v}{C_v}) \tag{3}$$

Where

$$M_l(i) = B_s(\text{mod}[i-i_1, F])$$
$$C_v = chip\ interval$$
$$l = 0,\ 1...P\text{-}1,\ (here\ P=4)$$

If the base symbol is considered at n=1 i.e. 0001, the number of possible shift given is P=4 and can be represented as

$$B_s = 0001 \begin{cases} 0001 \\ 1000 \\ 0100 \\ 0010 \end{cases} \tag{4}$$

The bits transmitted per symbol is R=2 (from equation 1). Figure 1and 2 show the symbols of B_s and S_s respectively.

The CSK (2, 1) is used in this approach as each symbol is repeated only once and per symbol two bits are transmitted. As the spectrum utilized is more while signal power is constant, the interference is reduced and more bits can be transmitted. If the pilot bits are increased, channel estimation is improved.
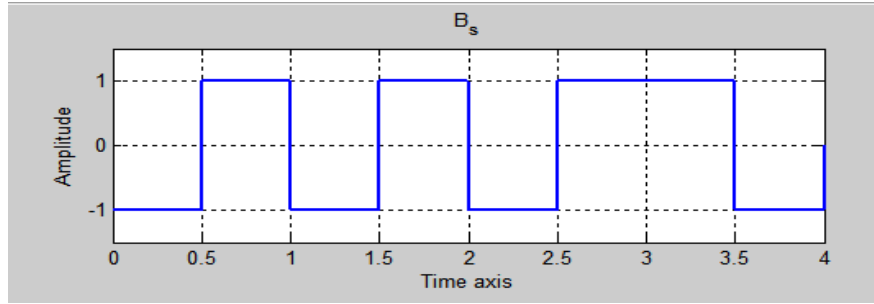
Fig.1. Base Symbol of B_s (1).

Only the authenticated user could decode it and retrieve the original information from the signal received.
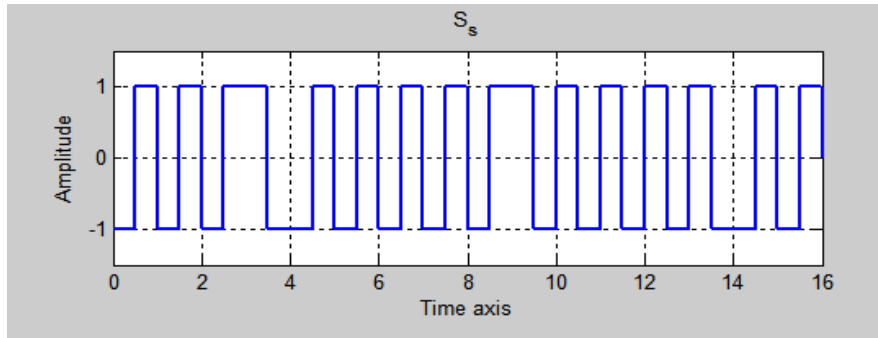
Fig. 2. Concatenation of Cyclic shifted codes (S_s).

The block diagram of the pilot encoder and decoder blocks can be represented in Fig.3 and Fig.4 respectively. Hex codes starting from 0-15 (i.e. 0000 - 1111) total of 64-bits are used in the block of hex code generator (HCG) (see Fig.3) instead of PR generator to mitigate the synchronization problem at the receiver persisted when PR sequence was used, however, one can increase these bits by using some other codes.

$$HCG(n) = \prod_{0}^{15} n \tag{5}$$

(Represented in 4-bit binary system)
where n is the concatenation series of sequence 0, 2...15 represented in binary 4-bit hex value (i.e., 0 0 0 0…...1 1 1 1).
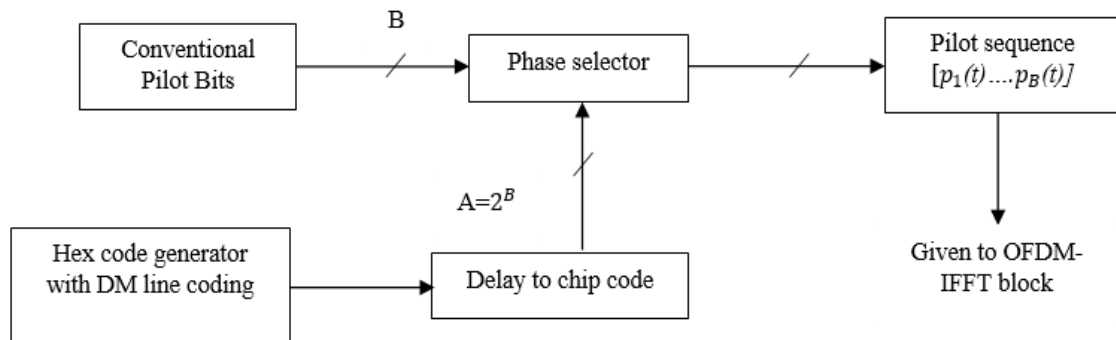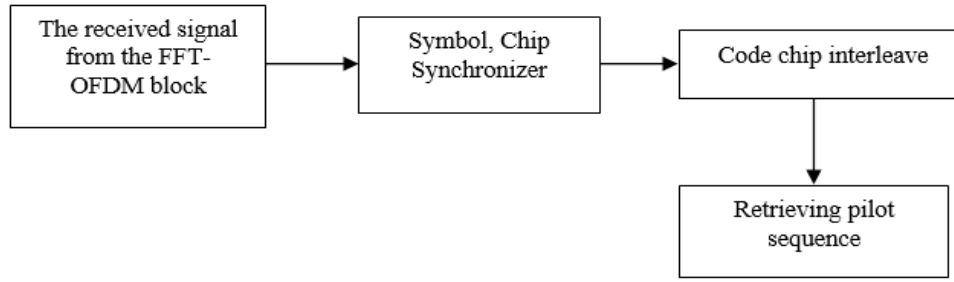

Fig. 3. Pilot encoder block.

Fig. 4. Pilot decoder block.

The processor speeds are improved tremendously and hence the excess and simple hardware blocks will hardly affect the entire system. The pilot contamination is minimized using the CSK technique and hence the channel estimation is optimized when compared to existing approaches. In the presented approach Modified Expectation Propagation Estimation (MEPE) is used to estimate the channel [28]. It follows an algorithm based on an iterative method to search for the finest approximation to a preferable distribution from the group of traceable distribution. Unlike conventional EPE, MEPE utilizes correlated covariance. Though the pilot contamination is reduced the other factors (i.e., quantization and aging error) still have their effect on the channel state information (CSI). Therefore, imperfect channel estimation is considered in this approach.

B. Model of the system for MEPE

In a massive MIMO system consider 'Z_t' and 'Z_r' are transmitter and receiver antennas respectively. At each channel usage, the transmitter vector symbols are given as $v = [v_1, v_2, ...v_{Z_t}] \in W^{Z_t \times 1}$ (W represents the set of real numbers) where the elements of the vector form a constellation (β_m is the union of the real and imaginary constellation) of symmetric M-ary Quadrature amplitude modulation (QAM) with an average energy of 0.5'G_e'. The channel matrix is denoted by 'H' where $H \in W^{Z_t \times Z_{r1}}$ with the complex symmetric zero-mean distribution of Gaussian having a matrix of covariance as D_h.

Therefore, the vector received can be represented as $y = Hv + n$, where $n \in W^{Z_r \times 1}$ is a vector of additive noise. $SNR = 10\log_{10}(\frac{Z_t G_e}{\sigma_n^2})$ The covariance matrix of this noise can be represented as

$$D_n = \begin{pmatrix} 0.5\bar{D}_n & 0 \\ 0 & 0.5\bar{D}_n \end{pmatrix} \tag{6}$$

The posteriori probability density function (p_d) is expressed as

$$p_d(y/y, H) \propto N(y/H_v, D_n)\prod_{j=1}^{Z_t} I_{v_j} \tag{7}$$

For correlated noise channels, the factorized structure of eq. 7 is exploited by exponential group distribution and improves each of the factors by employing matching moment conditions. Therefore $I_{v_{j \in \beta_m}}$ is replaced by Gaussian p_d i.e. $r_j(v_j) = N(v_j/k_j, \theta_j)$ where k_j is the mean and $\theta_j \geq 0$ is the variance of the distribution. Therefore eq. 7 is approximated by $r(v)\alpha N(y/H_v, D_n)\prod_{j=1}^{Z_t} r_j(v_j)$. By using [23], after several iterations the final value for the estimation of symbols transmitted can be obtained as $\hat{v} = [\hat{v}_1, \hat{v}_2, ...\hat{v}_{Z_t}]^T$ can be obtained as (R and l denotes the real and imaginary parts respectively

$$R(\hat{v}_j) = \arg\min |v - \varphi(j)|^2 \tag{8}$$

where $v \in R(\beta_m)$

$$l(\hat{\gamma}_j) = \arg\min |v - \varphi(Z_t + j)|^2 \qquad (9)$$

where $v \in l(\beta_m)$, j = 1,2,... Z_t,

$$\varphi = V(H^T D_n^{-1} y + k), \ V = (H^T D_n^{-1} H + U)^{-1}, \ k = [{k_1}/{\theta_1}, {k_1}/{\theta_1}, \dots {k_{2Z_t}}/{\theta_{2Z_t}}]^T \quad \text{and}$$

$$U = dig[{1}/{\theta_1}, {1}/{\theta_2}, \dots {1}/{\theta_{2Z_t}}]$$

4. Simulation Results

Here we present our simulation results. Initially the channel matrix 'H' is generated with covariance matrix D_h. The block of information which is to be transmitted through this channel is formed by inserting the pilot bits first, and then data bits are inserted. The receiver estimates H using pilot bits that are known to it and uses H to decode the data bits from the received signal. Signal to noise ratio $SNR = 10\log_{10}({Z_t G_e}/{\sigma_n^2})$ dB and Symbol error rate (SER) is observed in each graph. The Smoothing parameters are used to stabilize first and second moments for moment matching [23]. The rest of the parameters are shown in Table 1. Fig 5 represents the variation of bit error rate (BER) with the number of antennas.

Table 1. Simulation parameters.

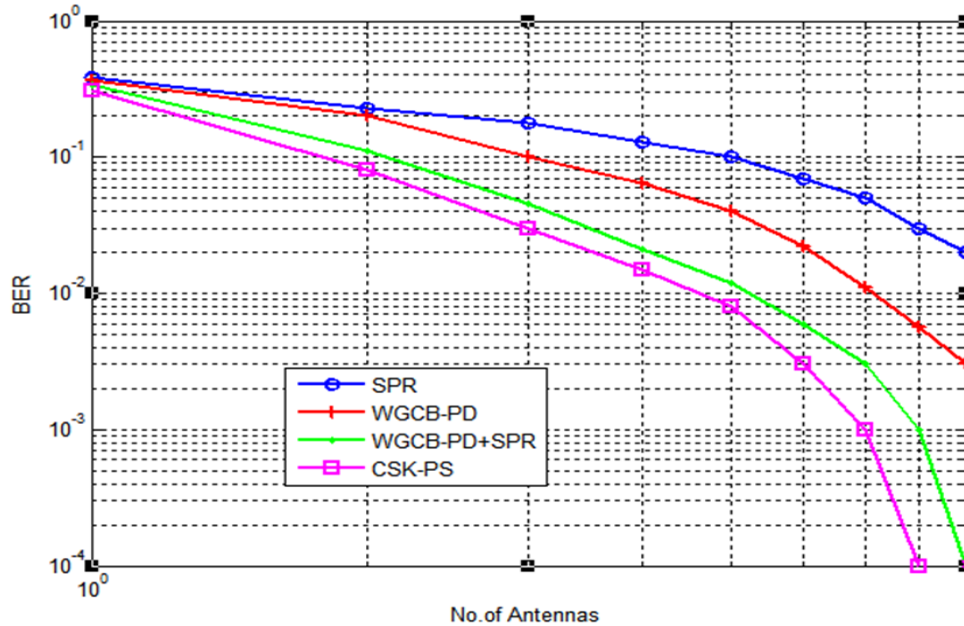| S.No	Parameter	Value/type
1	Modulation	16-QAM
2	Kronecker parameter for the channel	$z_t = 0.1$
		$z_r = 0.5$
3	Smoothing parameters	$\gamma = 0.2$
		$\delta = 5 \times 10^{-7}$
4	Channel	Imperfect & uncorrelated
5	No. of antennas in a base station	32 – 2048
6	Power of transmission	5 – 25 dB
7	Spectral efficiency loss	0.06
8	Fading of shadowing	7 dB

Fig.5. Number of Antennas vs BER (Bit Error Rate)

From the Fig.5, it is observed that the proposed technique performs better as the number of antennas increases. The BER of the proposed CSK-PS technique is less when compared to other pilot designing methods (SPR, WGCB-PD, WGCB-PD+SPR). As the pilot signals obtained in the proposed approach are orthogonal which helps to optimize the channel estimation by reducing the error.
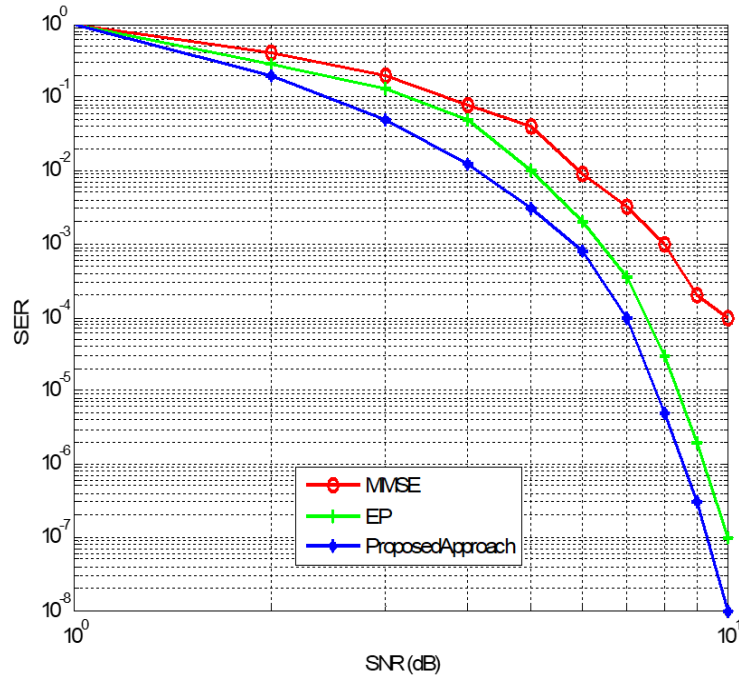
Fig.6.SNR versus SER with $Z_t = Z_r = 32$.

The number of transmitting and receiving antennas is varied and graphs are plotted between SER and SNR as represented in Fig.6 and Fig.7. In Fig.6, 32×32 massive MIMO system is used and in Fig.7, 64×64 massive MIMO system is used to the dominance of errors in channel estimation. For high SNRs, the proposed estimator is efficient as it uses the appropriate covariance matrix of error and orients its area of search towards the direction of error estimation.

The proposed channel estimation technique i.e. (MEPE) is compared with Minimum mean square error (MMSE) and Expectation propagation (EP) channel estimation techniques. For EP and MEPE nearly 12 iterations are carried out and from the Fig.7, it is clear that the proposed technique outperforms the other two methods and gives minimum SER. The MEPE is more sensitive to errors in CSI when compared to conventional techniques as the pilot contamination is reduced by CSK.
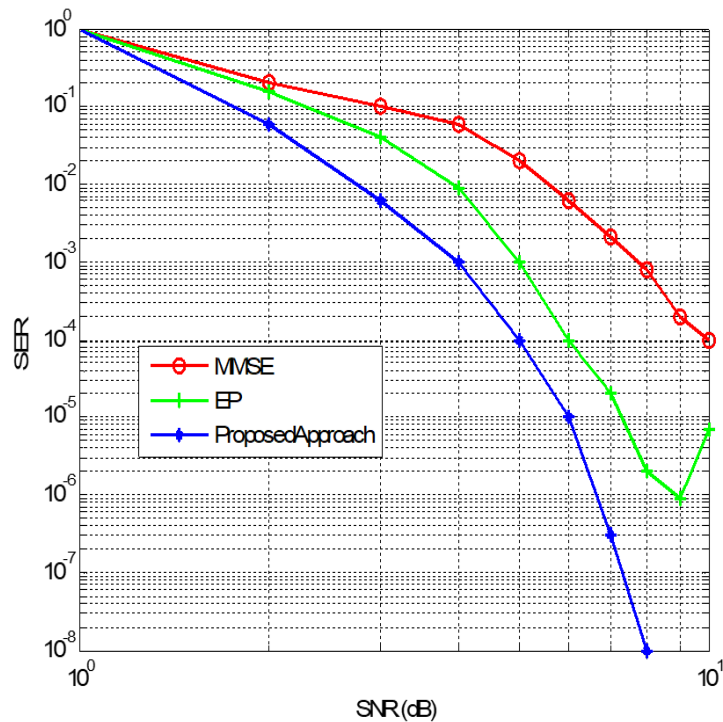

Fig. 7. SNR versus SER with $Z_t = Z_r = 64$

5. Conclusion and Future Work

An optimized channel estimation technique is being proposed using MEPE based on orthogonal pilots generated by the CSK technique. These pilots follow orthogonality property and are known to both transmitter and receiver which improve the channel estimation in massive MIMO. The proposed estimation technique using Pilot based MEPE improves 8 dB over MMSE method 5 dB over EP method. The proposed estimation performs better when compared to the conventional estimators as it employs an error covariance matrix. The simulation result shows that the proposed approach outperforms the existing approaches.

In the proposed system the complexity may increase if the number of antennas is increased as a greater number of iterations are required to find the preferred distribution. In future, researchers may explore to minimize this issue SDN can be introduced in massive MIMO systems as future prospective for the research community.

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