IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735
PP 43-51
www.iosrjournals.org

An Area Efficient Decoder For Sc-Fdma Mimo Using Higher Order Constellations And Its Performance Analyzes

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Abstract— *Multiple-input multiple-output (MIMO) single carrier frequency division multiple access (SC-FDMA), which combines the advantage of diversities with frequency domain equalizers (FDE), has drawn great attention recently. Due to invention of digital video broadcasting 16-QAM and 64-QAM schemes are most widely used in recent wireless systems. In this paper we introduce a novel low-complexity multiple-input multiple-output (MIMO) detector tailored for single-carrier frequency division-multiple access (SC-FDMA) systems, suitable for efficient hardware implementations. The proposed detector starts with an initial estimate of the transmitted signal based on a minimum mean square error (MMSE) detector. Then in order to improve the initial estimate rate less reliable symbols with more candidates in the constellation are soft decoded. Efficient high-throughput VLSI architecture is used to achieve superior performance compared to the conventional MMSE detectors. The efficiency of MIMO over high order constellations are verified through MATLAB BER simulation and complexity reduction is proved with hardware synthesis results.*

Keywords—*SC-FDMA,LTE,MIMO,MMSE,VLSI IMPLEMENTATION*

I. INTRODUCTION

The 3rd generation partnership project (3GPP) defined long term evolution (LTE) to meet the requirements of the 4G wireless communication. LTE combines multiple-input multiple-output (MIMO) technology with orthogonal frequency division-multiple access (OFDMA) technology in the downlink and single carrier-frequency division multiple access (SC-FDMA) in the uplink to achieve peak data rates of 300 Mbps and 75 Mbps, respectively.

The SC-FDMA utilizes a discrete Fourier transform-spread OFDM (DFT-S-OFDM) modulation with similar performance compared to the OFDM. Its main advantage is to provide a lower peak-to-average power ratio (PAPR), which makes it the technology of the choice for the uplink . However, the implementation of a MIMO detector in an SC-FDMA system is significantly more complicated than that of an OFDMA system. This is due to the fact that the transmitted data is mixed together because of the extra DFT block used naturally in an SC-FDMA system. Therefore, the implementation of a low-complexity MIMO detector is needed and is the main challenge in the SC-FDMA framework.

Several designs have been proposed for SC-FDMA MIMO detectors among which the linear frequency domain equalizer (FDE) receivers, including the minimum mean square error (MMSE) and zero forcing (ZF), are often used due to their simplicity . Considering the compromise between the BER performance and the complexity, typically suboptimal methods are employed. In this paper, a detection scheme is proposed for MIMO SC-FDMA systems, which near-optimal performance with a significant reduction in the complexity especially for large constellation.

II. SYSTEM MODEL

A.TRANSMITTER

Fig. 1 shows the transmitter side of a MIMO SC-fdma system with M_R transmit and M_R receiver antennae supporting users. The data stream on each transmit antenna is groupedinto
blocks of symbols, as follows

$$\mathbf{s_{n(t)}^{(k)}=[s_{n(t)}^{(k)}(0),s_{n(t)}^{(k)}(1),\ldots,s_{n(t)}^{(k)}(m-1)]^T}, \quad (1)$$

where the s n_t is the antenna index, M is the DFT size, and
$S_{n(t)}^{(k)}$ represents the data on the transmit antenna $n_{(t)}$ for user K , whose elements are chosen from a-ary quadrature amplitude modulation (QAM) constellation. After the DFT operation, the frequency domain(FD) representation of data on antenna $n_{(t)}$ is obtained and is denoted by $s_{n(t)}^{(k)}$.

The next step in the SC-FDMA transmitter is to map the M frequency domain outputs of the DFT block to N existing orthogonal sub-carriers, denoted by the “Sub-carrier mapping” in Fig. 1. The resulting FD SC-FDMA signal, $D_{n(t)}^{(k)}$, is transformed into the time-domain (TD) through an -point inverse fast

Fourier transform (IFFT) operation, resulting in the TD signals as follows.

$$\mathbf{D_{n(t)}^{(k)}=F_N^{-1}T_{N,M}^{(K)}F_M S_{nt}^{(k)},} \qquad (3)$$

Where F_M is the normalized M-point DFT matrix, and $F^{-1}{}_{N\ IS}$ the normalized -point IFFT matrix. Finally, a cyclic prefix(CP) is inserted and the final SC-FDMA signal is ready for transmission.

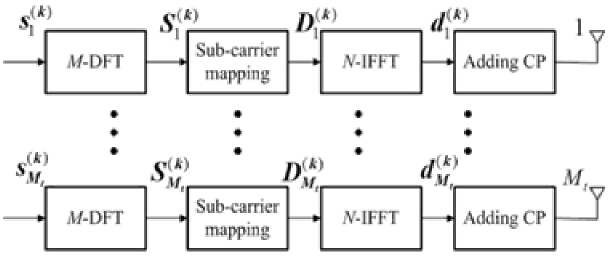


Fig.1. MIMO SC-FDMA transmitter for user with M_r transmit antenna

B.RECEIVER

A conventional linear SC-FDMA detector for user K is

depicted in Fig. 2. After the CP removal on antenna n_r at the SC-FDMA receiver with M_r receive antennae, the received signal is denoted as

$$\mathbf{r_{n(r)}= \sum\sum h_{nrnt}^{(k)} ©_N D_{nt}^{(k)}+w_{nr},} \qquad (4)$$

where is the -point circular convolution, $w_{n(r)}=[w_{n(r)}(0),w_{n(r)}(1),\ldots,w_{n(r)}(m-1)]^T$ represents the additive white Gaussian noise (AWGN) on antenna n_r, and $h_{n(r)n(t)}^{(k)}$ the channel impulse response (CIR) between the transmit antenna

$n_{(t)}$ and the receive antenna $n_{(r)}$ for user . Using an –point fast Fourier transform (FFT) and performing the sub-carrier de-

mapping, the FD signal of user K , received at antenna n_k is denoted as

$$\mathbf{Y_{n(r)}^{(k)}=[T_{N.M}^{(k)}]^T F_N r_{n(r)},} \qquad (5)$$

Therefore, the transmitted signal of each user can be detected individually, implying that index can be removed, hereafter,for brevity of discussion.

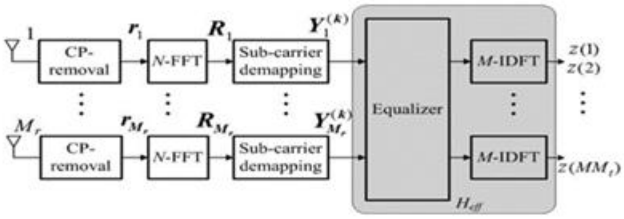


Fig.2. MIMO SC-FDMA receiver for user with M_R receive antennae

In this paper, without loss of generality, it is assumed that the number of transmit and receive antennae are the same. Let $s=[s_1^T,s_2^T,...,s_{m\ t}]^T$, an$(M\ M_t)\times 1$ matrix, be a set of constellation points at the transmitter, consisting of the signals of all sub-carriers and all antennae and $Y=[Y_1^T,Y_2^T,..,Y_{Mr}^T]$,an $(M\ M_r)\times 1$ matrix, be the de-mapped signal obtained from the receiver antennae. Therefore, the effective channel matrix H_{eff} can be defined as an $(M\ M_r)\times(M\ M_{t)}$ highlighted in Fig. 2 by a gray box, which takes the mixed effects of both thechannel and DFT block into account.

III. HARD DECISION DETECTION

The PDP algorithm in this paper, consisting of three stages, is illustrated in Fig.3, where is the channel matrix for the sub-carrier and the superscript is the Hermitian transform. These stages are described in the sequel.

First Stage: An MMSE equalizer1 is utilized to produce the initial estimate of the symbol sequence by reversing the channel effect for each sub-carrier to estimate the transmitted FD signals. Subsequently, an –point IDFT operation is executed on all sub-carriers to find time-domain signals. Therefore, the effect of the channel and the DFT are taken into account independently in this stage of the detection process. The IDFT outputs are then mapped to the constellation points and grouped to produce symbols in the initial estimate.

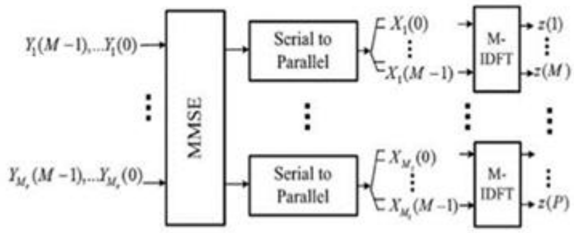


Fig.3. The first stage of the proposed architecture.

Second Stage: In order to improve the initial MMSE estimate, a number of symbols in the initial estimate are selected. For the selected symbols, extra possible candidates in the constellation are explored to see if they result in a better estimate. The selected symbols are, in fact, the ones that were initially more prone to error, called the "erroneous symbols." In order to find the erroneous symbols, are liability metric (i.e., the error probability (EP) metric) is defined for each symbol representing its error probability. To calculate the EP metric, each symbol in the initial estimate is replaced with all other possible constellation points, with their corresponding Euclidean Distances(ED) calculated while other symbols remain unchanged.

- ***Stage1: Initial estimation of received symbols by channel reversing .To find frequency domain estimation through IDFT. IDFT outputs are mapped to produce initial estimate.***
- ***Stage2: Possible candidates in the constellation are explored.To compare it with initial estimate to find erroneous symbols.To carry out the error probability (EP) metric calculations.Initial estimate symbol is replaced with all other possible constellation points***
- ***Stage 3: For each erroneous symbols corresponding EDs are calculated while other symbols remain unaltered.To start iterative algorithm .only specified number of erroneous symbols are selected in each iteration for resource sharing.***

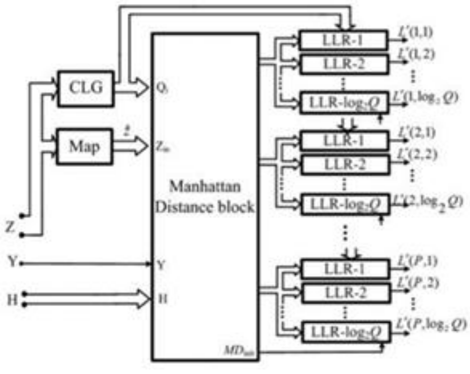


Fig.5.second and third stage of the MMSE soft detection architecture.

Third Stage : In the conventional ML-PDP, an ML detection is performed on a subset of the initial estimate (i.e., the erroneous symbols) in order to improve the result. However, the complexity of this process grows exponentially with the number of selected symbols

- ***Step1: log-likelihood ratios (LLR) calculated by the MIMO detector. Consider it as initial estimation***
- ***Step2: An ED calculation of this initial estimation over stage 2 MMSE output is carried out. Instead of checking all the possible combinations, only the vectors, which are identical to the MMSE output to generate Manhattan distance block.***
- ***Step3: simplified LLRs are scaled before feeding these values to the decoder. These scaling factors which can be calculated in the MMSE detector in the first stage of the detection.***

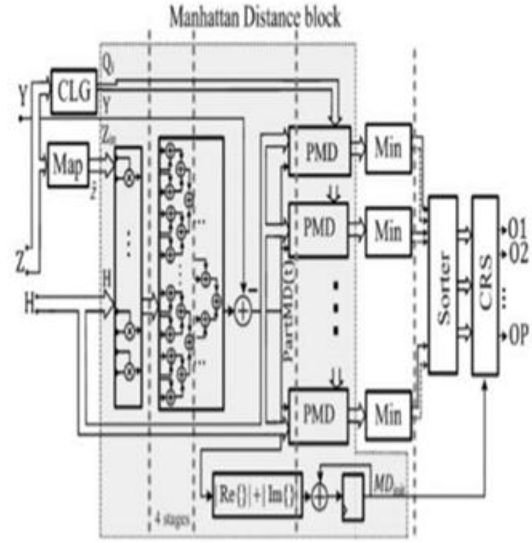


Fig.4.The second and third stages of the proposed hard PDP architecture

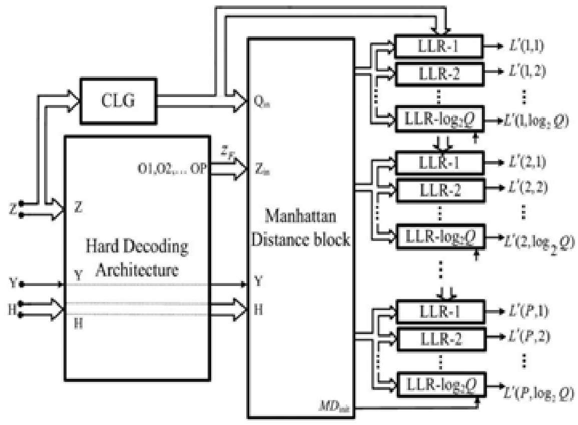


Fig.6.The architecture of the PDP soft decoding scheme.

IV. SOFT DETECTION SCHEME

The architecture provides a hard decision output (i.e.,) based on the transmitted symbols. While the proposed structure provides a superior BER performance compared to the conventional MMSE receivers, a soft-coded system is proposed that complies with advanced wireless standards. In a coded system, the transmitter encodes the message by using an error-correcting code. At the receiver, the decoding is performed based on the extrinsic log-likelihood ratios (LLR) calculated by the MIMO detector. The LLRs are in fact the soft information representing the reliability of the detection. In contrast to a hard MIMO detector where a hard decision is made for each bit, a soft MIMO detector generates a value for each bit representing the probability of its being one or zero.

In order to enhance the performance of the coded system, the MIMO detector will have to generate a soft decision based on the transmitted symbols. In a-ary QAM modulation, LLR values must be calculated for all bits in each symbol resulting in log2 Q×P of LLR calculations for symbols.

V. RESULT AND DISCUSSION

The BER performance of the proposed architecture for a 4 x4 MIMO detector, with one resource block allocated toeach user was evaluated through MATLAB simulations, with and for 16-QAM and 64-QAM schemes, respectively and effectiveness in enhancing the performance is based on the BER performance of the baseline MMSE detector.

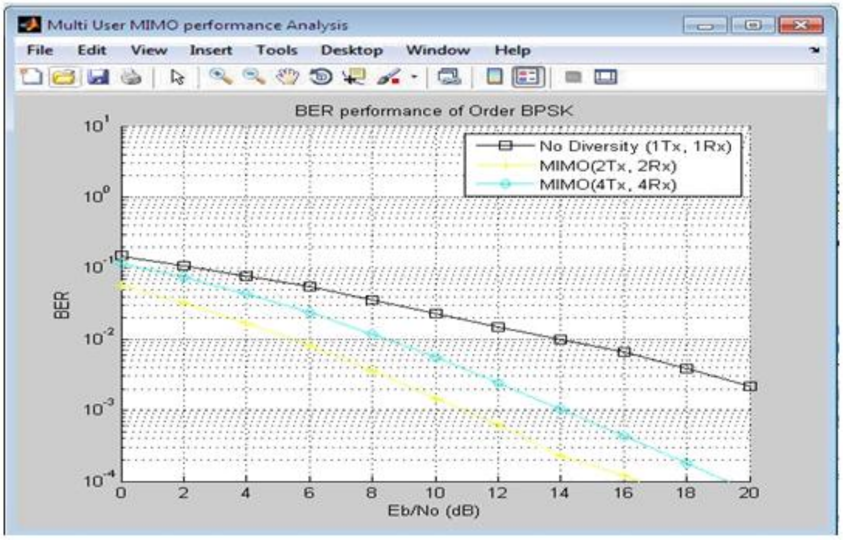


Fig.7.BER performance of MIMO over QPSK modulations

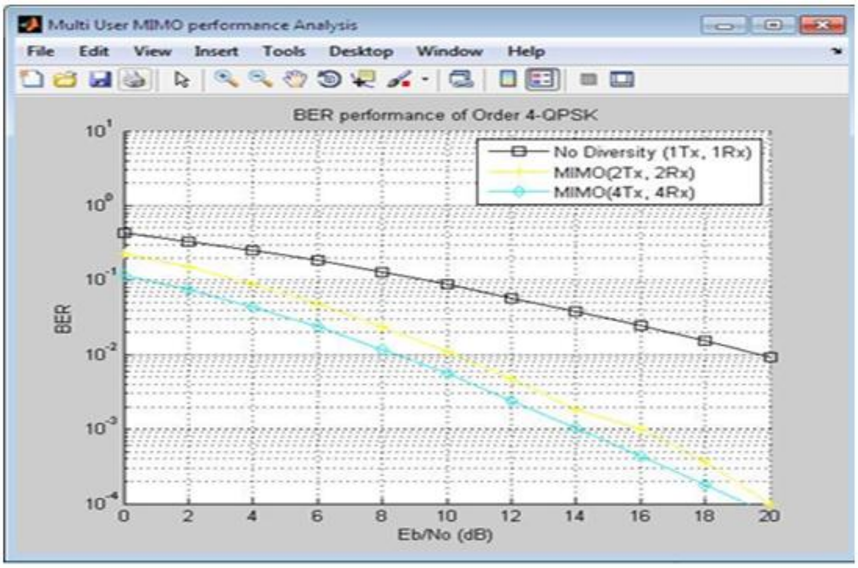


Fig.8. BER performance of MIMO over BPSK modulations

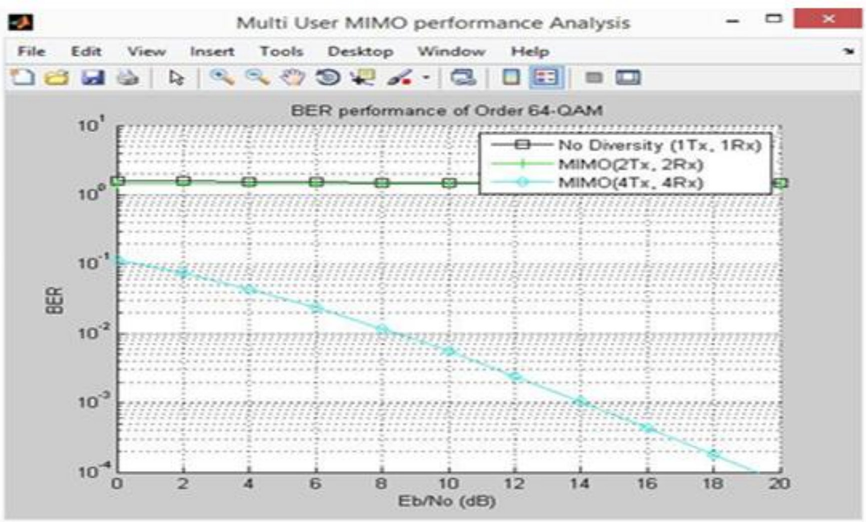


Fig.9.MIMO over 64- QAM modulation

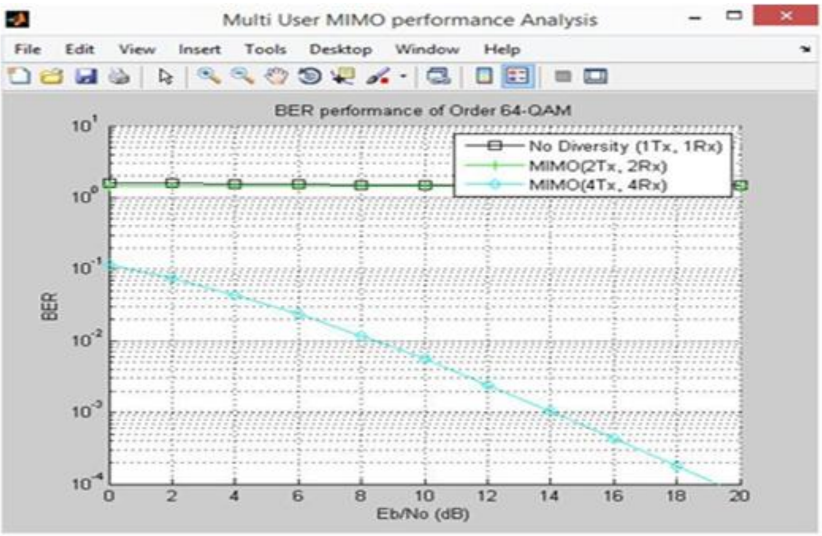


Fig.10. BER performance of LS,MMSE and ML over L=5

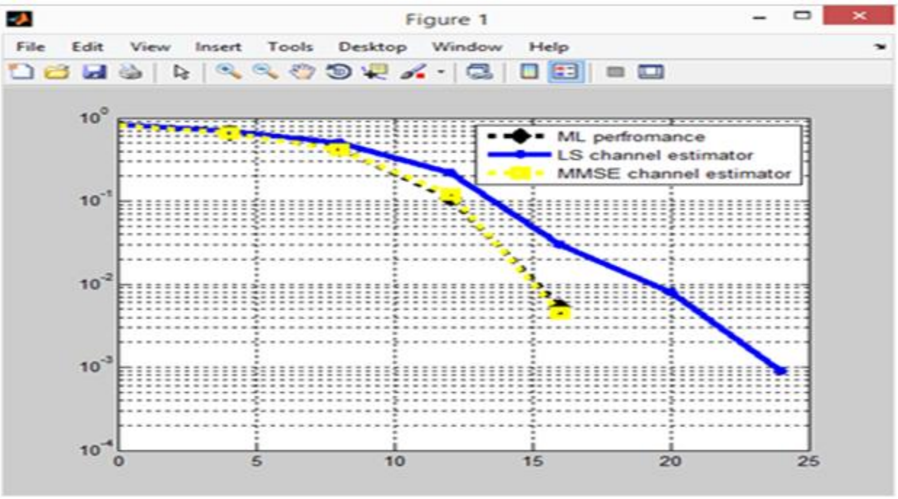


Fig.11. BER performance of LS,MMSE and ML over L=5

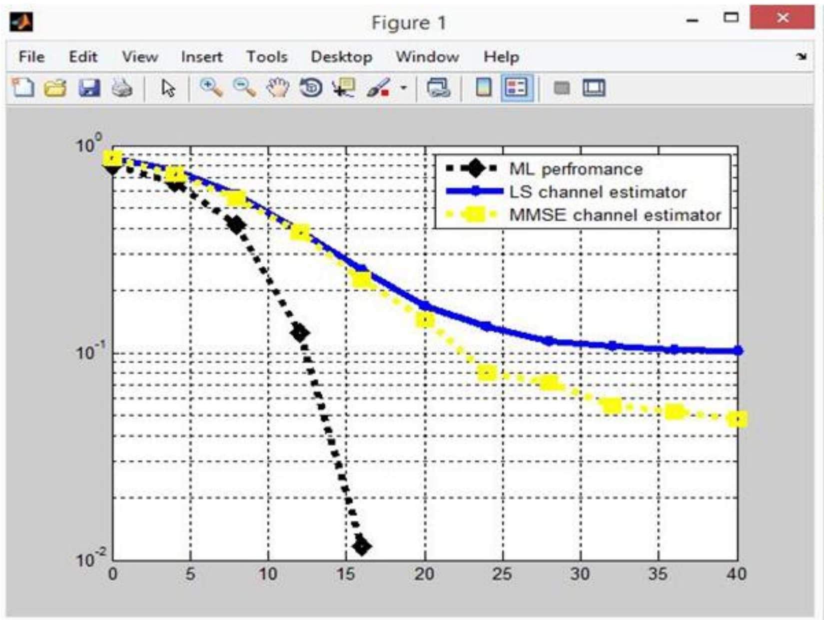


Fig.12. BER performance of LS,MMSE and ML over L=10

The proposed PDP architecture for the 16-QAM and 64-QAM schemes was implemented and fully tested on a Xilinx Virtex-6 xcvlx240t using the ML605 evaluation kit and shows the result of the field programmable gate array (FPGA) implementation. The normalized throughput demonstrates the data rate per transmit antenna. The hard decoding architectures for the 16-QAM and 64-QAM schemes and the soft PDP architecture for the 16-QAM scheme were also synthesized and placed and routed in a 0.13 1P/8M CMOS technology.

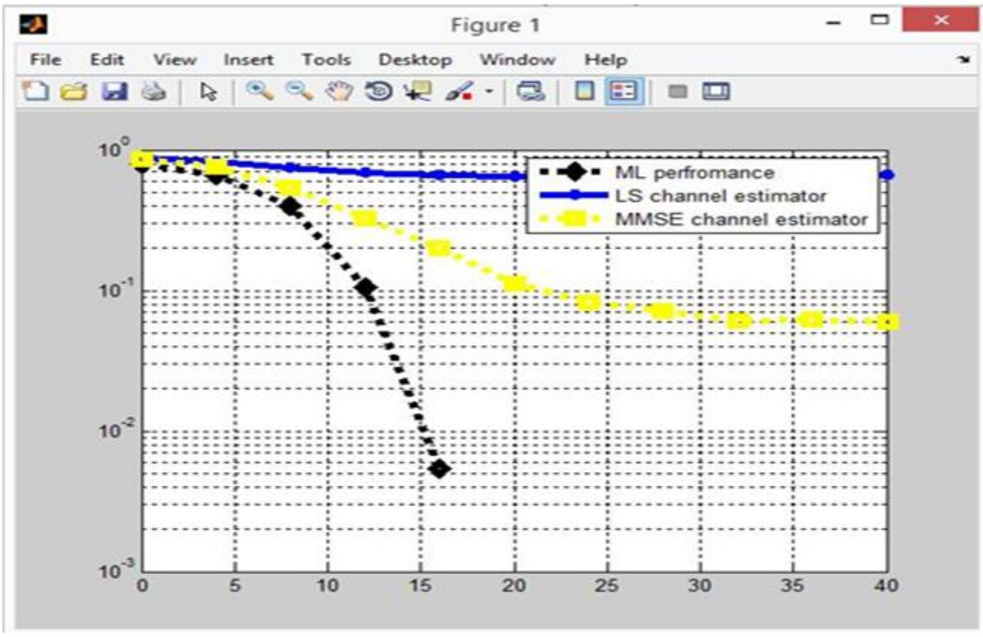
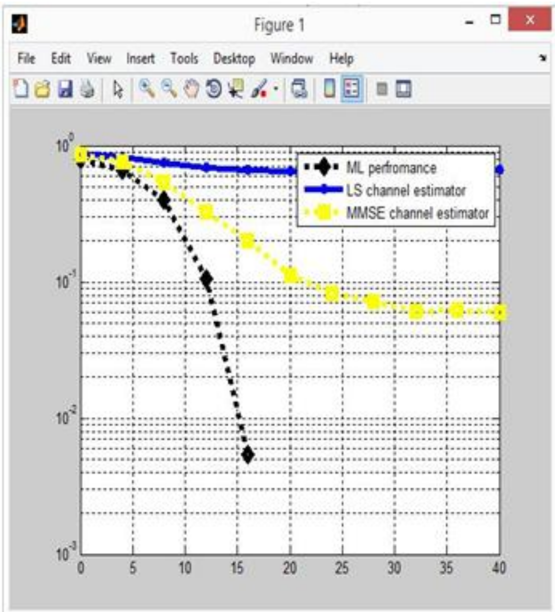


Fig.12.BER performance of LS,MMSE and ML over L=10

TABLE I *Trade off analyzes of ML Vs MMSE with QUARTUS II hardware synthesis using CYCLONE III family (EP3C16F484C6)*

EQUALIZER TYPE	AREA	SPEED
ML	1487 with 112 MUL	67.74MHz(RX) 430.66MHz(TX)
MMSE	958 with 64 MUL	126.45MHz(RX) 427.9 MHz(TX)
MMSE with SOFT decoding	1447 with 64 MUL	131.06MHz(RX) 483.09MHz(TX)



Comparsion of the ML,MMSE and MMSE With soft decoding equalizers for area and speed.MMSE with soft decoding is better in reducing consumption of area and increasing speed.

VI. CONCLUSIONS

In this paper, we analyze the performance of different equalization algorithm for SCFDMA system. Initially we analyzes the MIMO sytems and SCFDMA multiple access scheme with psk,qpsk,qam modulation schemes over distance metrics .The proposed algorithm is based on channel estimation that exploits the sparsity of the estimated error signal. We also perform MMSE with soft decoding based symbol selection in each iteration to prove the fast convergence. We illustrated the performance of our algorithm in numerical simulations, and our algorithm shows a 22% performance improvement compared to linear equalizers, while the BER rate is much lower compared to feeding back one symbol at a time for channel estimation.

VII. FUTURE SCOPE OF WORK

To extend the objectives of complexity reduction all multipliers used at receiver side for signal detection will be replaced by shifter/adder in order to reduce the complexity . we are going to increase the QOS by adding variable puncture rate based error correction used for channel accuarcy.

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