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# Design and Implementation of Spatial Modulation Technique For 5G Wireless Networks

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**Abstract—** The Orthogonal Frequency Division Multiplexing with Index Modulation (OFDM-IM) is a specialized multicarrier transmission technique which has being implementing recently in 5G technology as an alternative to classical MIMO-OFDM. Here, OFDM with index modulation (OFDM-IM) is the combination of MIMO and Index modulation transmission technique it is prefered to get more advantages in 5G technology. The main concept of IM is to utilize the index subcarrier to pass the data to receiver. Therefore spatial modulation in OFDM with MIMO is considered as a more efficient transmission technique for 5G systems. The main principle of index modulation is to utilize the active subcarriers indices deals with orthogonal multiplexing system as an extra source of information. And, it is verified by the MMSE dectectors that arrange index modulation in OFDM-IM to accomplishes higher performance of bit error rate and this establish OFDM with multiple antennas for better BER(Bit Error Rate) performance in system configuration. Here we have proposed MIMO-OFDM with IM that achieves efficiently higher BER performance than the classical OFDM in different system configurations.

***Keywords— Bit Error Rate (BER), Index Modulation (IM), Orthogonal Frequency Division Multiplexing (OFDM), Multiple- Input Multiple-Output (MIMO), MIMO-OFDM-IM, 5G networks.***

## 1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has become one of the most popular multicarrier transmission techniques for broadband wireless communications in recent years. Awaited to its dominance such as well organized implementation and robustness to frequency selective weakening channels, OFDM has been confined in several standards as mentioned as Long Term Evolution (LTE), Digital Video Broadcasting (DVB) and IEEE 802.16e-WiMAX.IEEE 802.11x Wireless Local Area network (WLAN), Considering the benefits of Multiple-Input Multiple-Output (MIMO) systems over single antenna systems such like improved data rate and energy potency, the mixture of OFDM and MIMO transmission techniques look as a potential candidate for future wireless standards such as 5G and beyond. OFDM with Index Modulation (OFDM-IM) might even be a totally distinctive multicarrier transmission theme that transmits the information not only by the information symbols chosen from M- ary signal constellations, however by the indices of the active subcarriers. The system design provides a stimulating trade-off between performance and spectral potency. Index modulation for OFDM has very important attention from the researchers because of its wide spread introduction.

Active subcarriers throughout extra versatile because of the more increase in spectral efficiency an OFDM-IM programme is generalized in. The difficulty of the choice of flawless integer of active subcarriers is investigated. In subcarrier level block interleaving is introduced for OFDM-IM so as to enhance its error performance by gaining from unrelated subcarriers. In, OFDM-IM with interleaved grouping is accorded to vehicular communications. Latterly, OFDM-IM is combined with coordinate interleaving principle to urge tons of diversity gains.

The recently projected novel multicarrier transmission technology that appears as a durable replacement to classical MIMO-OFDM for 5G networks. Throughout this scheme, every transmit antenna transmits its own OFDM-IM frame to promote the rate of information bits and at the receiver side, these frames are separated and demodulated employing a utterly distinctive minimum mean square error (MMSE) detector.

In this study, we trade with the maximum likelihood (ML) detection performance of the MIMO-OFDM-IM scheme to benefit from the diversity gain of MIMO transmission. The Average Bit Error Probability (ABEP) of the MIMO-OFDM- IM scheme is derived by the calculation of pairwise error probability (PEP) of the MIMO-OFDM-IM sub blocks. In order to scale back the decoding complexity of the brute-force ML detector of the MIMO-OFDM-IM scheme, a low complexity near-ML detector is preferred, which is shown for better Bit Error Rate (BER) performance than classical Vertical Bell Lab Layered Space-Time (V-BLAST) type MIMO-OFDM for different configurations.

The other content of the paper is formulated as follows. In Section 2, our system model is presented. In Section 3, performance analysis of MIMO-OFDM-IM is given. The near-ML detection in MIMO-OFDM-IM is proposed in Section 4. Simulation results are provided in Section 5 and Section 6 concludes the paper.

## 2. LITERATURE REVIEW

Low-complexity detectors is derived from the SMC theory for the MIMO-OFDM-IM system. The primary sub block-wise detector that attracts samples at the sub block level, exhibiting the near-optimal performance for the MIMO-OFDMIM system. The second planned subcarrier-wise detector attracts samples at the subcarrier level, that are considerably reducing the quality with a marginal performance loss. A reasonable quality examination technique has been developed to couple with the subcarrier wise detector. Computer simulation and numerical results have validated the better performance and place the planned detectors alternatively to attain the better spectral efficiency in the spatial modulation technique.

An awfully distinctive theory named as MIMO-OFDM [1], [2] with index modulation has been planned as another multicarrier transmission technique for 5G networks. It is been shown via intensive personal computer simulations that have the planned scheme that will offer necessary BER performance enhancements over classical MIMO-OFDM for many entirely altogether different configurations. Ensuing points keep unresolved throughout this study: i) Performance analysis, ii) The choice of best N and K values, iii) Diversity techniques for MIMO-OFDM-IM, iv) Implementation scenarios for high mobility.

Recently intended MIMO-OFDM-IM theory [3], [8] has been investigated for next generation 5G wireless networks. For the MIMO-OFDM- IM theory, new detector varieties like ML, near-ML, MMSE-LLR-OSIC, simple MMSE detectors have planned and their unit inIM theory examined. It is shown via intensive advanced personal computer simulations that MIMO-OFDM-IM system that provides an interesting trade-off between quality, spectral potency and error performance compared to the classical MIMO-OFDM theory and it can be treated as a viable candidate for 5G wireless networks.

The foremost alternatives of MIMO-OFDM-IM unit can be sometimes summarized as follows: i) better BER performance, ii) flexible system design with variable number of active OFDM subcarriers and iii) Adaptive. However, fasinating topics like diversity modes, generalized OFDM-IM cases, high mobility implementation and transmit antenna indices choice still keep to be investigated for the MIMO-OFDM-IM scheme.

ML and near-ML detectors [4], [5] are the recently introduced MIMO-OFDM-IM scheme to enhance its error performance compared to MMSE based altogether detection. The ABEP upper bound system of the MIMO-OFDM-IM scheme with ML detection has been borrowed and it has been set out that the borrowed logical upper bound can be used as an adequate tool to presume the BER performance of the MIMO-OFDM-IM scheme. It has been shown via personal computer simulations that MIMO-OFDM-IM scheme [4] that will offer necessary enhancements in BER performance by classical MIMO-OFDM using various form of detectors and MIMO configurations.

Performance Analysis in the OFDM With index modulation, through this we here have planned the low-complexity detector [4] that supported the milliliter criterion, that dispenses with a priori information of the noise variance and the potential realizations of the active subcarrier indices. supported the framework of OFDM-I/Q- IM victimizing the planned milliliter detector, the linear ABEP and also the definite coding gain achieved by OFDMI/Q-IM [13] are derived, that exactly matches the simulation results.

Moreover, the exact coding gain including spectral trade-off between the system performance and also the spectral efficiency of OFDM-IM by the improvement of the bulk of active sub carriers. And they have being simulated by the computer simulations of the OFDM-IM therory that achieves the higher error performance over the classical OFDM-IM , this error performance is done by the ML/near-ML dectectors at different configuration to attain the better Bit error rate peformance.

The detection of the large- scale multiuser MIMO-OFDM systems [5],[6], here we have planned a enlargement of low-complexity approximate message passing algorithms that is during a position to provide better exchange between performance and complexity. It is verified through the simulations that the original accurate message transmitting algorithms can do the best performance with the low complexity. Compared with existing turbo detection algorithms, the intended patterns can obtain or even outstrip the performance of some advanced algorithms of OFDM-IM, a tiny low quality to the unvarying committal to writing supported STS-SD and MMSESIC. In extension, the number of iterations enforced to attain near-optimal performance was small and not increase with the system dimension.

### 3. System Model of MIMO-OFDM-IM

The diagram of the MIMO-OFDM-IM transceiver [4] is shown in Fig. 1. A MIMO system with the T transmitter and R receiver antennas is taken into account. A total number of mT data are bits processed by the MIMO-OFDM-IM transmitter for the transmission of every MIMO-OFDM-IM frame. These mT data bits are here divided into T groups and the corresponding m bits are processed in each and every branch of the transmitter by the OFDM index modulators.

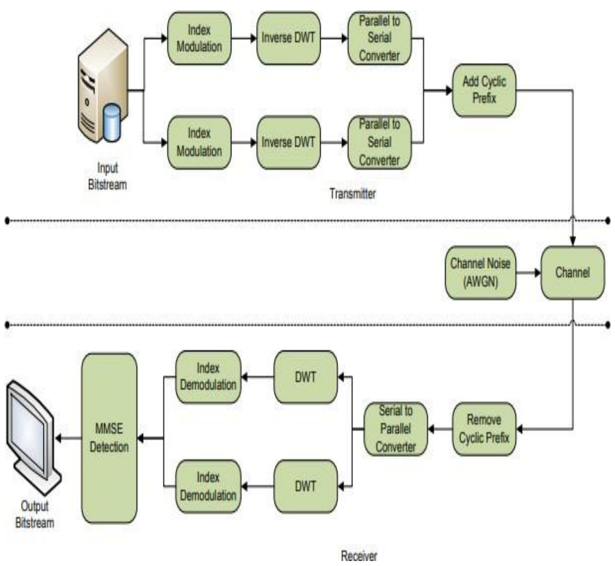


Figure 1. Transceiver Structure of the MIMO-OFDM-IM Scheme for a T × R MIMO System [4]

The incoming m data bits unit recycled to attain the $N_F \times 1$ in OFDM-IM block $X_t = [x_t(1)\ x_t(2) \dots x_t(N_F)]^T$ , $t = 1,2, \dots, T$ [3] in every division of the transmitter, where $N_F$ is the size of the Fast Fourier Transform (FFT) and $x_t(n_f) \in \{0, S\}$, $n_f = 1, 2, \dots, N_F$, where S stands for M-ary signal constellations. To stand with the OFDM-IM principle [4s], these m bits are slit into G teams it contains $p = p_1 + p_2$ bits, that unit accustomed kind of OFDM-IM sub blocks.

$X_t^g = x_t^g(1)\ x_t^g \dots x_t^g(N)^T$ , $g = 1,2, \dots, G$ of length $N = N_F/G$, where $x_t^g(n) \in \{0, S\}$ , $n = 1, 2, \dots, N$. To stay with the corresponding $p_1 = [\log_2(N/K)]$ bits, only K and N convenient sub carriers are selected as active by theindex selector at every sub block g, where as the rest $N - K$ subcarriers are inactive and it is then fixed to zero.

Index selector in every sub block g, where as the rest $N - K$ subcarriers are inactive and fixed to zero. On the selection process, the remaining $p_2 = k \log_2(M)$ bits are mapped onto the intentional M-ary signal constellation like M-PSK or M- QAM at every sub block. Therefore, conflicting classical MIMO- OFDM, $x_t$, $t = 1, 2, \dots, T$ contains some zero terms whose positions carry data for MIMO-OFDM-IM.

OFDM-IM extended to a MIMO configuration is shown in Fig.2. A MIMO system is assumed with T transmit and R receive antennas. As seen from Fig.1, a data stream filled with mT data bits enter the MIMO- OFDM-IM transmitter for the transmission of each MIMO- OFDM-IM frame. These mT bits are split into T sets and that the parallel m bits are being processed in each and every branch of the transmitter by the OFDM index modulators [2] as shown in Fig.2. Conflicting the classical OFDM, these m bits are processed not only in M-ary modulation however that intervals as collection of the indices of active subcarriers and $N_F \times 1$ OFDM-IM block.

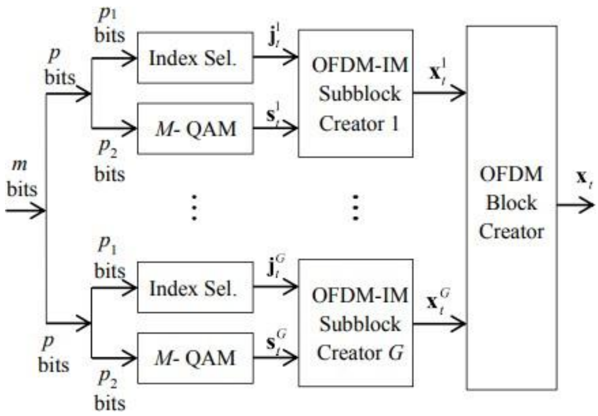


Fig. 2. OFDM index modulators at each branch of the transmitter [3]

$$X_t = [x_t(1)\ x_t(2) \dots x_t(n_F)]^T \ , t = 1,2,3, \dots, T \qquad (1)$$

is obtained in every branch of the transmitter, where here $n_F$ is that the size of the fast Fourier transform (FFT) and $x_t(n_f) \in \{0,S\}$ , $n_f = 1, 2, 3, \dots, N_F$. Likewise OFDM-IM principle [10], which is disbursed at the same time in evey branch of these transmitter, the m bits are splited into G groups containing $p = p_1 + p_2$ bits, which are used to form OFDM-IM sub blocks of length $N = N_K/G$.

$$X_t^g = x_t^g(1)\ x_t^g \dots x_t^g(n)^T \ , g = 1,2,3, \dots, G \qquad (2)$$

Here $X_t^g(n) \in \{0, S\}$ , $n = 1, 2,3, \dots, N$. At all sub block g, considering the corresponding $p_1 = [\log_2(N/K)]$ bits, significantly K out of N available subcarriers are chosen as active by the index selector, wherever the indices that having active subcarriers are estimated.

Table 1. Reference Look-up Table for N=2, K=1 and P1=2[4]

| *Bits* | *Indices* $(\mathbf{j}_t^g)^T$ | *OFDM-IM subblocks* $(\mathbf{x}_t^g)^T$ |
|---|---|---|
| [0 0] | [1 3] | $[s_t^g(1)\ 0\ s_t^g(2)\ 0]$ |
| [0 1] | [2 4] | $[0\ s_t^g(1)\ 0\ s_t^g(2)]$ |
| [1 0] | [1 4] | $[s_t^g(1)\ 0\ 0\ s_t^g(2)]$ |
| [1 1] | [2 3] | $[0\ s_t^g(1)\ s_t^g(2)\ 0]$ |

$$j_t^g(1) = [j_t^g(1)\ j_t^g(2) \dots j_t^g(k)]^T \qquad (3)$$

where $j_t^g(k) \in \{1, \cdots, N\}$ , $k = 1, 2, \dots, K$. On the selection theory, the remaining $N - K$ subcarriers unit are inactive and set to zero. At the similar time, the remaining $p_2 = K \log_2(M)$ bits are mapped onto the M-ary quadrature amplitude modulation (M-QAM) signal constellation to induce.

$$S_t^g = [s_t^g(1)\ s_t^g(2) \dots s_t^g(K)]^T \qquad (4)$$

where $S_t^g(k) \in S$, $k = 1, 2, \dots, K$. For each OFDM-IM sub block $X_t^g$, the K elements of $S_t^g$modulates the K active subcarriers whose indices given by $j_t^g$. Therefore, dissimilar classical MIMO-OFDM where $x_t$ , t = 1, 2, . . . , T contains some zero terms whose positions carry information data for MIMO-OFDM-IM.o

Active subcarrier index numerous is performed at OFDM index modulators of the transmitter by either pattern reference look-up tables for the smaller values of the active subcarriers (K) and associated sub block (N) or degree index process based on the support of the combinatorial theory for the higher values of K and N. The thought-about reference look-up tables for N = 2, K = 1 and N = 4, K = 2 are given in Tables I, severally, where $s_k \in S$ for k = 1, 2, . . . K.

Assume as seen from Table I, for N = 2 and K = 1, p1 = 2 bits is in addition to the accustomed verify the indices of the different active subcarriers out of four applicable subcarriers confer the reference look-up table of size C = $2p_1$ = 8. For higher K and N values, the combinatorial algorithm provides the chosen indices according to the incoming $p_1$ bits [3].

In every branch of the transmitter, these OFDM with index modulators constructs the OFDM-IM sub blocks channels initially, then the sequence of these G sub blocks is to urge the foremost OFDM-IM blocks $x_t$ , t = 1, 2,. . . , T. G × N block interleavers (Π) that are employed at the transmitter to transmit the elements of the sub blocks from unrelated channels. Then, inverse FFT (IFFT) operators technique the interleaved OFDM-IM frames. $\widetilde{y}_t$ where, t = 1, 2, . . . , T and accquire $q_t$ , t = 1, 2, . . . , T. It is assumed that the time-domain OFDM symbols unit normalized to process unit energy, i.e., $\widetilde{E}_q H_t$ $\widetilde{q}_t$ = NF for all t.

In the every IFFT operation, the cyclic prefix (CP) of $C_p$ samples is included at the beginning of the OFDM frames in every branch of the transmitter. Once parallel-to-serial and digital-to-analog conversions, the next signals are sent at identical time from T transmit antennas over a frequency- selective Rayleigh fading MIMO channel that can be drawn by $g_{r,t} \in C^{L\times 1}$ , where L is the total number of channel taps[3]. Supported the assumption that the wireless channels kept constant throughout the transmission of a MIMO-OFDM-IM frame and $C_p > L$, once removing the $C_p$ and the input and output relationship of the MIMO-OFDM-IM scheme at intervals in the frequency domain is obtained for r = 1, 2, . . ., R as follows:

$$\tilde{y}_r = \sum_{t=1}^{T} \mathrm{diag}(\widetilde{X}_t)\, h_{r,t} + W_r \qquad (5)$$

In (5), $\tilde{y}_r = \tilde{y}_r(1)\ \acute{y}_r(2) \cdots \tilde{y}_r(N_F)$ T is that the vector of the received signals in receive antenna r, the frequency response of wireless channel between transmit antenna t and receive antenna r are denoted by $h_{r,t} \in C^{NF\times 1}$, and $W_r \in C^{NF\times 1}$ that stands for the generalised vector of noise samples at the receiver and transmitter[3].

The elements of $h_{r,t}$ and $W_r$ follow CN (0, 1) and CN (0, $N_0$,S ) distributions, severally, where $N_0$,S denotes the variance of the noise samples and it is related to the variance of the noise samples at intervals the time domain as $N_{0,F} = (K/N)N_{0,T}$ when deinterleaving operation, the received signals for receive antenna r are obtained as

$$y_r = \sum_{t=1}^{T} \mathrm{diag}(X_t)\, \breve{h}_{r,t} + \breve{w}_r \qquad (6)$$

for r = 1, 2, . . . , R, where[ where$\tilde{y}_h$, $\breve{h}_{r,t}$ and $\breve{w}_r$ are deinterleaved versions of $h_{r,t}$ and $w_r$, respectively. As seen from Fig. 1, before that the detection process of the MIMO-OFDM-IM theory, the receiving signals in (6) that are being divided for every sub block channels g = 1, 2,3, . . . , G as

$$\begin{aligned} y_r &= \left[ (y_r^1)^T (y_r^2)^T \cdots (y_r^G)^T \right]^T \\ x_t &= \left[ (x_t^1)^T (x_t^2)^T \cdots (x_t^G)^T \right]^T \\ \breve{h}_{r,t} &= \left[ (\breve{h}_{r,t}^1)^T (\breve{h}_{r,t}^2)^T \cdots (\breve{h}_{r,t}^G)^T \right]^T \\ w_r &= \left[ (w_r^1)^T (w_r^2)^T \cdots (w_r^G)^T \right]^T \end{aligned} \qquad (7)$$

The signal-to-noise ratio (SNR), it given as *SNR = $E_b/N_{0,T}$ where $E_b = (N_F + C_P)/m$* [joules/bit] is that the general transmitted energy per bit. The spatial efficiency of the MIMO-OFDM-IM theory is calculated as $mT/(N_F + C_P)$ [bits/s/Hz].

*A. MMSE and LLR Detection of MIMO-OFDM-IM*

MMSE and LLR detector of the MIMO-OFDM-IM system is planned to implement a low compound MMSE detection. Considering the conditional statistics of $X_t^g(n)$, the MMSE and LLR detector of the MIMO-OFDM-IM theory calculates the following LLR adds value for the ordinal subcarrier of the transmitter of sub block.

$$\lambda_t^g(n) = \ln\left( \sum_{m=1}^{M} \exp\left( -\frac{\left|\hat{X}_t^g(n) - Q_n S_m\right|^2}{C_n} \right) \right) + \frac{\left|\hat{X}_t^g(n)\right|^2}{C_n} \qquad (8)$$

For n = 1, 2, 3,. . . , N, t = 1, 2,3, . . . , T and g = 1, 2, 3,. . . , G, where $s_m \in S$. For all the case of reference look-up tables, the MMSE-LLR detector calculates LLR sums for every part of the look-up table. If in case of the selection of active indices with combinatorial algorithm program, once the calculation of N LLR values from sub block, the detector decides on K active indices out of them having most LLR values. Denoting the indices of those subcarriers by

$$\hat{j}_t^g = \left[ \hat{j}_t^g(1)\ \hat{j}_t^g(2) \cdots \hat{j}_t^g(k) \right]^T \qquad (9)$$

the corresponding index choosing bits can be determined with demapping algorithm program, and therefore the M-ary symbols transmitted by the active subcarriers are determined for k = 1, 2, . . . , K as

$$\left(s_t^g(k)\right)_{MMSE} = \arg\min_{S_m \in s} \left| \hat{X}_t^g\left(\hat{j}_t^g(k)\right) - Q_{\hat{j}_t^g(k)} S_m \right|^2 \qquad (10)$$

## 4. SIMULATION RESULTS AND COMPARISON

We study the BER performance of the MIMO-OFDM-IM system for N = 4, K = 2 (Table I) with classical V- BLAST-OFDM utilize MMSE detectors and BPSK modulation. Two MIMO configurations are considered: 2×2, 4 × 4, where each system perform similar spatial efficiency frame of 1.

Here, fig.3 presents the fascinating trade-off provided by the MIMO-OFDM-IM system between BER performance and efficiency for a 4 × 4 MIMO system with MMSE-LLR detection. For the choice of active indices, we have a tendency to use the combinatorial ranging theory process [10], wherever all completely different N and K slots are considered. As seen from Fig. 5, for distinction spectral potency, the MIMO-OFDM-IM theory with M=9, N=18, K=15 provides approximately 3dB higher BER performance than the reference V-BLAST-OFDM theory for a BER range of $10^{-5}$.

On the alternative side, as seen from Fig. 4, MIMO- OFDM-IM which has the strechable of adjusting the spectral and energy efficiency by vigorous amount of active subcarriers K is a tremendous sub block, and can perform higher or worse BER performance than the reference MIMO-OFDM-IM system with 11.2 bits/s/Hz spectral ability. It got to be compelled to be noted that the BER performance of MIMO-OFDM-IM degrades once 64-QAM is employed; but, a extra sturdy BER performance than classical V-BLAST-OFDM is obtained for all completely different cases even with larger spectral efficiency.

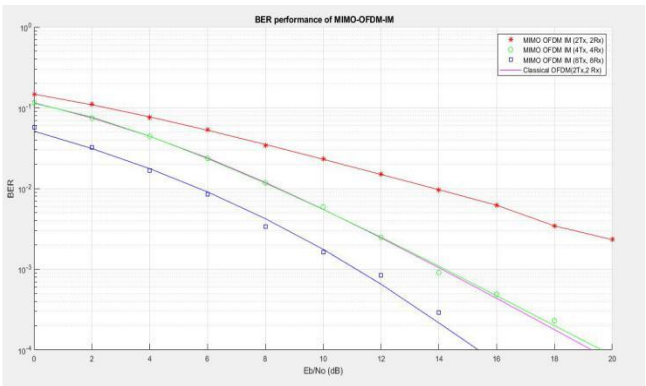


Fig.3. BER performance of MIMO-OFDM-IM

In Table 2, the decoding process has difficulty of MIMO-OFDM and MIMO-OFDM-IM theory that are unitly given in terms of total range of CMs performed per subcarrier for various analysis of the detectors. As seen from Figure 4, near-ML, MMSE-LLR and MMSE-LLR-OSIC detectors of MIMO-OFDM-IM have constant order decoding compared to brute-force ML, MMSE and MMSE-OSIC detectors of classical MIMO-OFDM, accordingly BER performance of the classical OFDM and different configurations of MIMO is estimated.

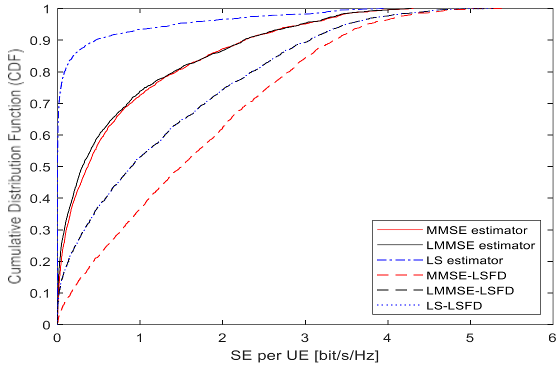


Fig.4. CCDF Comparison Graph

| S.NO | Eb/N0(dB) | BER for Classical MIMO | BER for MIMO-OFDM-IM(2×2) | BER forMIMO-OFDM-IM(4×4) | BER for MIMO-OFDM-IM(8×8) |
|---|---|---|---|---|---|
| 1. | 2dB | 0.075 | 0.2 | 0.075 | 0.04 |
| 2. | 4dB | 0.08 | 0.1 | 0.08 | 0.02 |
| 3. | 6dB | 0.075 | 0.01 | 0.075 | 0.01 |
| 4. | 8db | 0.03 | 0.08 | 0.03 | 0.004 |
| 5. | 10dB | 0.008 | 0.05 | 0.008 | 0.002 |
| 6. | 12dB | 0.075 | 0.05 | 0.075 | 0.0009 |
| 7. | 14dB | 0.001 | 0.03 | 0.0009 | 0.0003 |

Table 2. Comparison between the BER's of classical MIMO and MIMO- OFDM-IM with (2×2), (4×4),(8×8) MIMO-OFDM-IM

The above table that represents the comparison between the classical multiple-input multiple-output (MIMO) and the MIMO-OFDM-IM, it compares the bit error rate values at certain dB. Each BER value at particular dB that are plotted in graph are compared As per the above obtained result that plotted as graph in which the Bit Error Rate is compared as, For example in 10 dB the BER attained by the classical MIMO is 0.008 which is exactly equal to the MIMO-OFDM (4×4), and the bit error rate of the MIMO- OFDM (8×8) is 0.002 which is much smaller than that of all the values hence as per the result the MIMO-OFDM-IM (8×8) is lesser hence can accommodate high spectrum and energy efficiency.

## 5. CONCLUSIONS

Hence Index Modulation is an up coming approach for spectral and energy-efficient next generation wireless communications systems to be occupied for work in 5G wireless networks. IM techniques can attempt low-complexity still as spectrum-efficient and energy-efficient solutions toward the single/ multiple carrier, massive MU -MIMO, and cooperative communications systems. This can be hired in 5G wireless network for the superior spectral and energy efficiency. While in this project, we have reviewed the essential principles, advantages, recent advances, and application areas of the SM and OFDM -IM systems, that are the two predominent applications of the Index Modulation theory like Spatial Modulation and OFDM -IM. In this advantages and disadvantages of the reviewed IM schemes in terms of spectral efficiency and error performance are provided. The poor transceiver complexity in the design of IM proposal and uplink and downlink transmission protocol. So, Index Modulation schemes can be studied as attainable techniques for 5G wireless networks due to the impressive resolution they offer among error performance, complexity, and spectral efficiency, while there are still absorbing and difficult analysis issues that are require to be resolved so in order to further improvement of the spectral efficiency and energy efficiency of IM scheme. Finally in this paper we have discussed the various index modulation schemes and techniques that provide us better spectral efficient and energy efficient applications.

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