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Design of 5G Wireless Communication Using Massive MIMO Systems and detection of data symbol with Less Adjacent Channel Interference

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Abstract: It is well known that, in classical MIMO, multiple antennas at both ends exploit wireless channel diversity to provide more reliable high-speed connections. Massive MIMO (also known as Large-Scale Antenna Systems, Very Large MIMO, Hyper MIMO, and Full-Dimension MIMO) makes a bold development from current practice using a very large number of service antennas (e.g., hundreds or thousands) that are operated fully coherently and adaptively. After the Massive MIMO technology is introduced, the differentiation and flexibility of wireless network coverage in three-dimensional space have been greatly improved. The radio wave propagation model, user behaviour and service distribution, beam management and beamforming are more complicated, flexible and difficult to measure. massive MIMO is also considered a technique to improve wireless network coverage. From another point of view, radiated power from both base stations and terminals can be scaled down, making massive MIMO also a candidate for 'green communications.This paper presents theoptimal detection of data symbol in massive MIMO for 5G wireless communication. Based on the frequency non selective fading MIMO channel, we consider three difference detectors for recovering the transmitted data symbols and evaluate their performance for Rayleigh fading and additive white Gaussian noise (AWGN). At the results, we show that the probability of error rate (PER) performance of the detectors are significantly discussed.

Keywords: Multi-User MIMO, Quality of Service, Space Division Multiple Access, Synchronization Signal and PBCH block, long term evolution, Massive multiple-input-multiple-output, Adjacent Channel Interference.

I. INTRODUCTION

Figure 1 shows the speed improvement of wireless networks over the years starting from single-input-single-output (SISO) systems, single user (SU) and multiple users (MU) MIMO networks. MU-MIMO systems already provide significant advantages over earlier systems. Massive MIMO aims to further enhance this (to 10 Gbps and more) using hundreds of antennas exploiting advances in parallel digital signal processing and high-speed electronics. This brings huge improvements in throughput and energy efficiency, in particular when combined with simultaneous scheduling of numerous user terminals (e.g., tens or hundreds). DifferentMIMOconfigurations areSISO,SIMO,MISO,andMIMO.

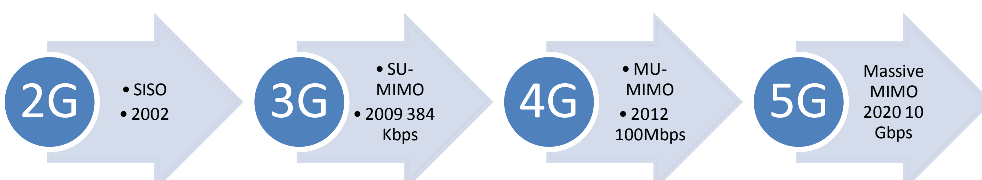

Fig 1: Evolving speed of wireless networks

MIMO is multiple antenna technique used in wireless communication. Multiple antenna techniques are categorized as 'diversity techniques' and 'spatial multiplexing techniques. In the former technique, the same signal is received through multiple antennas at the receiver or transmitted through multiple antennas at the transmitter thereby increasing transmission reliability. Thus, multiple antennas can be used to provide diversity gain and increase the reliability of wireless links if both transmit and receive diversity are considered. The wireless communication industry is currently experiencing a prolonged exponential growth in the demand for network traffic with no sign of it slowing down; the same is expected for the number of connected devices. Current networks are reaching their capacity limits concerning. the physical layer (because of the so- called 'spectrum deficit' or 'data tsunami'), especially in highly populated urban areas with a high density of connected devices.So, the big question in the wireless communications community is how to increase the network capacity to match the exponentially increasing traffic demand. The totalcapacity of a wireless network is directly related to the area throughput (in bps per unit area) of the network, which is a combination of three multiplicative factors:

$$\underbrace{\text{Area Throughput}}_{\text{bps area}^{-1}} = \underbrace{\text{Available Spectrum}}_{\text{Hz}} . \underbrace{\text{Cell Density}}_{\text{Cells area}^{-1}} . \underbrace{\text{Spectral Efficiency}}_{\text{bps Hz}^{-1}\text{cell}^{-21}}$$

Thus, higher area throughput can be, and traditionally has been, achieved by allocating more frequency spectrum (Hz) for wireless communications, increasing cell density (more cells per area), and improving the spectral efficiency (bps Hz−1 cell−1). So, with MIMO technology we improve spectral efficiency by increasing the capacity of the wireless communication system without any increase in available bandwidth. In wireless communication, MIMO has become an essential element of different communication standards including IEEE 802.11n (Wi- Fi), IEEE 802.11ac (Wi- Fi), HSPA+ (3G), Wi- MAX (4G), and LTE

(4G). Recently, it has been used for Power Line Communication for three-wire installations as a part of ITU G.hn standard and Home Plug AV2 specification.

1.1 Multi- user MIMO: Let us briefly review MIMO systems. Generally, MIMO systems are divided into two categories: single- user MIMO (SU- MIMO), as depicted in Figure 2.a, and multi- user MIMO (MU- MIMO), as depicted in Figure 2.b.

Fig 2: (a) A cellular base station tower with multiple antennas; (b) a Wi- Fi access point with multiple antennas.

In SU- MIMO (Figure 3.a), the transmitter and receiver are equipped with multiple antennas.Performance gain in terms of coverage, link reliability and data rate can be achievedthrough techniques such as beamforming, diversity- oriented space-time coding, andspatial multiplexing of several data streams. These techniques cannot be fully used atthesametime;thus,wetypicallyfindatrade- offbetweenthem.Forexample,adaptiveswitching between spatial diversity and multiplexing schemes is adopted in LTE.

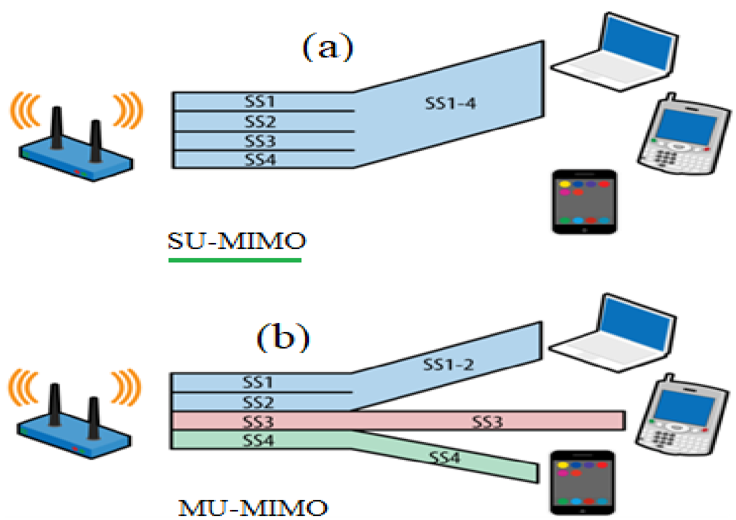

Fig 3: (a) Single- user MIMO; (b) multi- user MIMO.

MU- MIMO (Figure 3.b) isradicallydifferent. Thewirelesschannelisnowspatiallysharedbydifferentusers,andtheuserstransmitandreceivewithoutjointencodingand detection among them. By exploiting differences in spatial signatures at the base stationantenna array induced by spatially dispersed users, the base station communicatessimultaneouslytotheusers.Asaresult,performancegainsintermsof the sumratesofalluserscanbeimpressive.Amajorchallengeis,however,theinterferenceamongtheco-channel users. Signal processing in MU- MIMO often aims at suppressing inter- userinterference, so spatial channel knowledge becomes more crucial compared with SU- MIMO. In general, by exploiting the spatial domain of wireless channels, MIMO hasmany key advantages compared with single- antenna systems. Better coverage can beobtained through beamforming, improved link reliability through diversity, highercapacity through spatial multiplexing, and decreased delay dispersion are some of themajor advantages of MU- MIMO as compared with SU- MIMO.

1.2 Massive MIMO: Massive MIMO is a form of MU-MIMO system where the number of BS antennas and the number of users is large. In Massive MIMO, hundreds or thousands of BS antennas simultaneously serve tens or hundreds of users in the same frequency resource. A further promising way to improve spectral efficiency is now commonly referred to as massive MIMO or large- scale MIMO. The idea is to dramatically increase the number of antennas at the base station (in the order of hundreds to thousands). This technology is based on invoking large scale statistical effects that (in optimal conditions) eliminate small scale fading, interference, and noise from the communication system, as well as focus the transmitted energy only at the intended target. This allows many more UTs to be scheduled than is possible today, hence immensely increasing overall spectral efficiency. Interestingly, the assumption of hundreds of antennas might not be so far-fetched, as a 4G/LTE- A base station at maximal size already has 240 antenna elements. Massive MIMO has attracted much attention from the research community and its potential is being investigated by many. Crucially, many approaches to making the basic premise more practical have been discovered. Advances have been made on the problem of CSI estimation of the hundreds of channels (each BS antenna to each user antenna). The problem of the computational cost for the precoding schemes is being treated and energy efficiency aspects are being looked at. Even hardware impairments, which are certainly important as the cost per transceiver needs to be reduced when using hundreds of them, are being investigated.

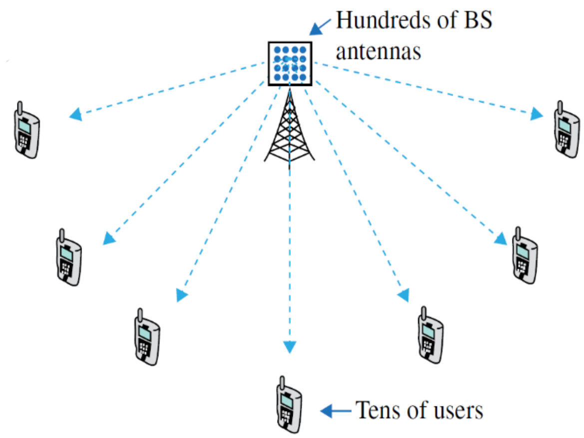

Fig 4: Basic concept of massive MIMO.

While the traditional radio devices often have just two, four, or a maximum of eight TRX channels, the radio devices powered by Massive MIMO technology can have 32 or 64 TRX channels, with up to 512 or even more antenna elements, which can lead to substantially higher capacity gain than traditional equipment. Furthermore, while the traditional devices focus more on coverage in the horizontal dimension, Massive MIMO offers much better flexibility also in the vertical dimension. Massive MIMO can exploit to a great extent the resources in space dimension and enable the users under the same base station to use the same time and frequency resources, which significantly enhances the network capacity without denser base stations and wider frequency bandwidth. One of the greatest things in our era is that 5G is helping realize the Intelligent Internet of Everything (IIoE), bringing great changes to people's lives, many vertical industries and the entire society with making the world a better connected and digital one. Massive MIMO, as one of the core technologies of 5G, is key to meeting the high-performance requirements and new service requirements of this amazing new era. Massive multiple-input-multiple-output (MIMO) systems use a few hundred antennas to simultaneously serve a large number of wireless broadband terminals. It has been incorporated into standards like long term evolution (LTE) and IEEE802.11 (Wi-Fi). Though Massive MIMO does offer great promises for highly capable 5G with wider bandwidth, more connections, lower latency and better reliability, realizing its full potentials requires effective responses to the challenges of network coverage, user experience, and network capability, which is relevant to all the mobile network operators and system vendors.

1.3 Evolution of MIMO Towards Massive MIMO: In both SU- MIMO and MU- MIMO, theoretically, the more antennas the transmitter and/or receiver are equipped with, the larger is the scale on which the spatial domain can be exploited. This leads to better performance in terms of the above- mentioned MIMO advantages. By letting the number of base station antennas grow without limit in MU- MIMO scenarios, the first important phenomenon is that the effects of additive receive noise and small- scale fading disappear, as does intracellular interference among users. The only remaining impediment is intercellular interference from transmissions that are associated with the same pilot sequence used in channel estimation. It is concluded that the throughput per cell and the number of terminals per cell are independent of the cell size, the spectral efficiency is independent of the system bandwidth, and the required transmit energy per bit vanishes. So, this is an important direction in which cellular systems may evolve.

Scaling up MIMO provides many more degrees of freedom in the spatial domain than any of today's systems. This rescues us from the situation where the wireless spectrum has become congested and expensive, especially in frequency bands below 6 GHz. In contrast to conventional MU- MIMO with up to eight antennas, we call MIMO with a large number of antennas 'massive MIMO', 'very- large MIMO', or 'large- scale MIMO'. The basic concept of massive MIMO is explained in Figure 11.

In massive MIMO operation, we consider an MU- MIMO scenario, where a base station equipped with a large number of antennas serves many terminals in the same time-frequency resource. Processing efforts can be mostly made at the base station side, andterminals have simple and cheap hardware. Until now, many theoretical and experimental studies have been done in the massive MIMO context. These studies have shown that massive MIMO can greatly improve spectral efficiency while decreasing radiated output power. Massive MIMO has the potential to meet these future requirements. In frequency bands below 6 GHz, massive MIMO is a candidate for smooth evolution from LTE to pre- 5G or the so- called 4.5G. In high-frequency bands, e.g., in millimetrewave transmission, using many antennas is a potential solution to overcome high propagation losses. Thanks to the large array gain, massive MIMO is also considered a technique to improve wireless network coverage. From another point of view, radiated power from both base stations and terminals can be scaled down, making massive MIMO also a candidate for 'green communications.

II. PROPOSEDMODEL

Spatial Multiplexing of Deterministic MIMO Channels:

Consider, $X \epsilon C^{N_t}$ as transmitted signal, $Y \epsilon C^{N_r}$ as received signal, $W \sim C\ N(0, N_0 I_{N_r})$ as white Gaussian noise, then, the time- invariant channel is defined as $Y = HX + W$,

Consider, the following MIMO channel model as shown in Figure 4.

The channel matrix $H \epsilon C^{N_t X N_r}$ is is given by

$$H = \begin{bmatrix} h_{11} & \dots & h_{11} \\ h_{21} & \dots & \dots \\ h_{t1} & \dots & h_{rt} \end{bmatrix}$$

where h_{ij} is the channel coefficient between the i^{th} receiver antenna and the j^{th} transmitter antenna.The channel matrix is deterministic and known to both transmitter and receiver. It is assumed to be constant at all times. This is a vector Gaussian channel. The capacity is calculated by decomposing the vector channel into a set of parallel independent scalar Gaussian subchannels. Capacity is computed at the receiver through multidimensional signal processing, which is very difficult and rather practically impossible. For enabling easy calculations, a one- to- one channel matrix is realized without interference, i.e., h_{11}, h_{22}, ...

To satisfy Figure 3, consider the following equation:

$$\begin{bmatrix} y_1 \\ .. \\ y_r \end{bmatrix} = \begin{bmatrix} h_{11} & 0 & 0 \\ 0 & h_{22} & 0 \\ 0 & 0 & h_{33} \end{bmatrix} \begin{bmatrix} x_1 \\ .. \\ x_t \end{bmatrix} + \begin{bmatrix} n_1 \\ .. \\ n_r \end{bmatrix}$$

where H is a diagonal matrix.

This diagonal matrix can be obtained by using singular value decomposition (SVD). We can represent H using SVD as:

$$H = U \wedge V^*$$

where $U \epsilon C^{N_r X N_r}$ and $V \epsilon C^{N_t X N_t}$ are unitary matrices and $\wedge \epsilon C^{N_r X N_t}$ is a diagonal matrix whose off- diagonal elements are zero and diagonal elements represented by $\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq \cdots \ldots \lambda_{nmin}$ are singular values of channel matrix H, where, $n_{min} = \min(n_t, n_r)$. Now, the one-to-one channel is realised if we cancel U and V from the above equation, i.e., UU* = I, VV* = I. Thus, pre- processing at the transmitter and post-processing at the receiver is required, i.e., multiply X by U* and Y by V. This is summarized in Figure 4.

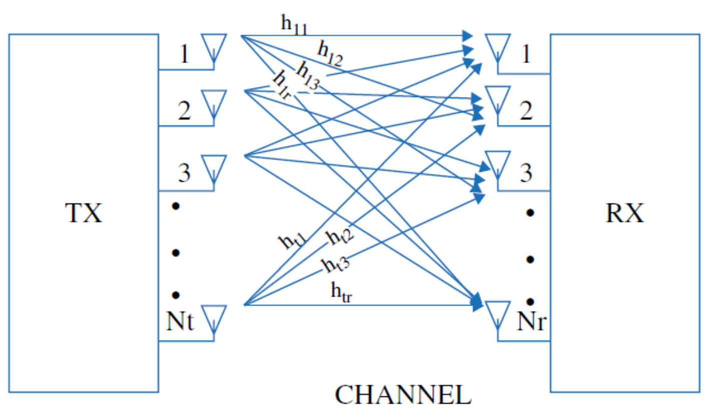

Fig 5: MIMO channel matrix.

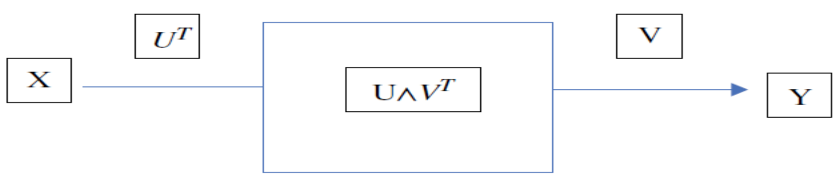

Fig 6: Pre- processing at the TX and post- processing at the RX.

In SVD, the input and output relationship is very simple; input is expressed in terms of a coordinate system defined by the columns of V and the output is expressed in terms of a coordinate system defined by the columns of U. The capacity of the time-invariant MIMO channel is thus given by:

$$C = \sum_{i=1}^{n_{min}} \log\left(1 + \frac{P_i^* \lambda_i^2}{N_0}\right) \text{bpsHz}^{-1}$$

where P_i^* is water filling power allocations at the transmitter given by:

$$P_i^* = \left(\mu - \frac{N_0}{\lambda_i^2}\right)^+$$

For the proposed work massive MIMO-OFDM LTE-Advanced System have been reviewedthrough many research papers related to massive MIMO and FFT-OFDM. To provide low biterrorrate(BER)atgivenSignaltoNoiseratioanditssimulationisnowveryimportant field of interest. So designing a software tool for field engineer particularlyin the next generation communication model is the problem formulation of this thesisworks. To solve this problem,proposed method uses a massive MIMO and OFDMforRayleighChannel. Adesignofproposed work willbedoneinMATLABSIMULINK2017a. The information bits are transmitted by Bernoulli binary generator with 20 samples perframe,encodercomprisesofCRCgeneratorandinitiallyencodedbytheTurboencoder with a data rate equal to 1/3. The encoded bits are then interleaved. LTE-Advanced supports a various modulation and coding, and can be applied dependingupon the channel condition. The encoded data stream is modulated with modulationschemes,namelyBPSK,QPSK,16-QAM and64-QAM. Theperformanceevaluationforthe SingleChannelmassive MIMO-OFDMsystemwithdifferentmodulation is experimented and compared with referencemodel[2]. Theproposedmodelisdesignedfor20samplesperframeandusingaturbocodegenerator of rate 1/3 with AWGN channel and observed better BER of 0.0092 at 5dbSNRandBER of0.0065at9dbSNR for16QAM. For designing of massive MIMO-OFDM LTE-Advanced System number of antenna,channelconditions, size of FFT and the loss in data due to channel noise would be majoranalyzingparameters. By experimenting for set of input digital data the proposed model will be designed tomake userfriendlyforanydesignengineer.

2.1 ArchitectureofProposedModel*:* The massive MIMO-OFDM LTE-Advanced system was modeled using Matlab (version 2017a) to allowvarious parameters of the system to be varied and tested. The aim of doing the simulations was tomeasure the performance of massive MIMO-OFDM LTE-Advanced system under different modulationtechniques, and to allow for different testing configuration. The massive MIMO-OFDM LTE-Advancedsystem was modeled using Matlab and is shown in Figure 6 and Figure 7 A brief descriptionofthemodelis providedbelow.

Bernoulli Binary Generator is used as the digital information source, bits are transmittedbyBernoullibinarygeneratorwith20samples perframe. General CRC Generator is an encoder comprises of CRC generator and initially encodedby the Turbo encoder with a data rate equal to 1/3. The encoded bits are then interleaved. Theinterleaverusedis a randominterleaver. Modulator Baseband which encodes the input data, LTE-Advanced supports a variousmodulation and coding, and can be applied depending upon the channel condition. The encodeddata stream is modulated with modulation schemes, namely BPSK, QPSK, 16-QAM and 64-QAM. OFDMBlockis used for orthogonal frequency division multiplexing, this block plays akey role in LTE Advanced system. The main idea behind OFDM is the so-called Multi-CarrierModulation(MCM)transmissiontechnique.MCMistheprincipleoftransmittingdatabydividing the input bit stream into several parallel bit streams, each of them having a much lowerbit rate, and by using these sub-streams to modulate several carriers[2] The main drawback ofOFDMisInter symbolInterference(ISI)to removethiscyclicprefix isadded afterthisblock.

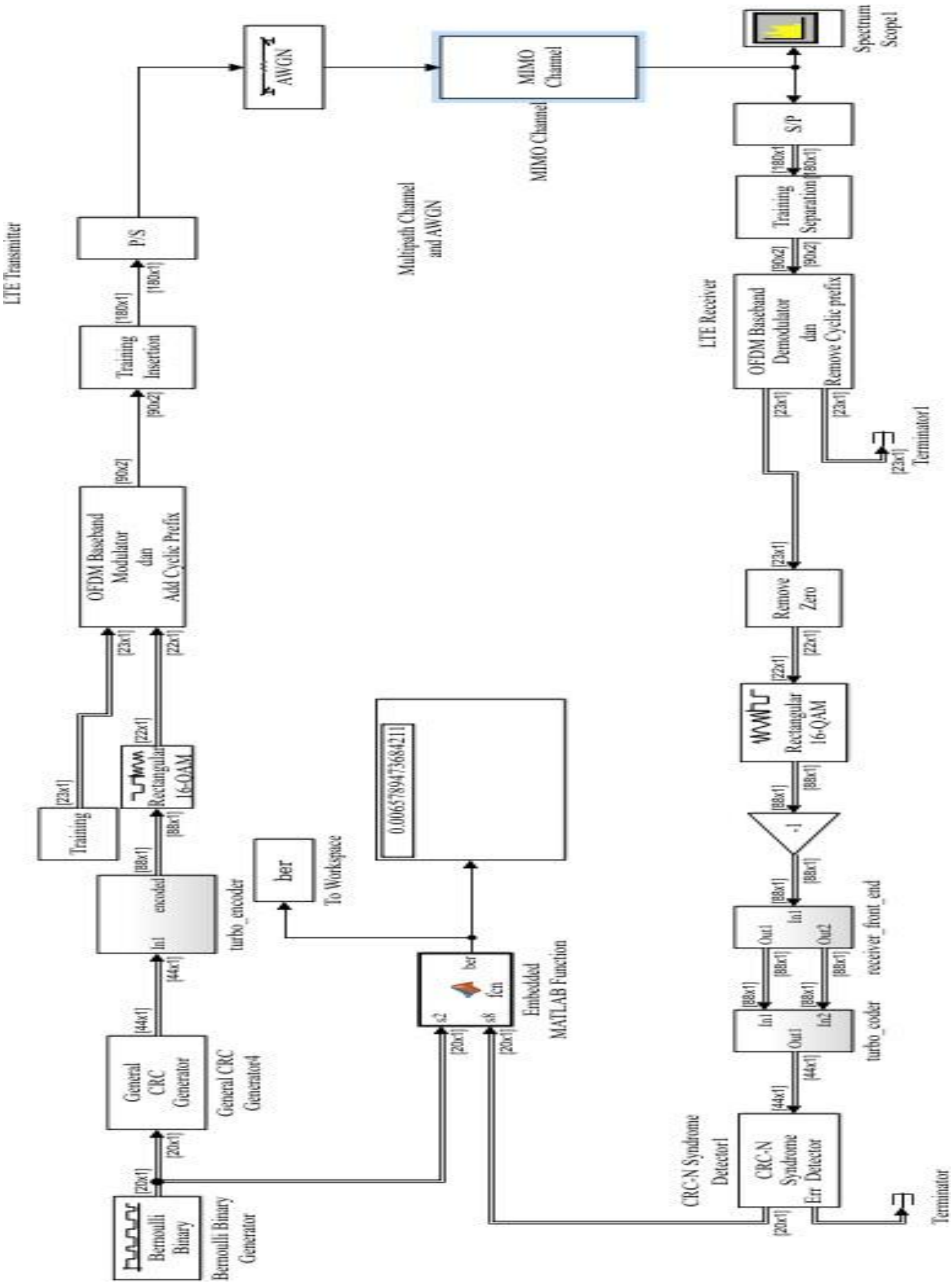

Fig.7Block diagramofLTE-ADVANCEDSYSTEMfor 16QAM

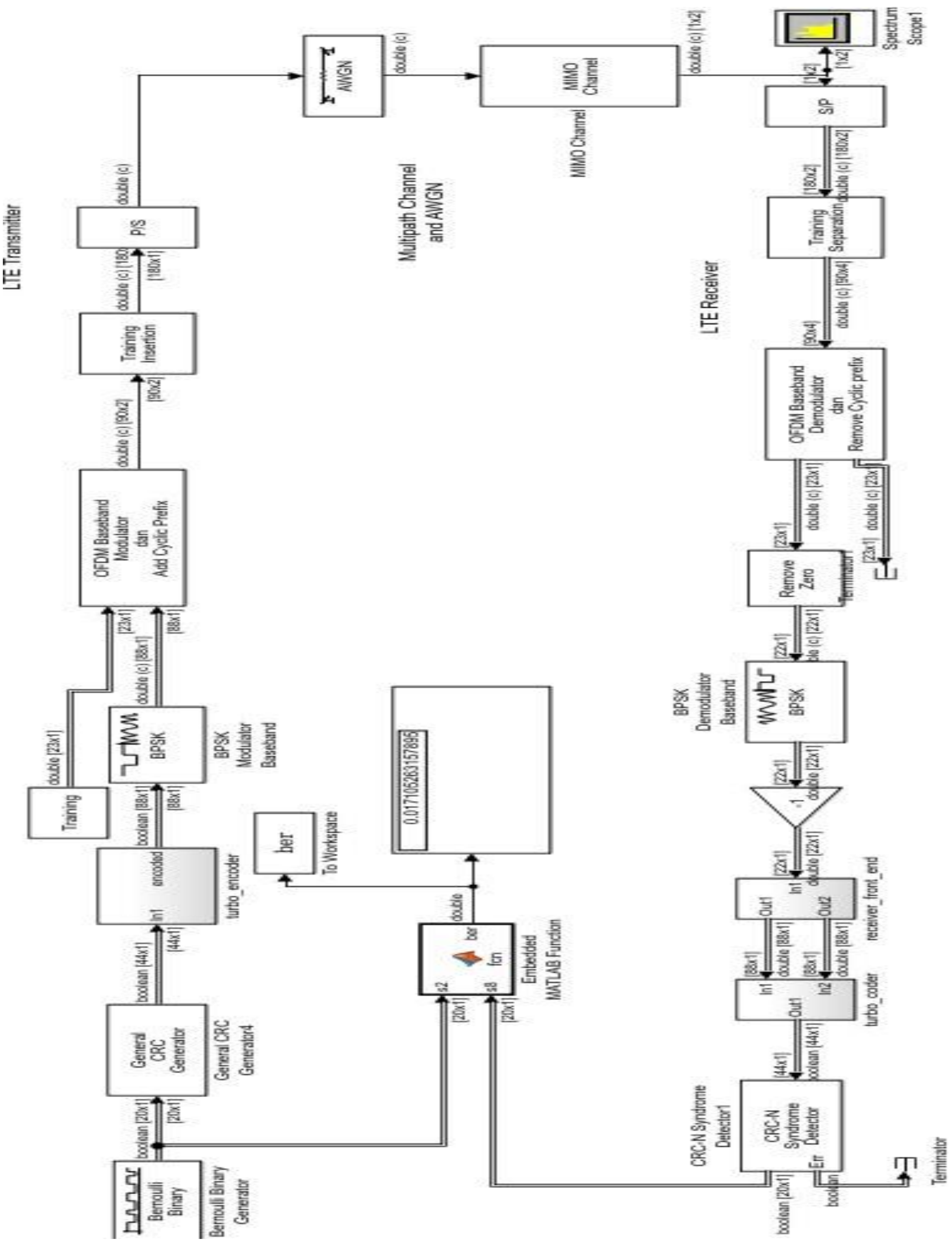

Fig.8 BlockdiagramofLTE-ADVANCEDSYSTEM forBPSKModulator

2.2 Flowchart*:* FlowchartoftheoverallprocessoftheLTEAdvanceddesignisshownbelowin figure 4. Cyclic Prefix is done to remove Inter symbol Interference. The Cyclic prefix (CP) acts as aguard time between successive blocks. It is a copy of the last part of the transmitted OFDMsymbol which is appended in front of the same symbol for each transmitted OFDM symbol.Inter-symbol interference and inter-carrier interference are the two major consequences of thetransmission over time varying frequency selective channels [3]. The cyclic prefix is used in theproposed LTE Advanced transceiver, to reduce the influence of the inter-symbol interference andalso it converts a discrete time linearconvolution into a discrete time circular convolution.However, the length of the cyclic prefix must be at least the same or longer than the length of thechannelimpulseresponse,inordertopreventtheoccurrenceofinterference[3].

Parallel To Serial consists of Unbuffed block. The Unbuffed block unbuffers an Mi-by-Ninput into a 1-by-N output. That is, inputs are unbuffered row-wise so that each matrix rowbecomes an independent time-sample in the output. The rate at which the block receives inputs isgenerallyless thantherate atwhichtheblockproduces outputs.

Additive White Gaussian Noise (AWGN)Channel block adds white Gaussian noise to areal or complex input signal. When the input signal is real, this block adds real Gaussian noiseand produces a real output signal. When the input signal is complex, this block adds complexGaussian noise and produces a complex output signal. This block inherits its sample time fromthe inputsignal.

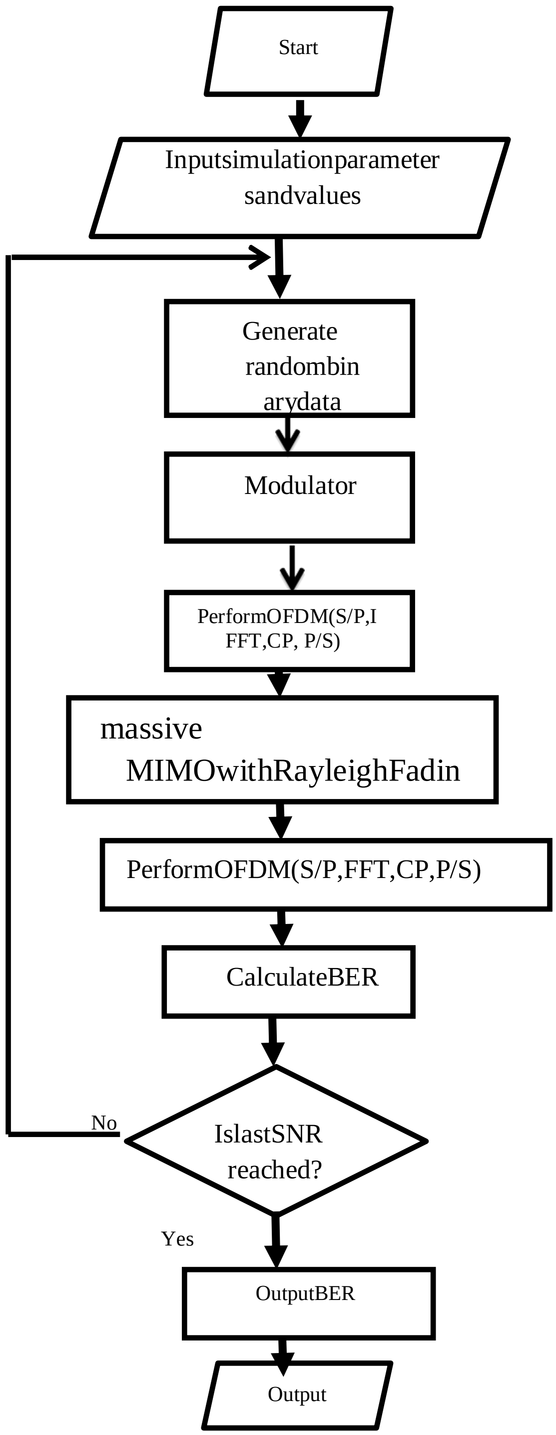

Fig.9FlowChartofLTEAdvanced system

BER Tool application enables to analyze the bit error rate (BER) performance of communicationssystems.BER ToolcomputestheBERasafunctionofsignal-to-noiseratio.ItanalyzesperformanceeitherwithMonte-CarlosimulationsofMATLABfunctionsandSimulinkmodelsor with theoretical closed-form expressions for selected types of communication systems. Thedemodulation process is reverse of the modulation process to get the input signal, and to checkthe differencebetweeninputandoutputsignalBER Toolis used.

Multiple Input Multiple Output (massive MIMO) Channel Blockis an antenna technology forwireless communications. The massive MIMO Channel block filters an input signal using a multiple-input multiple-output (massive MIMO) multipath fading channel. Fading distribution specify the fadingdistributionofthechannelasRayleighorRician.Inthismodelourselection isRayleigh. Spectrum Analyzer block, referred to here as the scope, displays frequency spectra ofsignals. The Spectrum Analyzer block accepts input signals, through one or more input ports,withthefollowingcharacteristics:

- Discretesampletime
- Real-orcomplex-valued
- Fixednumberofchannelsofvariablelength
- Floating-orfixed-pointdatatype

The proposed model combines the advantages of both massive MIMO and OFDM, and provides effectivesolutions to ISI and spatial diversity (increase robustness). OFDM can completely remove ISI byaddingcyclicprefix.massive MIMOsystemsaddspacediversity tosystems,so they canincreaserobustness of the systems, for example transmitter send one symbol from two antenna, if onechannel between transmitter and receiver is in bad condition then it is more probable in SISOsystem to fail, but in massive MIMO system that symbol fail in one channel but received in anotherchannel, then we can say massive MIMO is robust. From the simulation results, we can see that massive MIMO-OFDM LTE-Advanced system outperforms in comparison to reference paper in terms of BERperformance.

III. RESULTS

PAPR Consider the MIMO OFDM system with L transmit antennas that uses N sub-carriers. In the case of two transmit antennas, the each of N-dimensional OFDM symbol is transmitted from antenna 1 and antenna 2 respectively. Generally, the PAPR of the transmitted OFDM signal is defined as:

$$PAPR = 10\ log\left(\frac{\max[x(t)x^*(t)]}{E[x(t)x^*(t)]}\right)$$

E(.) means the expectation operation. When calculating PAPR using discrete sampled signals, we cannot find the accurate PAPR because the true peak of continuous-time OFDM signal may be missed in the Nyquist sampling. So, we use 4 times over-sampling to improve accuracy of discrete PAPR. Besides, to show statistical characteristics of PAPR, we use CCDF (complementary cumulative distribution function), which is the probability that PAPR of OFDM signal exceeds a certain threshold PAPR .

The ICI of the proposed work and the peaks looks closer to the average value of the subcarriers of the OFDM signals, as the difference between peaks and average reduces ICI also gets reduces.

Lower Stopband = 0 - 500 Hz
Passband = 1600 - 2300 Hz
Upper Stopband = 3500 - 4000 Hz
Stopband Attenuation = 50 dB
Passband ripple = 0.05dB
Sampling rate = 8000 Hz

Determine the FIR filter length and the cutoff frequency to be used in the design equation.

We first determine the normalized transition band

$$\Delta f_1 = \frac{|1600 - 500|}{8000} = 0.1375$$

$$\Delta f_2 = \frac{|3500 - 2300|}{8000} = 0.15$$

Design a bandpass FIR filter with the following specifications:

The filter lengths based on above transition bands (for Hamming window) are

$$N_1 = \frac{3.3}{0.1375} = 24$$

$$N_2 = \frac{3.3}{0.15} = 22$$

The nearest higher odd$N$ is chosen as for the Hamming window

$N = 25$

The lower and higher cutoff frequencies for the band pass filter will be

$$f_1 = \frac{1600 + 500}{2} = 1050Hz$$

$$f_1 = \frac{3500 + 2300}{2} = 2900Hz$$

The normalized lower and higher cutoff frequencies for the bandpass filter will be

$$\Omega_L = 2\pi f_L T_s = 2\pi \times \frac{1050}{8000} = 0.2625\pi\text{radians}$$

$$\Omega_H = 2\pi f_H T_s = 2\pi \times \frac{2900}{8000} = 0.725\pi\text{radians}$$

In this case$2M + 1 = 25$ will be the number of taps for the bandpass filter.

The simulation has been done and observe that proposed work ICI is 2.96 db and BER is 0.6182.

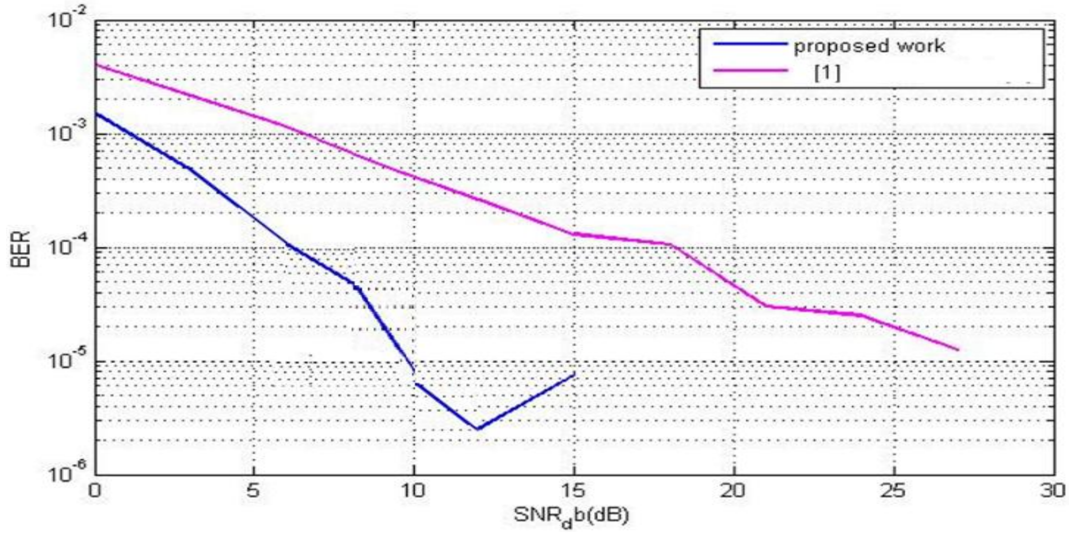

Figure 10 BER Comparative results with base [1]

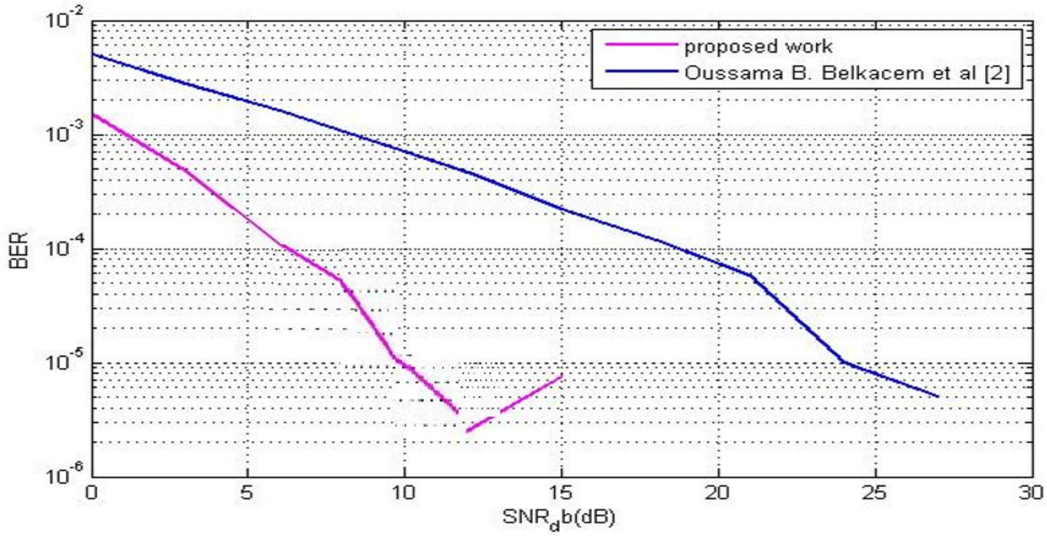

Figure 11 BER Comparative results with base [2]

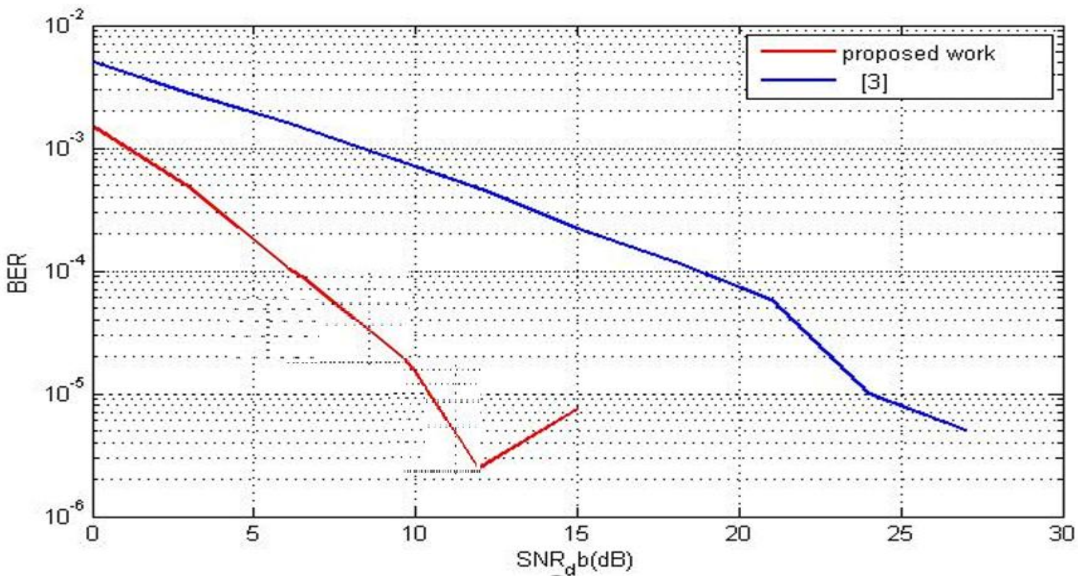

Figure 12 BER Comparative results with base [3]

Table 1 Comparative Results

Input Noise in db	*Proposed Work** 10^-3	W. Wu et al [1] *10^-3	A. M. Shteimanet al [2] *10^-3
0	*0.4005*	*0.508250*	*0.5055*
15	*0.0130*	*0.02225*	*0.02225*
30	*0*	*0*	*0.00175*

IV. CONCLUSION

This paper presents the basic principles of massive MIMO-OFDM LTE-Advanced for next generationwireless communication system. Multiple Input Multiple Output (massive MIMO) in combination withOrthogonal Frequency DivisionMultiplexing(OFDM)is arecently proposedtechniqueformultiple access communication. Thus, the number of antennas in massive MIMO and cyclic prefix used inOFDM must be carefully designed to ensure good performance, low memory requirements andlow computationalcomplexity.

Performance of the proposed model is experimented and compared for different modulators likeBPSK, QPSK, 16QAM, 64QAM. Comparison is done in terms bit error rate (BER) with otheralternative technologies in wireless communication system. The input data sequence is digitalsinceit's adigitalmodulationscheme. Thisworkconcludeswith thesuccessfulimplementation of proposedsinglechannelmassive MIMO-OFDM LTE-Advanced system for next generation wireless communication system. Theproposed model is experimented for different parameters like, different modulators and foundquite efficient. Performance of the proposed model is experimented and compared for differentmodulators namely, BPSK, 16QAM, 64QAM, and QPSK for Rayleigh Fading channel withtransmitter and receiver, and observed for better BER, and convergence are fast for wirelesscommunication system.Bit error rate (BER) is used for measuring performance. Results showsthat as we increase energy per bit to noise ratio (E_b/N_0) then BER decreases. The experimentalresults show better performance for BPSK and 16QAM at 5db and 9db respectively, whencomparedwithreferencepaper.

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