# Performance Analysis of MIMO-LTE over MQAM over fading channels using ANN

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*Abstract*—**LTE (Long Term Evolution) which is a 3GPP (Third Generation Partnership Project) wireless standard uses the standard OFDMA (Orthogonal Frequency Division Multiple Access) modulation, MU-MIMO (Multiuser Multiple Input Multiple Output) technology and different multipath fading models. This paper characterizes the downlink performance of LTE using ANN (Artificial Neural Network). The MIMO technology made a breakthrough in wireless communication by providing high data rate applications to the users and is defined in the LTE standard. ANN is used to provide an estimate of the channel to minimize the deficiencies of multi-user transmission under Rayleigh multipath fading and improve reception of MIMO-OFDM systems by providing superior Bit Error Rate (BER) s. The performance is characterized in terms of BER (Bit Error Rate). In this paper the LTE system is modelled and simulated using MATLAB and the BER for 2×2 and 4×4 MIMO-LTE using ANN and QPSK, 16QAM and 64QAM modulation schemes for Rayleigh fading environment are obtained against different SNR values using ANN.**

***Keywords- 3GPP; LTE; MIMO; PHY; ANN; BER; SNR***

## I. INTRODUCTION

Long Term Evolution (LTE) was designed to deliver users the benefit of faster data speed as well as high capacity voice support. LTE operates in the bands FDD (Frequency Division Duplex) and TDD (Time Division Duplex) of UMTS. It provides data rate of about 100Mbps in the downlink in 20MHz channel and 50Mbps in the uplink in 20MHz channel. Scalable bandwidth of LTE is from 1.4 to 20MHz. LTE makes use of some advanced signal processing techniques like the OFDMA (Orthogonal Frequency Division Multiple Access) technology which supports parallel transmission on large number of narrowband subcarriers and protects against multipath and frequency selective fading of the signal. It also improves the spectral efficiency. LTE also uses a multiple antenna technique known as the MIMO (Multiple Input Multiple Output) technology which is used at the transmitter and the receiver side to increase the quality or capacity at no added spectrum cost. LTE uses QPSK, 16QAM, 64QAM modulation schemes for the downlink whereas for the uplink 64QAM modulation is optional.

Channel estimation is one of the challenging areas which offer considerable scope to improve quality of service of the mobile networks and provide greater bandwidth. Innovative means are being formulated to tackle channel estimation and improve performance of mobile systems. One of the viable means to better channel estimation techniques is the use of soft-computing tools like ANN for channel estimation under multipath fading conditions. Application of ANNs for channel estimation is a challenging problem. An ANN can be used to provide an estimate of the channel which may help to mitigate some of the efficiencies of multi-user transmission. The ANN can be trained to make it robust enough to deal with multiple channel types and improve BER values. The work is related to channel estimation of a MIMO-OFDM system under Rayleigh multipath fading environment using ANN. Rayleigh multipath fading is a common occurrence where the signal suffers multiple reflections due to high rise structures. The work considers the use of an ANN to tackle a Rayleigh multipath faded channel to estimate the channel coefficients to determine the BERs.

## II. THEORETICAL BACKGROUND

LTE was developed by the 3GPP and can be considered as an evolution of UMTS and HSPA. LTE began in 2004 and was completed in 2008. It was known as 3GPP Release 8. LTE has several goals like improved system capacity and coverage, high peak data rates, low latency, reduced operating cost, multi-antenna support, flexible bandwidth operation, seamless integration with existing systems (UMTS, Wi-Fi, etc.). The radio interface which covers the interface between the UE (User Equipment) and the network is composed of the Physical layer, Medium Access Control layer and the Radio Resource Control layer. LTE uses the downlink air interface technologies OFDMA and MIMO. In the OFDMA technique multiple simultaneous users are allocated to different subcarriers. In the downlink there is one resource grid per antenna port. The downlink resource grid consists of Resource block, Resource elements and Resource element-groups. A resource block consists of 12 subcarriers in the frequency domain and 7 OFDMA symbols in the time domain with a subcarrier spacing of 15 KHz. Several number of resource blocks combine together to form the resource grid. Thus in the frequency domain the entire band is divided into blocks of 12 subcarriers or 180 KHz. These blocks form the Physical Resource Blocks (PRB). Fig. 1 shows the Resource elements, blocks and grid. The subcarriers in these resource blocks are modulated using QPSK, 16QAM, 64QAM techniques [1, 10, 13].

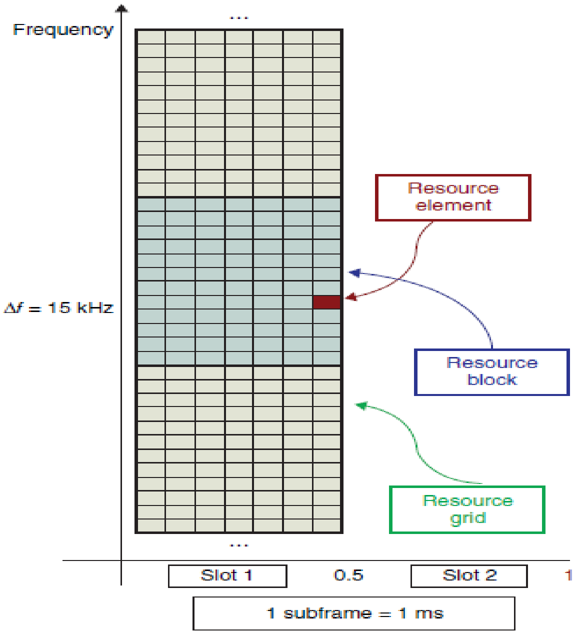


Figure 1. Resource elements, blocks and grid

If the frequency spectrum of the message signal does not fall within a fixed frequency range or is unsuitable for the channel, the carrier signal is changed according to the information in the message signal and this process is known as modulation. The receiver recovers the original signal through the process of demodulation. Modulation schemes should achieve low bit error rate in the presence of interferences like fading, Doppler spread and thermal noise. Higher order modulation schemes like 64QAM give best results with strong signals and lower order modulation schemes like QPSK gives best results with weak signals. As specified in the LTE standard the preferred channel coding techniques for LTE are Turbo Coding and Rate Matching [2, 3, 4].

MIMO technology is a breakthrough in wireless communication as it provides users with high data rate applications. This technology uses multiple numbers of transmitting and receiving antennas in wireless systems. In conventional wireless communications, a single antenna is used at the source and another antenna is used at the destination. In some cases this give rise to problems with multipath effect. When an electromagnetic field is obstructed by hills, canyons, buildings, utility wires etc. the wave fronts are scattered and thus they take many paths to reach the destination. The late arrival of scattered portions of the signal causes fading. The use of two or more antennas for transmission and reception of multiple signals at the source and the destination eliminates the trouble caused by multipath wave propagation and can even take advantage of the effect. Thus MIMO wireless technology is able to considerably increase the capacity and throughput of a given channel by using multiple antennas. Improvement in capacity and BER is also seen by the use of MIMO. Thus MIMO can actually be said to be a radio antenna technology as it uses multiple antennas at the transmitter and the receiver to carry the data. The block diagram of a MIMO is shown in Fig. 2. The channel with N outputs and M inputs is denoted as M×N matrix: [5, 6, 7, 8, 9]

$$H(n) = \begin{pmatrix} h_{(n,1,1)} & \cdots & h_{(n,1,N)} \\ \vdots & \ddots & \vdots \\ h_{(n,M,1)} & \cdots & h_{(n,M,N)} \end{pmatrix} \quad (1)$$

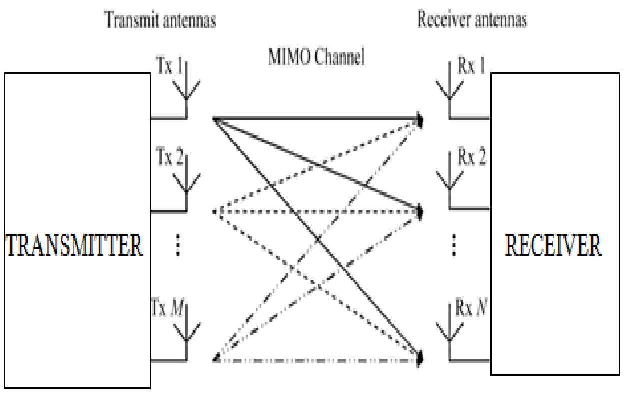


Figure 2. MIMO (Multiple Input Multiple Output)

A most common obstacle in wireless communication is multipath fading due to the propagation of multiple versions of the transmitted signals through different paths in the radio channel before they arrive at the receiver. The different signals exhibit varying signal power and time delays or phases. As a result the received signal can be modeled as a filtered version of the transmitted signal by the impulse response of the radio channel. The multiple signal paths may sometimes add constructively or sometimes destructively at the receiver causing variation in the power level of the received signal. Rayleigh fading is the form of fading which is often experienced in an environment where there are large numbers of reflections present. The Rayleigh fading model is normally viewed as a suitable approach for areas such as cellular communications in a well built up urban environment with number of reflections from buildings, etc. and a line of sight path is not there for analyzing and prediction of radio wave propagation performance [1, 6, 14]. In the 3GPP LTE standard three different multipath fading models are defined. They are EPA (Extended Pedestrian A), EVA (Extended Vehicular A), and ETU (Extended Typical Urban). The delay profiles of these three models were discussed [13, 15, 16, 17, 18].

LTE also makes use of Artificial Neural Network (ANN) which is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information to update or improve the accuracy of already existing system. A set of processing units when assembled in a closely interconnected network, offers a surprisingly rich structure exhibiting some features of the biological neural network structure called as the Artificial Neural Network (ANN). The general model of a processing unit consists of a summing part followed by an output part. The summing part receives N input values, weights each value, and computes a weighted sum which is called the activation value. The output part produces a signal from the activation value. In ANN several processing units are interconnected according to some topology to accomplish a pattern recognition task. Therefore the inputs to a processing unit may come from the outputs of other processing units and/or from external sources. The output of each unit may be given to several units including itself. The amount of the output of one unit received by another unit depends on the strength of the connection between the units and it is reflected in the weight value associated with the connecting link. The set of N activation values of the network defines the activation state of the network at that instant. Likewise the set of N output values of the network define the output state of the network at that instant. There are two major subdivisions in Neural Networks feed-forward/bottom-up and feedback/interactive networks. In the feed-forward setup, signals are restricted to travel in one direction; input to output. This means that the output of one layer does not affect that same layer; because of this feed-forwards are mostly used in pattern recognition. In feedback signals are allowed to travel in both directions. These networks are more powerful and dynamic; their 'state' is changing continuously until they reach an equilibrium point. Neural Networks are divided into layers; the input, hidden and output layers. The input units represents the data, the activity of the hidden (output) units is determined by the input (hidden) units and the weights on the connection between them [11, 12]. Fig. 3 shows the schematic diagram of the Artificial Neural Network.

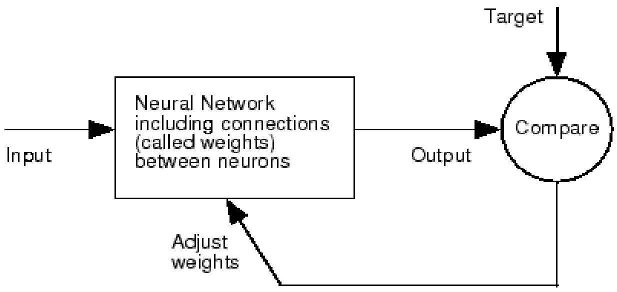


Figure 3. Artificial Neural Network

The Neural Network Design Steps are:

- Collect data
- Create the network
- Configure the network
- Initialize the weights and biases
- Train the network
- Validate the network
- Use the network

In [15, 16, 17, 18] the BER vs. SNR performance for an LTE MIMO system is observed for a Rayleigh fading environment using different modulation schemes like QPSK, 16QAM and 64QAM. In [19] the impact of EVA and EPA parameters on an LTE- MIMO system is studied. In this paper focus is mainly on the downlink LTE using ANN in a Rayleigh fading environment is discussed.

## III. SYSTEM MODEL

The structure of the LTE downlink transceiver is shown in Fig. 4. It is composed of a transmitter, a channel model and a receiver. In LTE Physical layer which is interfaced by the MAC layer is connected by the transport channels. In the transmitter side the transport channel performs CRC (Cyclic Redundancy Code) generation, turbo coding based on 1/3 rate and rate matching of the coded transport channel to handle any requested coding rates. The coded bits are then scrambled resulting in a block of scrambled bits. The blocks of scrambled bits are then modulated using modulation mapper, which produces complex valued modulation symbols. The complex valued modulated symbols are mapped onto one or several layers. The block of vectors from the layered mapping is then precoded using the precoder and produces an output.

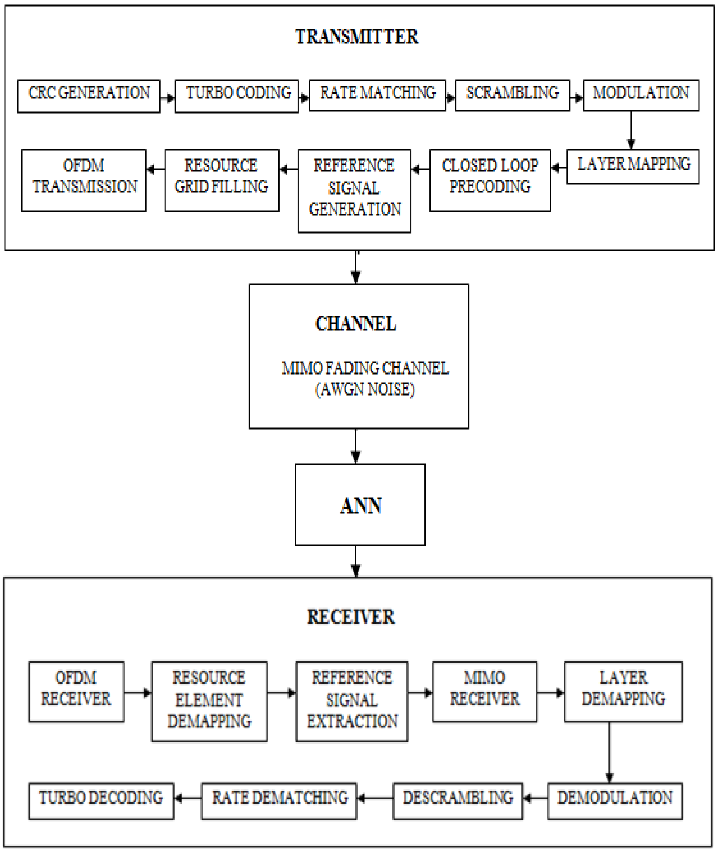


Figure 4. System Model of LTE Downlink using ANN

Reference Signals are needed to properly decode the data in LTE. After Precoding the reference signals are generated and the coded bits are then mapped to the physical resource blocks.

Then OFDM (Orthogonal Frequency Division Multiplexing) transmission is then applied to the resource grid which produces the transmitted symbols. The transmitted symbols passes through a channel which is distorted by AWGN noise and causes fading of the signal. ANN is used for better channel estimation and then the symbols are received at the receiver and in the receiver the symbols will be recovered based on the reverse operations as on the transmitter side. The receiver will receive the OFDM signals processed by the channel, an estimate of the noise variance per received channel, the transmitted reference signals and demodulate the OFDM symbols to generate the best estimate of the transmitted symbols [13, 15, 16, 17, 18, 19].

## IV. EXPERIMENTAL RESULTS

The information bits are generated in the transmitter side. The bits are than modulated using different modulation schemes such as QPSK, 16QAM and 64QAM. The modulated bits are transmitted using two and four transmitting antennas and sent to the receiving antennas through MIMO Fading Channel and AWGN noise is added. It is then demodulated to get the desired signal. The performance is characterised by plotting Bit-error rate (BER) against different SNR (Signal to Noise ratio) values. The system has been developed using communication tool box available in MATLAB.

### *A. Parameters Used*

The parameters used are listed in Table 1, Table 2 and Table 3.

TABLE 1. Cell Width Configuration

| **Parameters** | **Values** |
|---|---|
| No of Users | 2 |
| No of Frames | 1024 |
| No of resource blocks | 50 |
| No of Transmit antennas | 2/4 |
| Cell ID | 0 |
| Cyclic prefix | Normal (7) |
| Duplex mode | FDD (Frequency Division Duplex) |
| SNR Range | 0:8 (QPSK)<br>8:16 (16QAM) |
| Transmission mode | 4 (Spatial multiplexing) |
| Coding rate | 1/3 |
| Equalization mode | MMSE |
| Demodulation | QPSK, 16QAM |

TABLE 2. Channel Model Configuration

| **Parameters** | **Values** |
|---|---|
| No of received antennas | 2/4 |
| Downlink channel | PDSCH (Physical downlink shared channel) |
| Channel bandwidth | 20 MHz |
| Channel model | EVA 5Hz |
| Doppler shift | 5 |
| Fading type | Rayleigh |
| Noise type | AWGN |
| MIMO correlation | Low |
| Normalize path gain | On |
| Normalize for transmission antennas | On |

TABLE 3. ANN parameters used for training

| **Parameters** | **Values** | | |
|---|---|---|---|
| ANN type | Feed forward | | |
| Training algorithm | Levenberg - Marquardt (trainlm) | | |
| No of hidden layers | 1 | | |
| Transfer function combination | Tansig - tansig - tansig | | |
| Epoch | 1000 | | |
| **Modulation schemes** | **Best performance at epoch 1000** | **Gradient at epoch 1000** | **Mu at epoch 1000** |
| Qpsk 2x2 | 0.40959 | 0.00069244 | 0.001 |
| Qpsk 4x4 | 0.13889 | $2.6667e^{-05}$ | $1e^{-05}$ |
| 16Qam 2x2 | 0.10765 | $6.7712e^{-05}$ | $1e^{-07}$ |
| 16Qam 4x4 | 0.10412 | $1.3465e^{-05}$ | 0.001 |
| 64Qam 4x4 | 0.11252 | $2.3767e^{-05}$ | 0.0001 |

### *B. **BER vs. SNR plots***

The quality of the digital link is defined by the BER. It is calculated from the number of bits received with error divided by the number of bits transmitted by the transmitter i.e. the number of bit errors per unit time. SNR is defined as the ratio of the received signal strength over the noise strength in the frequency range of the operation. SNR is inversely related to BER, that is high BER causes low SNR. High BER causes increase in delay and decreases throughput. SNR is used to study the quality of a communication link.

The BER vs. SNR plots for QPSK, 16QAM and 64QAM using ANN and LTE PHY transceiver model for Rayleigh fading environment using MIMO are shown in Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9. BER values for 2×2 and

4×4 MIMO LTE for different values of SNR for QPSK, 16QAM and 64QAM Rayleigh fading are listed in Table 4, Table 5, Table 6, Table 7 and Table 8 respectively.

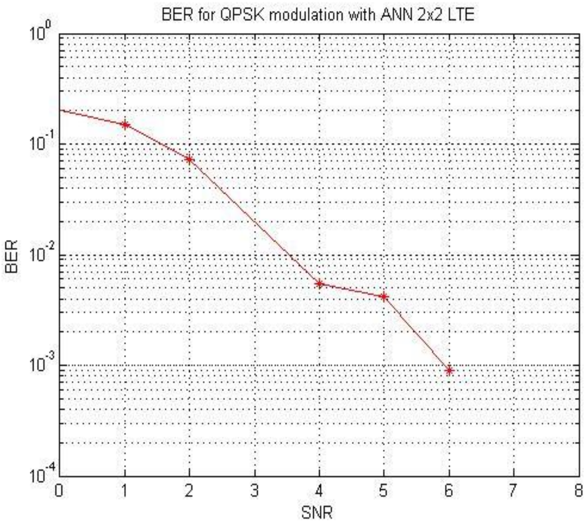


Figure 5. BER vs. SNR plot for 2×2 MIMO-LTE with QPSK modulation using ANN

TABLE 4. BER vs. SNR plot for 2×2 MIMO-LTE with QPSK Modulation using ANN

| Sl. No | SNR (db) | BER 2x2 QPSK MIMO- LTE |
|---|---|---|
| 1 | 0 | 0.2028000 |
| 2 | 1 | 0.1493000 |
| 3 | 2 | 0.0723300 |
| 4 | 4 | 0.0054510 |
| 5 | 5 | 0.0041300 |
| 6 | 6 | 0.0008868 |

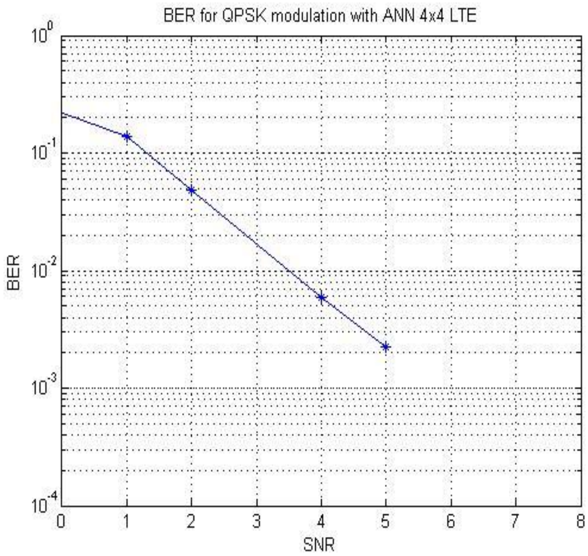


Figure 6. BER vs. SNR plot for 4×4 MIMO-LTE with QPSK modulation using ANN

TABLE 5. BER vs. SNR plot for 4×4 MIMO-LTE with QPSK Modulation using ANN

| Sl. No | SNR (db) | BER 4x4 QPSK MIMO- LTE |
|---|---|---|
| 1 | 0 | 0.218800 |
| 2 | 1 | 0.136600 |
| 3 | 2 | 0.048410 |
| 4 | 4 | 0.005965 |
| 5 | 5 | 0.002216 |

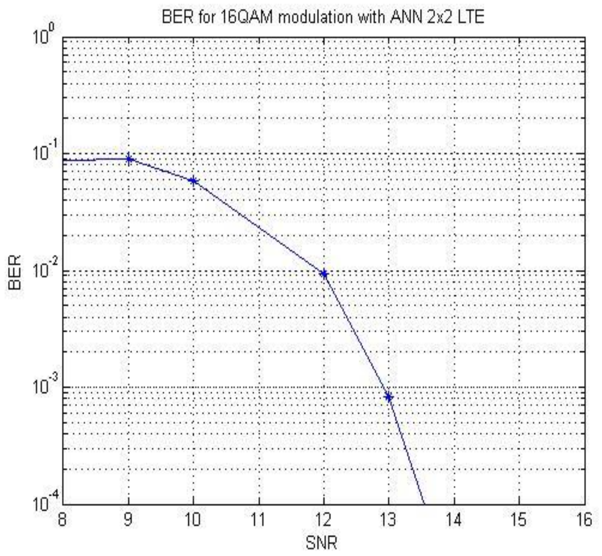


Figure 7. BER vs. SNR plot for 2×2 MIMO-LTE with 16 QAM modulation using ANN

TABLE 6. BER vs. SNR plot for 2×2 MIMO-LTE with 16 QAM Modulation using ANN

| Sl. No | SNR (db) | BER 2x2 16 QAM MIMO- LTE |
|---|---|---|
| 1 | 8 | 0.0875200 |
| 2 | 9 | 0.0898100 |
| 3 | 10 | 0.0577100 |
| 4 | 12 | 0.0093890 |
| 5 | 13 | 0.0008233 |

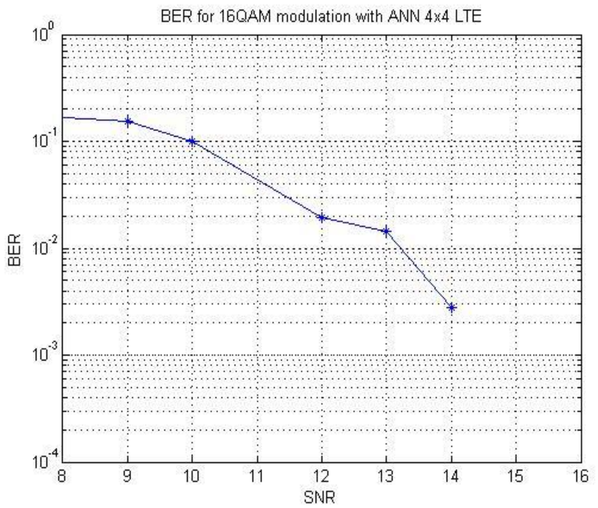


Figure 8. BER vs. SNR plot for 4×4 MIMO-LTE with 16 QAM modulation using ANN

Table 7. BER vs. SNR plot for 4×4 MIMO-LTE with 16 QAM Modulation using ANN

| Sl. No | SNR (db) | BER 4x4 16 QAM MIMO- LTE |
|---|---|---|
| 1 | 8 | 0.166900 |
| 2 | 9 | 0.152300 |
| 3 | 10 | 0.101200 |
| 4 | 12 | 0.019180 |
| 5 | 13 | 0.014200 |
| 6 | 14 | 0.002774 |

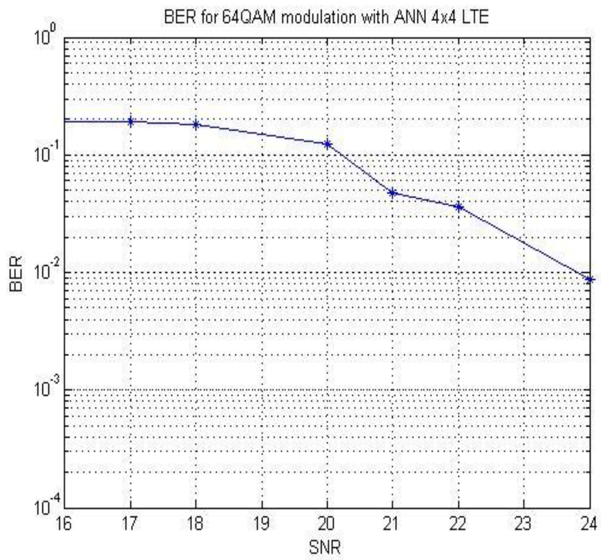


Figure 9. BER vs. SNR plot for 4×4 MIMO-LTE with 64 QAM modulation using ANN

Table 8. BER vs. SNR plot for 4×4 MIMO-LTE with 64 QAM Modulation using ANN

| Sl. No | SNR (db) | BER 4x4 64 QAM MIMO- LTE |
|---|---|---|
| 1 | 16 | 0.189200 |
| 2 | 17 | 0.191400 |
| 3 | 18 | 0.181800 |
| 4 | 20 | 0.124700 |
| 5 | 21 | 0.047210 |
| 6 | 22 | 0.036410 |

| | | |
|---|---|---|
| 7 | 24 | 0.008744 |

## V. CONCLUSION

Due to the potential increase in data rate and transmit diversity offered by the MIMO technology, 3GPP LTE seems to be a cornerstone in the present day scenario. In this paper the concept of 3GPP LTE has been demonstrated using the standard LTE model with transmission mode 4 with severely faded EVA 5Hz fading channel using MIMO technology. The signal is transmitted through Rayleigh faded environment. BER curves play a very important role in the performance of the system. With the increasing value of SNR the BER values must decrease for a better performance of the system. In this paper the BER vs. SNR values for 2×2 and 4×4 MIMO using ANN for QPSK, 16QAM and 64QAM modulation schemes are plotted and studied that the system performance increases as BER values decrease for higher SNR values. In this paper although EVA 5 Hz fading channel is considered several other severely faded channels can be used. The no of transmit and receive antennas can also be increased.

## REFERENCES

[1] Dr. H. Zarrinkoub, Understanding LTE with Matlab® From Mathematical Modeling to Simulation and Prototyping, Wiley, 2014.

[2] B. Sklar, Digital Communication, Prentice Hall, Upper Saddle River, NJ, Second Edition, 2008.

[3] S. Haykin, Communications Systems, Second Edition, Wiley, 1983.

[4] J. Proakis, Digital Communication,5th Edition, McGraw-Hill, 2007.

[5] A. Goldsmith, Wireless Communication, Cambridge University Press, 2005.

[6] T.S. Rappaport, *Wireless* Communications-Principles and Practice, Pearson Education 1997.

[7] R. U. Nabar A. J. Paulraj, D. A. Gore and H. B¨olcskei, "An overview of MIMO communications-- a key to gigabit wireless", Proceedings of the IEEE, vol. 92, no. 2, pp. 198–218, Feb. 2004.

[8] B. Stetler, "Maximizing LTE Performance Through MIMO Optimization", White paper, Gadgetwise (blog), New York Times, January 7, 2011.

[9] C. Cox, "An Introduction to LTE, LTE-advanced, SAE , VoLTE and 4G mobile communications", Second Edition, Wiley, 2014.

[10] Juho. Lee, Jin-Kyu Han and Jianzhong (Charlie) Zhang, Review Article MIMO Technologies in 3GPP LTE and LTE-Advanced Hindwai Publishing Corporation, EURASIP Journal on Wireless Communications and Networking, Volume 2009.

[11] B. Yegnanarayana, Artificial Neural Networks, Prentice-Hall, 2005.

[12] P. Gogoi and K. K. Sarma, "Channel Estimation Technique for STBC coded MIMO System with Multiple ANN Blocks", International Journal of Computer Applications (0975 – 8887), Volume 50 – No.13, July 2012.

[13] P. Gogoi, R. Borah, A. Sarma, B. Saikia, "On The Evolution of Downlink Physical Layer in multi-antenna 3GPP LTE / LTE-A: A review", 2015 International Symposium on Advanced Computing and Communication.

[14] M. K. Simon, M.-Slim Alouini, Digital Communication over Fading Channels, 2nd ed. New York: John Wiley and Sons, 2005.

[15] D. Kaushik, R. Borah, P. Gogoi, "3GPP LTE Downlink PHY transceiver using Closed-loop Spatial Multiplexing in Frequency Selective Fading Environment", International Journal of Computer Applications (0975 – 8887) Volume 134 – No.12, January 2016.

[16] A. Rajkhowa, D. Kaushik, B.J. Saikia, P. Gogoi, "Performance Analysis of MIMO over MIMO-LTE for QPSK considering Rayleigh Fading Distribution", International Journal of Research and Scientific Innovation (IJRSI) | Volume III, Issue VI, June 2016 | ISSN 2321–2705.

[17] D. Kaushik, A. Rajkhowa , P. Gogoi , B. Saikia, "Performance Analysis of MIMO over MIMO-LTE for MQAM Considering Rayleigh Fading Distribution", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 4, Ver. III (Jul.-Aug .2016), PP 41-49.

[18] D. Kaushik, A. Rajkhowa , P. Gogoi , B. Saikia, "Performance Analysis of MIMO-LTE for MQAM over Fading Channels", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE), e-ISSN: 2278-2834, p- ISSN: 2278-8735.Volume 12, Issue 1, Ver. III (Jan.-Feb. 2017), PP 11-17.

[19] A. Rajkhowa, D. Kaushik, B.J. Saikia, P. Gogoi, "The Impact of EVA & EPA Parameters on LTE-MIMO System under Fading Environment", International Journal for Research in Applied Science & Engineering Technology (IJRASET), ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887, Volume 5 Issue X1, November 2017.