3.1. Introduction:

In OFDM framework an arrangement of subcarriers is utilized, which are orthogonal to one another, keeping in mind the end goal to accomplished a high productivity. The signals are considered as orthogonal to each other and touch consequence of two signs are identical to zero (Litwin and Pugel, 2000). In a general sense the OFDM based structure refers to multicarrier change model which disconnects open extent towards various subcarriers. A segment, from usages of OFDM, is according to the accompanying WIMAX-LTE-Advance (Bloessl et.al., 2013). OFDM expect a basic part and diminish the multifaceted design of beneficiary however in this technique channel estimation and synchronization is basic (Divyatha and Reddy, 2013). In the event that ought to emerge an event of high speed correspondence, ISI is one of the noteworthy issues. ISI thought to be overcome at OFDM system with detaching a guard band with divided the channel (Reddy and Lakshmi, 2015; Suhagiya and Patel, 2014). The OFDM structure is quality to obscuring which is realized in view of multi way Interference. Cyclic Prefix is added to each picture to overcome the ISI sway which prompts high supernatural capability yet it moreover cause swells in power spooky thickness (Jiang et.al, 2007). In OFDM system there is instability of adequacy in far reaching entirety which achieves PAPR that cause nonlinear distortion in rational use of intensifier which makes the structure inefficient (Han et. al., 2005). In OFDM framework, the images are transmitted with longer time period so that the recipient has a lot of time to descramble the signs which makes it conceivable to recuperate a most noticeably awful flag. Due to some disadvantages of OFDM like PAPR, interference. The OFDM is combined with MIMO. In MIMO, the thought is to use the spatial multiplexing so as to get a level reaction of a channel because of its tight data transmission (Amn et.al, 2013). The Fading impact in OFDM framework can be minimized by sending the same sign through various receiving wires. The beneficiary part comprises of expansive number varieties of receiving wires which gets the same flag that has gone through the diverse way. The limit is likewise sending so as to be expanded the distinctive information at a same time (Omri and Bouallegue, 2011).
utilization of versatile adjustment and versatile plan with high information rate, sub bearer portion can facilitate increment (Uthansakul and Bailkowski, 2006). The MIMO could be used by a single user and different user can also access these systems which are also known as distributed MIMO. MIMO is also considered to be the better technique as compared to SISO (Single Input and Single Output) in terms of diversity gain. One of the major disadvantages of MIMO OFDM is that it needed a circuit that consumes a large amount of energy which increases the cost of the system and affect the performance of the battery (Devi and Talwar, 2013).

3.2. Characteristics of OFDM Signals:

Let us consider a block of N symbols $X(l) = [Y(k)]$, where $k = [0, 1, 2, 3 ... N - 1]$ is formed with modulating symbols with set of subcarriers (Leonid et.al, 2013).

Symbols associated with OFDM

$y(t) = \frac{1}{\sqrt{N}} \sum_{l=0}^{N-1} X(l)e^{i2\pi lt} , 0 \leq t \leq NT \tag{3.1}$

Where $j = \sqrt{-1}, N = N$ point symbol, $y(t)$ is received symbol, L= Length of input signal and $X(l)$ is input symbol.

Now Let us consider that input of OFDM signals are statistically independent and identically distributed if real part and imaginary part of OFDM signal are uncorrelated and orthogonal to each other. So considering the Central Limit Theorem (Rudzinski, 2014), Where N is large, than the distribution of both real and imaginary signals approaches to Gaussian distribution with Zero and mean variance i.e.:

$a^2 = E [Re(y(t))^2 + Im(y(t)^2)]/2 \tag{3.2}$

Where E = Expectation

So the probability distribution function is

$Pr(y(t)) = \frac{1}{\sqrt{2\pi\sigma}} e^{-y(t)^2/2\sigma^2} \tag{3.3}$

Where $Pr(y(t))$ is probability of received signal and $\sigma$ is variance.

3.3. System Design - OFDM

It encapsulates the number of parameters (Bittner, 2008)
i. Data Rate.
ii. Available Bandwidth.
iii. BER.
iv. Delay spread of the channel.

3.4. Implementation of OFDM System:

The OFDM system is implemented by combining the different blocks as shown in the Fig 3.1:

![Block Diagram of OFDM](image)

An OFDM is a Multicarrier modulation technique that uses an overlapped signal to divide the frequency selective channel into a number of narrow band flat fading channels. The FFT encodes the block of symbol; instead of sending the data sequentially on a single carrier at a high symbol rate. The sub-channels are made orthogonal by spacing the subcarriers at an increase of symbol time. The multipath fading can be nullified by making the symbol period of sub-channel longer in their length as compared to multipath delay spread. The signals having high noise and interference are deactivated, thus decreasing the effect of fading and interference. OFDM modulation technique is generated through the use of complex signal processing approaches such as fast Fourier transforms (FFTs) and inverse FFTs in the transmitter and receiver sections of the radio. One of the benefits of OFDM is its strength in fighting the adverse effects of multipath propagation with respect to inter-symbol interference in a channel. OFDM is also spectrally efficient because the channels are overlapped and contiguous. The block diagram of OFDM is shown in Fig 3.1. In this system input data are Forward Error Correction (FEC) coded with techniques such as convolution code. The diversity gain is obtained by interleaving the coded bit stream. The constellation points are mapped, after a group of channel bits are grouped together. Now the data is serial which is
represented by complex numbers. At this point Mapping Technique such as pilot mapped is used. A serial to parallel converter is used and IFFT is applied on the complex parallel data. As per the need of transmission subcarriers the transformed data are grouped. In every block of data cyclic prefix is inserted and the data is multiplexed in serial fashion. Now the OFDM data are modulated and the digital data are converted into analog by using a Digital to Analog Convertor (DAC) and RF modulation is also performed. The transmitted OFDM signals go through all anomalies and hostility of wireless channels. The receiver performs the down conversion of the signal and converts the signal into digital domain by using Analog to Digital Convertor (ADC). The synchronization is needed during the down conversion of the signal. The OFDM signal is demodulated by using a FFT. The channel estimation is performed and complex receive data are de-mapped according to the constellation diagram. At last the original signal is received by using the FEC coding and decoding (Syrjala and Valkama, 2010).

3.5. PAPR Reduction and OFDM with Clipping

3.5.1. Theory:
Due the increase in demand of high data rates in mobile communication, OFDM system is used in many applications. It efficiently overcome the effect of Inter-symbol Interference caused due to the fading of the channel but Peak to Average Power Ratio (PAPR) is one of the disadvantages in OFDM System. In the first stage of the work, OFDM system is designed with different Modulation Techniques like QAM, BPSK and QPSK and their BER is defined. In the latter stage we work on reduction of PAPR by using a clipping technique and we found the significant reduction in PAPR as compared to conventional clipping technique.

3.5.2. Classical OFDM System
The modulated signal can be shown by the following mathematical formulation -

\[ Y_n(t) = \frac{1}{N} \sum_{k=0}^{N-1} Y(n), Ke^{j2\pi k \Delta f t}, 0 \leq t \leq T_s \]  

(3.4)

Where \( T_s \) = Symbol duration, \( \Delta f \) = sub carrier spacing, \( N \) = Number of Sub – channel.

To make the signal orthogonal, it should satisfy the following condition \( T_s \cdot \Delta f = 1 \). With the orthogonal condition, the transmitted symbol \( Y(n), k \) can be received by the receiver as described in following equation:
The transmitted signal at $t = t + Ts$ is given by:

$$Y(n) = \frac{1}{Ts} \int_{-Tg}^{Tg} Y(n, k) e^{j2\pi k f(t + Ts)} dt.$$  

(3.6)

The impulse response of a channel is given by:

$$h(t) = a_i \delta(t - t_i)$$  

(3.7)

$a_i$ and $t_i$ are delay and square of complex amplitude of the $i^{th}$ path.

The received signal with impulse response of channel is given by:

$$X_n(t) = \sum_i Y_n x^k \delta(t - t_i) + n(t).$$  

(3.8)

Where $n(t)$ is noise of a signal and $x^k = a_i K$.

3.5.3. Proposed Methodology:

The block diagrams for implementation of proposed OFDM are shown from Fig. 3.2 to 3.4.
The results for transmitted and received signals input and output constellation plots for different modulation technique are obtained by using Mat-Lab Simulink.

3.5.4. Transmitted Signal:

The spectrum of BPSK, QPSK, QAM transmitted signals are shown in the following Fig.3.5 to Fig.3.7, which are generated by using a Bernoulli binary generator.
Fig. 3.5. Transmitted OFDM BPSK signal

Fig. 3.6. Transmitted OFDM QPSK signal
3.5.5. Received signal:

The received spectrum of BPSK, QPSK and QAM signals are shown in the following Fig.3.8 to Fig.3.10.

Fig.3.8. Received signal for BPSK.
Fig. 3.9. Received signal for QPSK

Fig. 3.10. Received signal for QAM

3.5.6. Input constellation:

The constellation diagram of BPSK, QPSK and QAM-16 signals are shown in the following Fig. 3.11 to Fig. 3.13.
Fig. 3.11. Input constellation for BPSK.

Fig. 3.12. Input constellation for QPSK.
3.5.7. Output Constellation:

The constellation diagram of BPSK, QPSK and QAM-16 signals are shown in the Fig.3.14 to Fig.3.16.
3.5.8. Clipping Technique:
Clipping approach or technique is used to discard the amplitude associated with signal which exceeds the threshold of the amplitude. This appends the clipping noise which is due to the distortion of power and expands the signal spectrum of transmitter which causes the interference in the signal (Davis and Jedwab, 2009).

3.5.9. System Model of Clipping Technique:
In our work we have considered an OFDM signal of N= 2464 sub-channels and length of FFT is 2048 with sampling rate of 2. The output of the simulation is reduction of PAPR, CCDF vs. SNR. The detailed methodology is described in Table.3.1.

Table.3.1. System Model of Clipping Technique

<table>
<thead>
<tr>
<th>BPSK</th>
<th>QPSK</th>
<th>QAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter the M-ary value : 2</td>
<td>Enter the M-ary value : 4</td>
<td>Enter the M-ary value : 64</td>
</tr>
</tbody>
</table>
The graph calculates peak-to-average power ratio (PAPR) reduction in OFDM. PAPR reduction graph is calculated. PAPR reduction is calculated for proposed PAPR reduction technique for M-ary modulation schemes such as BPSK, QPSK, 64-QAM. The Complementary Cumulative Distribution Functions (CCDF) of the PAPR for the transmitted signals are plotted in Fig. 3.17, 3.18 and 3.19. The PAPR techniques being employed by clipping, for clipping ratio, are plotted in subplot. From figure it is clear that the PAPR is reduced up to 3.3. The simulation Graph is repeated for modulation schemes such as BPSK, QPSK, and 64-QAM, In the system, clipping technique significantly reduce PAPR as shown in Table.3.2.

![Fig.3.17.PAPR reduction of OFDM using BPSK with Clipping Technique](image)
In the first part of the work, conventional OFDM is implemented which results in high BER and is not suitable for next generation mobile communication system. Hence, in later section of the work, next generation MIMO-OFDM is implemented for high and low order modulation schemes which give the complete analysis of future modulation techniques used in mobile communication system.
3.6. Design and Comparison of Next Generation MIMO-OFDM with Transmission Schemes:

3.6.1. Theory:

In the present work, we have designed MIMO-OFDM (Multiple Input and Multiple Output-Orthogonal Frequency Division Multiplexing) for different modulation schemes like BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM by using four antennas at the transmitter and eight antennas at the receiver side. A case for higher order modulation schemes such as 64-QAM, and 256-QAM has been considered, where ISI effect is more due to the number of symbols sending at a given bandwidth. The combination of MIMO-OFDM with MMSE (Minimum mean square error) equalizer and OSTBC encoder and decoder is used to reduce the effect of ISI for different transmission schemes. The proposed system is designed on MATLAB/SIMULINK. On the basis of BER estimation, transmitted-received signal, constellation plot and MMSE plot, simulation results are given to analyze the performance of MIMO-OFDM for different modulation schemes.

3.6.2. Proposed Methodology:

The proposed methodology from Fig.3.20 to Fig.3.24 is described in this section. Let us consider an OSTBC coded MIMO-OFDM with four and eight antennas at the transmitter and receiver side of the system. The input signal is encoded at the rate of 5/8 by using a matrix interleaver and puncture whose output is fed to matrix interleavers which interleave the block of the input signal by filling a matrix and send the content of matrix, column wise to a modulator. Here, the modulation techniques like BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM are used. The modulated signal is passed to an OFDM Transmitter (implement by using IFFT (Inverse Fourier Fast Transform)) which transmitted the different signals at a same time. The frequency hopping is used at the transmitter which spread the spectrum of an OFDM signal. The spread signal is mapped to OSTBC encoder which encodes the signal at the rate of ¾ orthogonal space time block over a fading channel. The fading channel has 32 links due to 4 transmitters and 8 receiver antennas. Here 4*8 antennas are designed by creating a subsystem of 32 Rayleigh fading channels through a 16-selector and then by concatenating all the channels and gains separately to the dimension of 2 and 3 on the basis of the sample. The AWGN channel is used in the system. The OSTBC combiner combines
the transmitted signals and output of an AWGN channel is decoded and demodulated. Finally, MMSE equalizer is used which reduced the variance between the transmitted signals at the equalizer output. It takes the mean square of a given matrix and generate the reduced error signal. Basically a similar transmitter and receiver is designed for proposed transmission schemes, only modulation schemes are changed to analyze the performance under similar conditions. The response of a channel from M-array transmitter antenna to M-array receiver is given by:

\[ h_{i,j}(k) = \sum_{k}^{L-1} a_{i,j}^{m}(k) * \delta(t - \tau_i) \]  

(3.9)

Where \( a_{i,j}^{m}(k) \) is multipath gain, L is path and \( \tau_i \) represent the path delay of \( k^{th} \) multipath component.

Fig.3.20. Block diagram for Proposed OFDM for BPSK modulation scheme.
Fig. 3.21. Block diagram for Proposed OFDM for QPSK modulation scheme.

Fig. 3.22. Block diagram for Proposed OFDM for 16-QAM modulation scheme.
3.6.3. System Model:

Let us consider a random binary number denoted by $X(k)$ i.e.

$$X(k) = x_1 + x_2 + x_3 \ldots \ldots x_n$$  \hspace{1cm} (3.10)
The convolution encoder encodes the $X(k)$ i.e. Conv = PolyTrellix ($X(k)$). The puncture takes the input and generates the output vector by removing the particular element of the input vector. The matrix interleaver fills the input matrix row by row and sent it column wise. The modulator is used to modulate the signal given in below equation:

$$Y(k) = Modulation \ of \ X(k)$$  \hspace{1cm} (3.11)

The IFFT of the signal is given by:

$$Y(n) = \frac{1}{N} \sum_{k=0}^{N-1} e^{\frac{j2\pi Kn}{N}}$$  \hspace{1cm} (3.12)

Where, $Y(n)$ is IFFT of input signal $Y(k)$, and $N$ is length of input sequence.

In Equation (3.13), the pilot symbols are added and zeros are padded

$$Y(n) = \frac{1}{n} \sum_{k=0}^{n} Y(k)e^{\frac{j2\pi Kn}{N}} + P_{i} + Z_{f}$$  \hspace{1cm} (3.13)

Where $P_{i} =$ pilot symbols and $Z_{f} =$ zeros padding

$$Y(n) = \left(\frac{1}{n} \sum_{k=0}^{n} Y(k)e^{\frac{j2\pi Kn}{N}} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.14)

In equation (3.14), the signal is spreaded by multiplying $Y(n)$ with $b_{n}$, where $b_{n}$ pseudo code generator.

Transmitted and received signals by using four and eight antennas with addition of the noise through the AWGN channel is given by:

$$Z_{1} = \left( h_{11} \ast Y_{1} + h_{21} \ast Y_{2} + h_{31} \ast Y_{3} + h_{41} \ast Y_{4} + N^{*} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.15)

$$Z_{2} = \left( h_{12} \ast Y_{1} + h_{22} \ast Y_{2} + h_{32} \ast Y_{3} + h_{42} \ast Y_{4} + N^{*} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.16)

$$Z_{3} = \left( h_{13} \ast Y_{1} + h_{23} \ast Y_{2} + h_{33} \ast Y_{3} + h_{43} \ast Y_{4} + N^{*} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.17)

$$Z_{4} = \left( h_{14} \ast Y_{1} + h_{24} \ast Y_{2} + h_{34} \ast Y_{3} + h_{44} \ast Y_{4} + N^{*} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.18)

$$Z_{5} = \left( h_{15} \ast Y_{1} + h_{25} \ast Y_{2} + h_{35} \ast Y_{3} + h_{45} \ast Y_{4} + N^{*} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.19)

$$Z_{6} = \left( h_{17} \ast Y_{1} + h_{26} \ast Y_{2} + h_{36} \ast Y_{3} + h_{46} \ast Y_{4} + N^{*} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.20)

$$Z_{7} = \left( h_{17} \ast Y_{1} + h_{27} \ast Y_{2} + h_{37} \ast Y_{3} + h_{47} \ast Y_{4} + N^{*} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.21)

$$Z_{8} = \left( h_{18} \ast Y_{1} + h_{28} \ast Y_{2} + h_{38} \ast Y_{3} + h_{48} \ast Y_{4} + N^{*} + P_{i} + Z_{f}\right) \ast b_{n}$$  \hspace{1cm} (3.22)
Generally, the above equation can be written as:

\[
Z_n = (h_{1n} \ast Y_1 + h_{2n} \ast Y_2 + h_{3n} \ast Y_3 + h_{4n} \ast Y_4 + N^* + P_i + Z_f) \ast b_n \quad (3.23)
\]

Where \(Z_{1-8}\) are the received signal and \(Y_{1-4}\) are transmitted signals. \(H(1,1) = H(m,n)\), Where \(m\) is transmitted signal and \(n\) is received signal by corresponding antenna and \(N^*\) is channel noise.

The received signal with addition of noise is given by:

\[
Z(n) = \left(AWGN \left(H_{i,j} \ast Y(k) + N + P_i + Z_f\right)\right) \ast b_n \quad (3.24)
\]

On removing pilot symbols, zeros padding and de-spread the signal, the equation (3.24) becomes:

\[
Z(n) = H_{i,j} \ast Y(k) + N^* \quad (3.25)
\]

The FFT of the signal \(Y(k)\) is given by:

\[
Y(k) = \sum_{k=0}^{n} Z(n) e^{-j2\pi Kn} \quad (3.26)
\]

\[
Y(k) = \sum_{k=0}^{n} (H_{i,j} \ast Y(n) + N^*) e^{-j2\pi Kn} \quad (3.27)
\]

Finally, the signal is demodulated and decoded to receive the original signal i.e. \(X_k\).

The MMSE equalizer is also used to minimize the ISI of demodulated output. Mathematically, the following operation is performed on the demodulated signal:

\[
MMSE = E \left\{ (X^* - X)^2 \right\} \quad (3.28)
\]

Where \(X\) is actual received signal and \(X^*\) random estimator which estimate the performance of a given distribution or it estimate the signal based on observed value. The equation (3.28) concludes, for higher MMSE, the signal is highly dispersed.

### 3.6.4. MMSE (Minimum Means Square Error) Equalizer:

The MMSE Equalizer is a linear equalizer that performs better as compared to Zero-forcing equalizer with same receiver complexity. MMSE equalizer can be used when the channel and noise information is accurately known by the receiver. It will not completely reduce the ISI but it reduces the parameters that cause ISI and also minimizes the noise power and mean
square error of signals (Mehana and Nosratinia, 2013). From equation (3.28), the MMSE is given by:

$$MMSE = E \{(X^* - X)^2\}$$

The approach of MSR to find the coefficient is given by:

$$F \{[G_y - X] [G_y - X] H\}$$  \hspace{1cm} (3.29)

In order to solve $X$, we need to derive a matrix $X$ which satisfy $GH=I$

Again the following equation is written to satisfy the above constraint:

$$G = [H^H H + No I]^{-1} H^H$$  \hspace{1cm} (3.30)

Where G is channel equalization matrix and No is noise, I is Identity matrix & H is channel matrix.

3.6.5. Transmitted Signal:

The spectrum of BPSK, QPSK, 16-QAM, 64-QAM-64 and 256-QAM transmitted signals are shown in the following Fig.3.25 to Fig.3.29. Which are generated by using a Bernoulli binary generator. The RBW is at 3.09 MHz, the span between the signals is 3.5 GHz.

![](image)

Fig.3.25. Transmitted signal for BPSK modulation scheme.
Fig. 3.26. Transmitted signal for QPSK modulation scheme

Fig. 3.27. Transmitted signal for 16-QAM modulation scheme

Fig. 3.28. Transmitted signal for 64-QAM modulation scheme
3.6.6. Received Signal:

The spectrum of BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM received signals are shown in the following Fig.3.30 to Fig.3.34, which are obtained by demodulating the modulated wave. Here RBW and the span are 4.8 MHz and 3.5 GHz simultaneously. The figures show the three peaks i.e. maximum peak for excellent coverage, medium peak for good coverage and zero peak corresponds to poor coverage.
Fig. 3.31. Received signal for QPSK modulation scheme.

Fig. 3.32. Received signal for 16-QAM modulation scheme.

Fig. 3.33. Received signal for 64-QAM modulation scheme.
3.6.7. MMSE Plot:

The plot of amplitude vs time denotes MMSE plot, which is the output of the MMSE equalizer, are shown from Fig. 3.35 to Fig. 3.39. It squares the input signal and produces a reduced error which is useful to minimize the Inter-symbol-interference.

Fig. 3.35. MMSE plot for BPSK modulation scheme.
Fig. 3.36. MMSE plot for QPSK modulation scheme.

Fig. 3.37. MMSE plot for 16-QAM modulation scheme.

Fig. 3.38. MMSE plot for 64-QAM modulation scheme.
3.6.8. Input Constellation:

The constellation diagrams of BPSK, QPSK, QAM-16, QAM-64 and QAM-256 are shown in the Fig.3.40 to Fig.3.44. The input constellation diagram is also known as a physical diagram which demonstrates all the probable symbols used by the communication system to transmit the data.
Fig. 3.41. Input constellation diagram of QPSK modulation scheme.

Fig. 3.42. Input constellation diagram of 16-QAM modulation scheme.

Fig. 3.43. Input constellation diagram of 64-QAM modulation scheme.
Fig. 3.44. Input constellation diagram of 256-QAM modulation scheme.

3.6.9. Output Constellation:

The output scatter plot of BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM are shown in Fig.3.45 to Fig.3.49.

Fig. 3.45. Output Constellation diagram for BPSK modulation scheme
Fig. 3.46. Output Constellation diagram for QPSK modulation scheme

Fig. 3.47. Output Constellation diagram for 16-QAM modulation scheme

Fig. 3.48. Output Constellation diagram for 64-QAM modulation scheme
3.7. Results and Discussion

The transmitted signal parameters for conventional OFDM from Fig.3.5 to Fig.3.7 and next generation MIMO-OFDM from Fig.3.25 to Fig.2.29 are given in Table.3.3. The maximum peak for conventional and next generation OFDM is given. Channel power for conventional OFDM increases with the increasing order of modulation but for next generation MIMO OFDM, channel power of QAM-64 is greater as compared to BPSK, QPSK, QAM-16 and QAM-256. Although channel power of next generation MIMO-OFDM is less as compared to conventional OFDM. The occupied bandwidth for conventional OFDM if higher for QAM as compared to BPSK and QPSK and Occupied bandwidth for next generation MIMO-OFDM is higher for QAM-64 as compared to other modulation schemes. The frequency error decreases with increase in order of modulation for conventional OFDM. The frequency error increases with increase in order of modulation for MIMO-OFDM.
## Table 3.3 Analysis of transmitted Signal characteristics for OFDM

The received signal parameters for conventional OFDM from Fig.3.8 to Fig.3.10 and next generation MIMO-OFDM from Fig.3.30 to Fig.2.34 are given in Table 3.4. The maximum peaks for conventional and next generation OFDM are given. Channel power for conventional OFDM increases with the increasing order of modulation but for next generation MIMO OFDM, channel power decreases with increasing order of modulation. Although channel power of next generation MIMO-OFDM is less as compared to conventional OFDM. The occupied bandwidth for conventional OFDM and next generation MIMO-OFDM increases with the increasing order of modulation. The frequency error increases with increase in order of modulation for conventional OFDM. The frequency error decreases with increase in order of modulation for MIMO-OFDM.

### Conventional OFDM

<table>
<thead>
<tr>
<th>S.no</th>
<th>Modulation Schemes</th>
<th>Max Peaks</th>
<th>Frequency</th>
<th>Channel Power</th>
<th>Occupied bandwidth</th>
<th>Frequency Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>BPSK</td>
<td>-10.05 dB</td>
<td>30mHz</td>
<td>18.969 dB</td>
<td>557.993MHz</td>
<td>2.0938 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-4.706 dB</td>
<td>-274.085mHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-9.511 dB</td>
<td>330.098mHz</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>QPSK</td>
<td>7.52 dB</td>
<td>-110.90mHz</td>
<td>20.644 dB</td>
<td>534.7283MHz</td>
<td>-5.7660 MHz</td>
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<td></td>
<td></td>
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</table>

### Next Generation MIMO-OFDM

<table>
<thead>
<tr>
<th>S.no</th>
<th>Modulation Schemes</th>
<th>Max Peaks</th>
<th>Frequency</th>
<th>Channel Power</th>
<th>Occupied bandwidth</th>
<th>Frequency Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>BPSK</td>
<td>-1.890 dB</td>
<td>0.179 GHz</td>
<td>21.145 dB</td>
<td>508.3087 MHz</td>
<td>201.5389 KHz</td>
</tr>
<tr>
<td></td>
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<tr>
<td>2.</td>
<td>QPSK</td>
<td>3.291 dB</td>
<td>-0.122 GHz</td>
<td>21.041 dB</td>
<td>508.3904 MHz</td>
<td>9.4076 KHz</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>QAM</td>
<td>8.247 dB</td>
<td>0.233 GHz</td>
<td>23.380 dB</td>
<td>547.3575 MHz</td>
<td>1.318 MHz</td>
</tr>
<tr>
<td>4.</td>
<td>64-QAM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>256-QAM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The received signal parameters for conventional OFDM from Fig.3.8 to Fig.3.10 and next generation MIMO-OFDM from Fig.3.30 to Fig.2.34 are given in Table 3.4. The maximum peaks for conventional and next generation OFDM are given. Channel power for conventional OFDM increases with the increasing order of modulation but for next generation MIMO OFDM, channel power decreases with increasing order of modulation. Although channel power of next generation MIMO-OFDM is less as compared to conventional OFDM. The occupied bandwidth for conventional OFDM and next generation MIMO-OFDM increases with the increasing order of modulation. The frequency error increases with increase in order of modulation for conventional OFDM. The frequency error decreases with increase in order of modulation for MIMO-OFDM.
Table 3.4 Analysis of received Signal characteristics for OFDM

Characteristics of the input constellation for conventional OFDM from Fig.3.11 to Fig.3.13 and next generation MIMO-OFDM from Fig.3.40 to Fig. 3.44 are given in Table.3.5. The peak values for conventional and next generation OFDM are generated by using Bernoulli binary generator which are random in nature. The EVM for conventional OFDM is higher for BPSK and QPSK as compared to QAM. Similarly, EVM for MIMO-OFDM increases with the increasing order of modulation. Overall, EVM for conventional OFDM is greater as compared to MIMO-OFDM. MER of MIMO-OFDM is more as compared to conventional CDMA.

Table 3.5 Analysis of input constellation characteristics for OFDM

<table>
<thead>
<tr>
<th>S.no</th>
<th>Modulation Schemes</th>
<th>EVM PEAK</th>
<th>MER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional OFDM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>BPSK</td>
<td>-4.666 dB</td>
<td>-4.185 dB</td>
</tr>
<tr>
<td>2</td>
<td>QPSK</td>
<td>-3.904 dB</td>
<td>-3.632 dB</td>
</tr>
<tr>
<td>3</td>
<td>QAM</td>
<td>-7.87 dB</td>
<td>-7.975 dB</td>
</tr>
<tr>
<td>Next Generation MIMO-OFDM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>BPSK</td>
<td>-8.446 dB</td>
<td>-6.499 dB</td>
</tr>
<tr>
<td>2</td>
<td>QPSK</td>
<td>-8.888 dB</td>
<td>-6.133 dB</td>
</tr>
<tr>
<td>3</td>
<td>16-QAM</td>
<td>-7.994 dB</td>
<td>-7.964 dB</td>
</tr>
<tr>
<td>4</td>
<td>64-QAM</td>
<td>-5.775 dB</td>
<td>-3.499 dB</td>
</tr>
<tr>
<td>5</td>
<td>256-QAM</td>
<td>-5.755 dB</td>
<td>-3.499 dB</td>
</tr>
</tbody>
</table>

Characteristic parameters of the output constellation for conventional OFDM from Fig.3.14 to Fig.3.16 and next generation MIMO-OFDM from Fig.3.45 to Fig. 3.49 are given in Table.3.6. The peak values for conventional and next generation OFDM are generated by using Bernoulli binary generator which are random in nature. The EVM for conventional OFDM is higher for BPSK and QAM as compared to QPSK. Similarly, EVM for MIMO-OFDM decreases with the increasing order of modulation. Overall, EVM for MIMO-OFDM is greater as compared to conventional OFDM. MER for conventional OFDM is higher for QAM as compared to BPSK and QPSK. MER for MIMO-OFDM increases with increasing order of modulation.

Table 3.6 Analysis of output constellation characteristics for OFDM

<table>
<thead>
<tr>
<th>S.no</th>
<th>Modulation Schemes</th>
<th>EVM</th>
<th>PEAK</th>
<th>MER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional OFDM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>BPSK</td>
<td>-2.398 dB</td>
<td>-2.399 dB</td>
<td>2.399 dB</td>
</tr>
</tbody>
</table>
Characteristics of the Minimum Mean Square Error plot for next generation OFDM from Fig 3.35 to Fig 3.39 are given in Table 3.7. The peak to peak and RMS value for BPSK are higher as compared to other modulations. The rise time for BPSK is less as compared to other modulation schemes.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Modulation Scheme</th>
<th>MMSE Value</th>
<th>Maximum peak*10^8</th>
<th>Time (µs)</th>
<th>Peak to Peak MMSE value</th>
<th>RMS</th>
<th>Rise time (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BPSK</td>
<td>2.74e+10</td>
<td>19.6654 M</td>
<td>100</td>
<td>19.654 M</td>
<td>4.528 M</td>
<td>1.098</td>
</tr>
<tr>
<td>2</td>
<td>QPSK</td>
<td>2.18e+10</td>
<td>15.729 M</td>
<td>100</td>
<td>15.299 M</td>
<td>3.26 M</td>
<td>11.02</td>
</tr>
<tr>
<td>3</td>
<td>16-QAM</td>
<td>2.737e+10</td>
<td>19.594 M</td>
<td>100</td>
<td>19.594 M</td>
<td>4.515 M</td>
<td>10.970</td>
</tr>
<tr>
<td>4</td>
<td>64-QAM</td>
<td>2.735e+10</td>
<td>19.594 M</td>
<td>100</td>
<td>19.594 M</td>
<td>4.515 M</td>
<td>10.970</td>
</tr>
<tr>
<td>5</td>
<td>256-QAM</td>
<td>2.736e+10</td>
<td>19.594 M</td>
<td>100</td>
<td>19.594 M</td>
<td>4.515 M</td>
<td>10.970</td>
</tr>
</tbody>
</table>

Table 3.8. BER vs SNR for conventional OFDM with BPSK, QPSK and QAM

<table>
<thead>
<tr>
<th>SNR(dB)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPSK BER</td>
<td>0.2127</td>
<td>0.1875</td>
<td>0.1454</td>
<td>0.1284</td>
<td>0.1175</td>
<td>0.1121</td>
<td>0.0384</td>
<td>0.0012</td>
</tr>
<tr>
<td>QPSK BER</td>
<td>0.1358</td>
<td>0.1304</td>
<td>0.1301</td>
<td>0.1298</td>
<td>0.1192</td>
<td>0.1115</td>
<td>0.0321</td>
<td>0.0007</td>
</tr>
<tr>
<td>QAM BER</td>
<td>0.4821</td>
<td>0.4797</td>
<td>0.4621</td>
<td>0.4592</td>
<td>0.4492</td>
<td>0.3245</td>
<td>0.2245</td>
<td>0.010</td>
</tr>
</tbody>
</table>

Table 3.9. BER vs SNR for MIMO-OFDM with BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM.
Initially, the simulation of OFDM is performed for different modulation schemes like BPSK, QPSK and QAM. It is seen from the simulation that the capacity is doubled in QPSK as compared to BPSK at same BER. As shown in Table 3.8, QPSK is considered as best modulation schemes as compared to BPSK and QAM but this technology is not suitable for high speed communication systems. Hence, in the latter section of the work, MIMO-OFDM 4x8 antennas with OSTBC and MMSE equalizer are simulated for different modulation schemes like BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM. The use of MIMO-OFDM enhanced the capacity, speed and radio-link of a proposed system. Further, MMSE equalizer has been used to minimize the ISI that usually occurs for higher order modulation schemes. The BER was calculated and found that QPSK is the best modulation scheme as compared to BPSK, 16-QAM, 64-QAM, and 256-QAM as shown in Table 3.9. It is also concluded that Cyclic Prefix (CP) was a huge advantage for fourth generation mobile communication system but the same CP is considered as a disadvantage for fifth generation mobile communication due to utilization of extra spectrum that contain the CP symbols. In next section, UWB is explored which is considered as one of the most promising technology if properly utilized for long and short ranges of communications.