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Simulation and Analysis of OFDM and SC-FDMA with STBC using Different Modulation Techniques

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Abstract: Rapidly growing demand of multimedia services and the growth of internet services lead to requirement of high speed communication in current 4G and other wireless communication systems. Orthogonal Frequency Division Multiplexing (OFDM) and Single Carrier Frequency Division Multiple Access (SC-FDMA) are a major part of future mobile communication standards like Long Term Evolution (LTE), LTE-Advanced and Ultra Mobile Broadband (UMB). OFDM is a well known technique for the broadband wireless communication system which is utilized for achieving high spectral efficiency in communication systems [1].The undesirable high PAPR of OFDM led 3GPP to choose a different modulation format for the LTE uplink. OFDM is used in the WiMAX uplink but LTE continued to use SC-FDMA.SC-FDMA is a new hybrid modulation scheme that cleverly combines the low PAPR of single-carrier systems with the multipath resistance and flexible subcarrier frequency allocation offered by OFDM [2]. In this paper, we have explored both the multiple access techniques i.e. OFDM and SC-FDMA and implemented it in GUI MATLAB 7.10.0 alongwith the coding algorithm of space-time block codes (STBC) by using different modulation techniques i.e. QPSK, QAM and PSK.

Index Terms- BER, OFDM, PAPR, SC-FDMA, WiMAX.

I. INTRODUCTION

In modern wireless communication systems, some parameters like BER, data rate, bandwidth etc are required to produce a reliable and efficient communication. Many techniques have been proposed to solve these problems till yet and OFDM combined with MIMO system has gained much attention. OFDM technique was first developed in 1960s and nowadays OFDM is been in use for the communications devices that requires high data rate. It has evolved as a popular access technique which is being used in various applications such as digital audio broadcasting (DAB), digital video broadcasting (DVB), internet services,4G mobile communications etc [1].OFDM provides a large number of advantages such as its immunity to selective fading, it is resilient to interference, it makes efficient use of the spectrum, resilient to ISI and narrow-band effects and much simpler channel equalization. Besides its several advantages, it has also a major disadvantage of high peak-to-average power ratio (PAPR).Also it has to face some other disadvantages like sensitivity to Doppler shift, sensitivity to frequency synchronization problems, loss of efficiency caused by cyclic prefix/guard interval etc [3].

SC-FDMA is another widely used multiple access technique which can overcome this drawback of OFDM. SC-FDMA utilizes single carrier modulation at the transmitter and frequency domain equalization at the receiver. This technique has almost similar performance and essentially the same overall structure as those of an OFDM system [4].It can be regarded as DFT-spread orthogonal frequency division multiplexing (OFDM), where time domain data symbols are transformed to frequency domain by DFT before going through OFDM modulation [4]. The orthogonality of the users stems from the fact that each user occupies different subcarriers in the frequency domain, similar to the case of OFDM. Because the overall transmit signal is a single carrier signal, PAPR is inherently low in this as compared to the case of OFDM which produces a multicarrier signal [5].

Designers of wireless communications constantly seek to improve the spectrum efficiency, capacity, coverage of wireless networks and link reliability. Space-time wireless technology that uses multiple antennas along with appropriate signaling and receiver techniques offers a powerful tool for improving wireless performance. More advanced MIMO techniques are planned for future mobile networks in wireless Local Area Network (LANs) and Wide Area Network (WANs). When multiple antennas are used with appropriate Space-Time Coding (STC) techniques, then it can achieve huge performance gains in multipath fading wireless links. It has evolved as a most vibrant research area in wireless communications. Recently, Space-Time Block Codes (STBC) has been trying to incorporate in the forthcoming generation of mobile communication standard which aims to deliver true multimedia capability. In this paper, we have presented the SC-FDMA with the Space-Time Block Codes (STBC) for wireless networks that uses multiple numbers of antennas at both transmitter and receiver. The simulations have been done in GUI MATLAB [6].

The rest of the paper is organized as: Section II gives a brief overview of OFDM system, SC-FDMA system and STBC. Section III describes the methodology used in the simulation. Section IV discusses the results and Section V gives the conclusion.

II. BRIEF OVERVIEW OF OFDM, SC-FDMA AND STBC

A. OFDM

Orthogonal frequency division multiplexing (OFDM) is a promising and widely used technique in modern high data rate wireless communication system. OFDM is used as a multi carrier modulation method, which is the concept of splitting a signal into a number of signals, modulating each of these new signals to several frequency channels, and then combining the data received on the multiple channels at the receiver [2]. In OFDM, the multiple frequency channels, known as sub-carriers, are orthogonal to each other [3].

In an OFDM system, the input bit stream is multiplexed into N symbol streams, each with symbol period Ts and each symbol stream is used to modulate parallel, synchronous sub-carriers. The sub-carriers are spaced by 1 in frequency, thus they are orthogonal over the interval (0, Ts).

OFDM has been adopted by several mobile communication standards [2]. It provides a large number of applications in various communication systems, such as Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB), Digital television DVB-T/T2 (terrestrial), Wireless LAN IEEE 802.11a, IEEE 802.11g, IEEE 802.11n, IEEE 802.11ac, and IEEE 802.11ad, WiMAX [3], ADSL and VDSL, LTE (Long Term Evolution) and LTE Advanced 4G mobile phone standards, Modern narrow and broadband power line communications etc.

B. SC-FDMA

SC-FDMA is the combination of the properties connected with SC transmission with an OFDM-like multiple access and also the attempts which take benefit of the strengths of Low PAPR (peak-to-average power ratio). SC-FDMA has a precoded DFT-processing step. It has become an attractive choice to OFDM, you can say in the uplink communications especially where lower peak-to-average power ratio (PAPR) provides great benefits to the mobile terminal with regard to transmit power efficiency and also in the reduced cost of the power amplifier.. It has been adopted as the uplink multiple access scheme in 3GPP Long Term Evolution (LTE), or Evolved UTRA (E-UTRA).

In this, the data source is mapped into signal constellation according to the QPSK, BPSK, 16-QAM, 64-QAM, PSK or QAM modulation. Although the QPSK/QAM symbols tend not to directly modulate the subcarriers; these symbols have to pass through a serial to parallel converter. Then these symbols are followed by a FFT (fast fourier transform) block that construct discrete frequency domain representation of the QPSK/QAM symbols. From the output of FFT block, we get discrete fourier symbols as result which we get to mapped in subcarrier mapping block with the sub-carriers. When mapping is done in the frequency domain; the modulated subcarriers then pass through IFFT (inverse fast fourier transform) block for time domain conversion [5]. The remaining operation of transmitter is sort of similar to OFDM. The receiver side includes one de-mapping block, one IFFT (or IDFT) block, and one detection block for each user signal. Guard intervals (called cyclic prefixes i.e. CP) with cyclic repetition are introduced between blocks of symbols in order to efficiently eliminate inter-symbol interference(ISI) from time spreading which is caused by multi-path propagation among the blocks [8].The SC-FDMA receiver is very similar to OFDM receiver. In this, at the output of the IFFT block, there is an extra IDFT de-spreading block to undo the transmitter procedures. The received signal is then passed through the RF stage and CP is removed to alleviate multipath interference. Now this symbol is passed to FFT where the time domain signal is transformed to frequency domain signal. Then de-mapping is done at the subcarrier de-map stage. The next step is to de-spread the signal by using IDFT to transform the data into symbols and at last to original bit stream using logic of detection [2].

C. STBC

STBC is space-time block codes. It is a scheme utilized in wireless communications which pass on several copies of a data stream across some number of antennas. It also exploits the several received versions of the data to recover the consistency of the transfer of data. In fact, it combines the received signal's all copies in a best possible way to take out as much information from each of them as possible. The original scheme was based on Trellis Codes but the simpler block codes were utilized by Siavash Alamouti and later Vahid Tarokh, Hamid Jafarkhani and Robert Calderban to develop space–time block-codes (STBCs). In particular, in STBC, the data stream is encoded in blocks, which are then divided among spaced antennas and across time. It is not necessary to have multiple receive antennas, while it is necessary to have multiple transmit antennas, even though to do so improves performance. STBC is utilized for MIMO systems which facilitate the transmission of several copies of data stream crossways a number of antennas and to exploit the several received versions of the data to improve the reliability of data-transfer.

Space-time block codes (STBC) [5] are a comprehensive version of Alamouti scheme but with similar key features. We can say that space-time block codes are a complex version of Alamouti's space-time code, where on both the transmitter and receiver sides the schemes of encoding and decoding are almost similar as there in the Alamouti space-time code. The data of space-time block codes are usually constructed as a matrix in which its columns represent the number of the transmit antennas and its rows represents the number of the time slots required to transmit the data. At the receiver side, the signals received are first combined and then sent to the maximum likelihood detector where the decision rules are applied [3]. The figure 3 shows the format of space-time block codes (STBC) in which it is represented by a matrix.

Transmit antennas

$$\begin{bmatrix} S_{11} & S_{12} \cdots & S_{1nT} \\ S_{21} & S_{22} \cdots & S_{2nT} \\ S_{T1} & S_{T2} \cdots & S_{TnT} \end{bmatrix}$$

Time-slots

Fig 1: Representation of Space-Time Block Codes (STBC)

Here, 'S_{ij}' is the modulated symbol which is to be transmitted in time slot 'i' from antenna 'j'. There are to be 'T' time slots and transmit antennas as well as n_R receive antennas and this block is considered to be of length 'T' usually. And if we want to measure how many symbols per time-slot it transmit on an average over the course of one block, then we have to calculate the code rate of an STBC [5]. When a block encodes 'k' symbols, then code-rate is given by, $r = \frac{k}{T}$.

In space-time block coding the transmission of several copies of the data is involved. This helps to pay compensation for the channel problems i.e. thermal noise and fading etc. Although redundancy is present in the data, some of the particular copies may arrive less corrupted at the receiver.

Alamouti's Code

Alamouti's code is the basis of the Space Time Coding technique. In 1998, Alamouti invented the simplest of all the STBC. The term "space–time block code" even though was not coined by himself. This code was designed for a two-transmit antenna system and has the coding matrix [14].

$$C_2 = \begin{bmatrix} c_1 & c_2 \\ -c_2^* & c_1^* \end{bmatrix}$$

Fig 2: Representation of Alamouti's Code

Here * denotes complex conjugate. This is a rate-1 code. It takes two time-slots to transmit two symbols.

III. METHODOLOGY

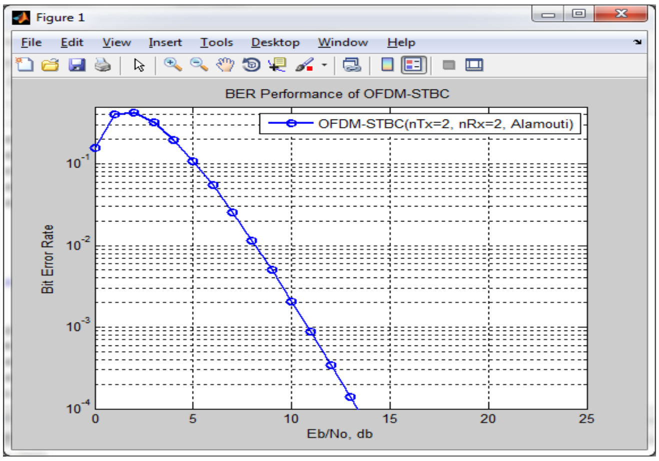
In this, we are going to implement single-carrier frequency division multiple access i.e. SC-FDMA and orthogonal frequency division multiplexing i.e. OFDM with Alamouti's space-time block codes (STBC) in GUI MATLAB. The following steps have been followed to achieve the required goal:
The following steps have been used in the proposed algorithm approach to achieve the objectives:
1. Generate a signal. After generating signal the next process to be applied on that generated signal is modulation.
2. Now apply modulation on the generated signal. We have used three modulation techniques here i.e. QPSK, QAM and PSK.
3. The next step is to apply multiple access technique i.e. SCFDMA and OFDM on the signal.
4. Then generate Alamouti's STBC (space-time block codes).
5. Now generate noise i.e. AWGN (Additive White Gaussian Noise) and channel i.e. Rayleigh Fading channel.
6. This generated noise is now to be added to the signal that was previously generated and had undergone certain conversions.
7. Then receiver equalization is performed.
8. After this, demodulation is applied, which demodulate the generated signal.
9. After the signal has been applied all the conversions, the last step is to calculate bit error rate (BER) and peak-to-average power ratio (PAPR).

IV. SIMULATION RESULTS AND DISCUSSION

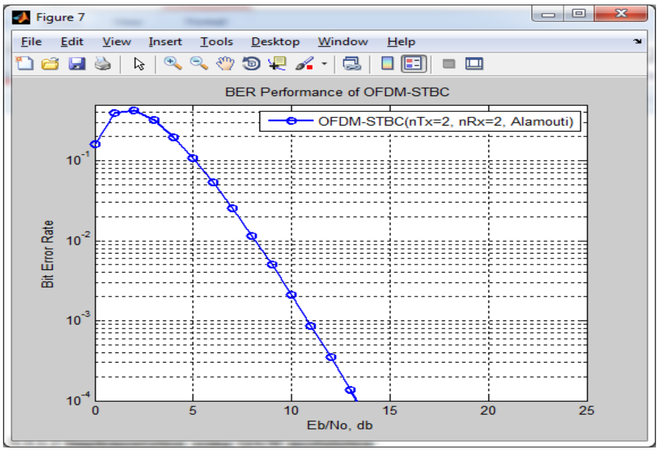
We have implemented OFDM-STBC and SCFDMA-STBC in GUI MATLAB using three modulation techniques i.e. QPSK, QAM and PSK. Two parameters i.e. bit error rate (BER) and peak-to-average power ratio (PAPR) have been calculated in it. The results are shown here in two sub-sections: A) Implementation of OFDM-STBC and B) Implementation of SCFDMA-STBC.

A.) Implementation of OFDM-STBC

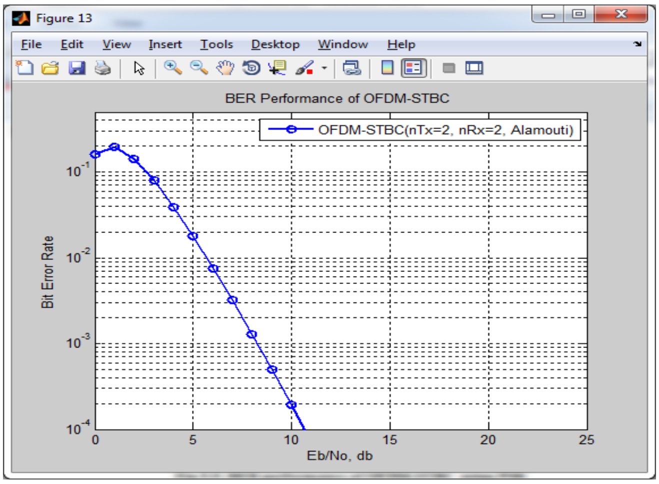
Firstly BER performance have been calculated and then PAPR performance using all the three modulation schemes i.e. QPSK, QAM and PSK respectively. The following figure 5 shows the result graphs of BER performance of OFDM-STBC using QPSK, QAM and PSK respectively.



(a)



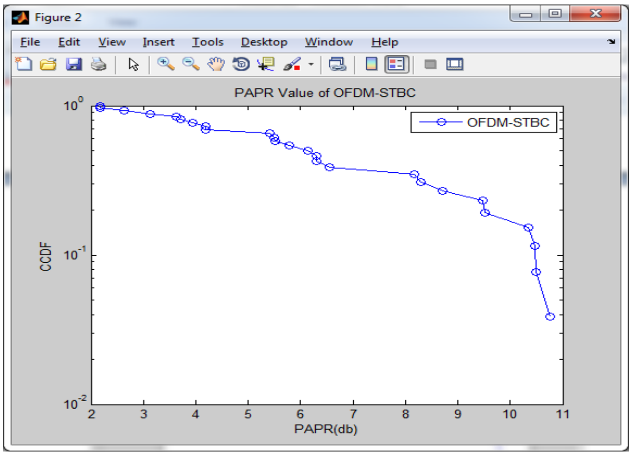
(b)



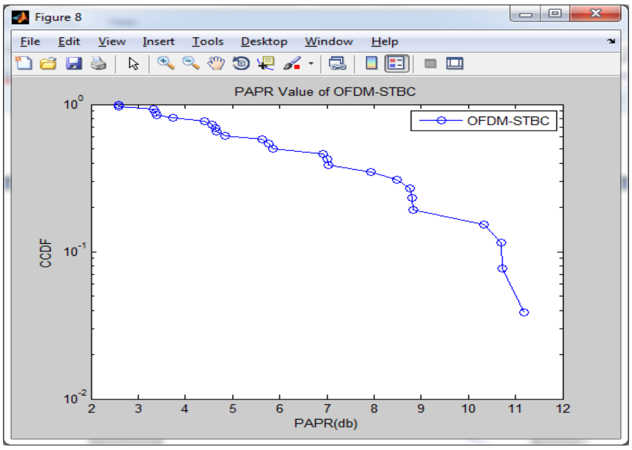
(c)

Fig 3: BER Performance of OFDM-STBC using (a) QPSK, (b) QAM and (c) PSK

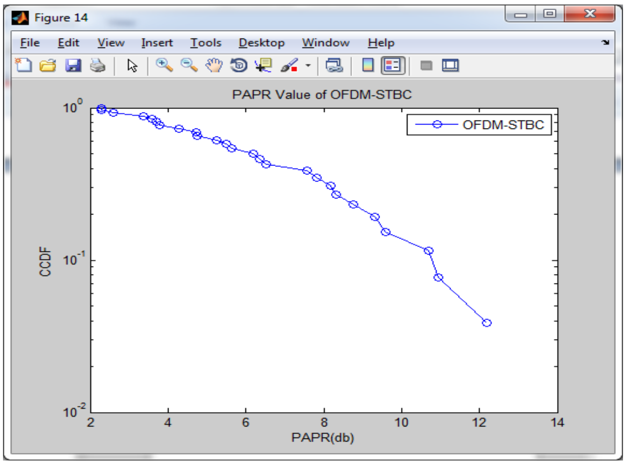
Then its PAPR performance has been calculated. The figure 6 shows the result graphs of PAPR performance of OFDM-STBC using QPSK, QAM and PSK modulation schemes.



(a)



(b)

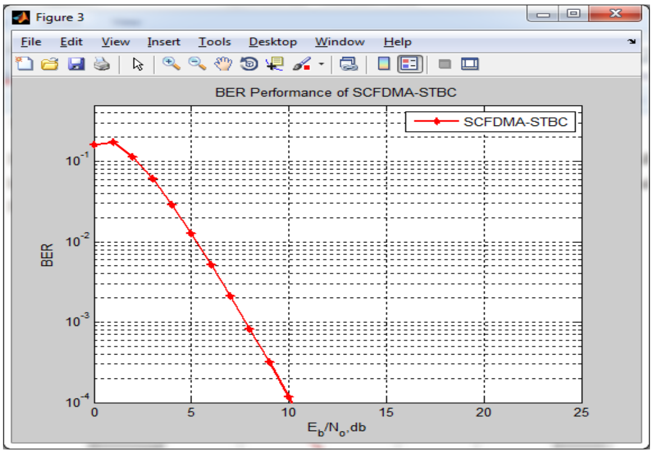


(c)

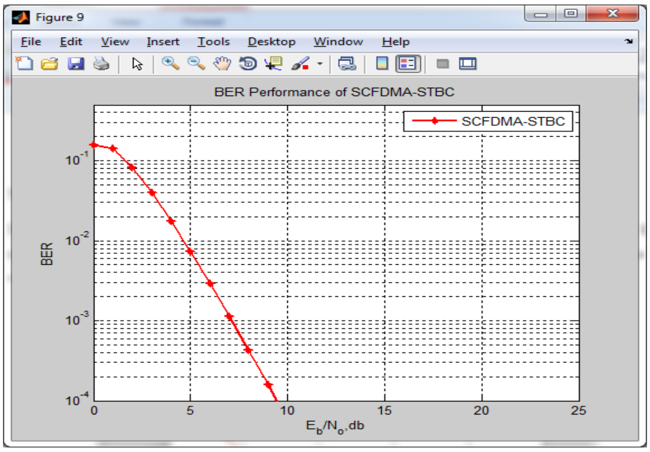
Fig 4: PAPR Performance of OFDM-STBC using (a) QPSK, (b) QAM and (c) PSK

B.) Implementation of SCFDMA-STBC

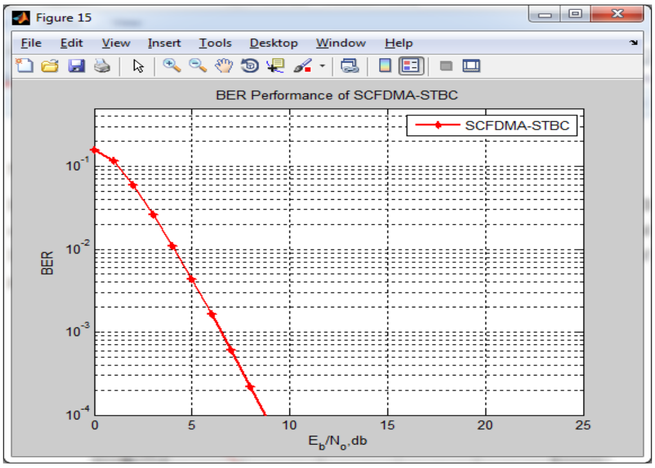
After the above implementation, then we have implemented SCFDMA-STBC in GUI MATLAB. And BER and PAPR performances have been calculated in this implementation too. The following figure 7 shows the result graphs of BER performance of SCFDMA-STBC using QPSK, QAM and PSK modulation schemes.



(a)



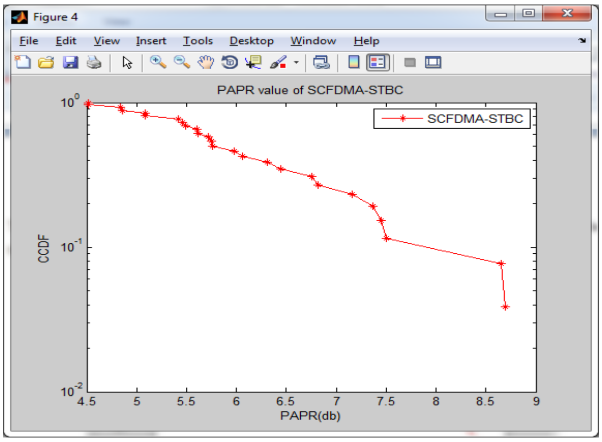
(b)



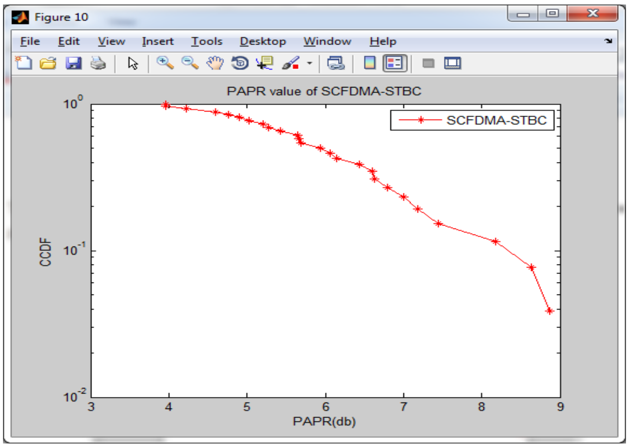
(c)

Fig 5: BER Performance of SCFDMA-STBC using (a) QPSK, (b) QAM and (c) PSK

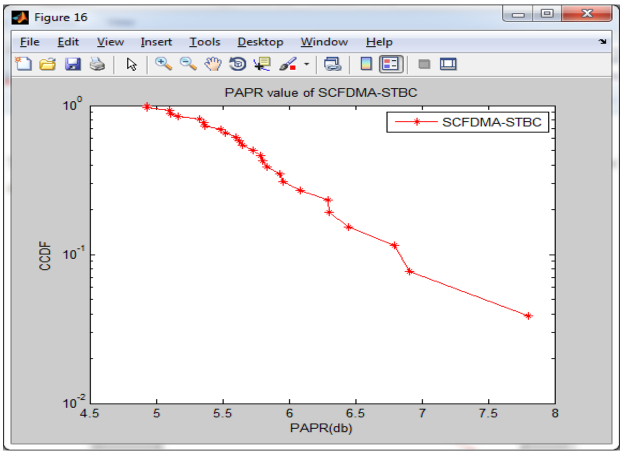
Then PAPR performances of QPSK, QAM and PSK in SCFDMA-STBC are calculated. The figure 8 shows the result graphs of PAPR performance of SCFDMA-STBC.



(a)



(b)



(c)

Fig 6: PAPR Performance of SCFDMA-STBC using (a) QPSK, (b) QAM and (c) PSK

After analyzing the above results, we have observed that SCFDMA-STBC has significantly lower BER than the OFDM-STBC in all the modulation schemes. Also values of PAPR are lesser in SCFDMA-STBC as compared to the OFDM-STBC system.

V. CONCLUSION

With the results of BER along with PAPR graphs, we can conclude that SCFDMA-STBC is more effective and performs better than the previous work i.e. OFDM-STBC as it has lower BER as well as lesser PAPR too which is a severe disadvantage of OFDM system. SCFDMA-STBC reduces the particular limitations that came across the technique of OFDM-STBC.

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