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BER ANALYSIS OF MIMO-OFDM SYSTEM

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ABSTRACT

MIMO is a system where a number of antennas are used at the transmitter and receiver side. A MIMO system takes advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment. The combination of OFDM systems with MIMO technology has provided us with increase in link reliability and an improvement in spectral efficiency. For 4G communication MIMO-OFDM is one of the most competitive technologies. The combination of OFDM and MIMO seems to be very promising when aiming at the design of very high-rate wireless mobile systems. This paper takes into consideration both these system and proposes a way for Ber-Analysis of the two system combined

KEYWORDS: MIMO, OFDM, Frequency spectrum, Rayleigh fading, Modulation.

INTRODUCTION

This article provides an overview of the basics of MIMO-OFDM technology and focuses on the BER Analysis of MIMO-OFDM systems. 3 G popularly known as third generation mobile communication systems cannot meet the requirements of a variety of business types because of its low data rates. Secondly, voice transportation in 3G is conversant to second-generation (2G) communication systems because they both use circuit switching technology rather than Internet Protocol approach. Because of these limitations many countries have introduced the revolutionary,(4G) communication systems that provides a far-reaching and secure IP solution where data, voice and multimedia can be provided to users with increased data rates than previous technologies. Communication in the wireless medium takes place through electromagnetic waves which carry the signals over the communication path. This term is mainly used in the telecommunications industry in order to refer to telecommunications systems (e.g. receivers, radio transmitters, remote controls etc.) which use energy to transfer information without the use of wires. This means the transfer of data between two or more points that are not physically connected by an electrical conductor. It can be divided into-Wireless at fixed location, portable locations and wireless in mobile applications. Cellular telephones and personal digital assistants are included under fixed and portable communication. Modulation is one of the most important process in wireless communication, it involves varying some features of a carrier signal with the message signal which contains information to be transmitted. Fading is the change in attenuation that affects a signal over certain propagation media. Different signal copy's will experience different fading and hence will be attenuated in a different manner. Delay and phase profoundly affect the transmitted signal. This results in either constructive or destructive interference, which amplifies or attenuates the signal power seen at the receiver. Destructive interference may result in temporary failure of communication due to a severe drop in the channel's signal-to- noise ratio. OFDM is a special form of multicarrier modulation, where a single data stream is transmitted over a large number of lower rate sub-carriers.

DIFFFERENT TECHNOLOGICAL SYSTEMS

MIMO

MIMO technique has garnered attention in wireless communications, because it increases the data throughput and link range without additional bandwidth or an increase in transmitted power. It is one of several forms of smart antenna technology. It achieves this objective by spreading the total transmitted power over different antennas to achieve an array gain which improves the spectral efficiency (bits per second per hertz of bandwidth are increased) and achieves a diversity gain that enhances the link reliability and reduces fading. Because of these properties,

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MIMO is also an important part of modern wireless communication standards such as WiMAX, IEEE 802.11n,3GPP, 4G, Long Term Evolution.

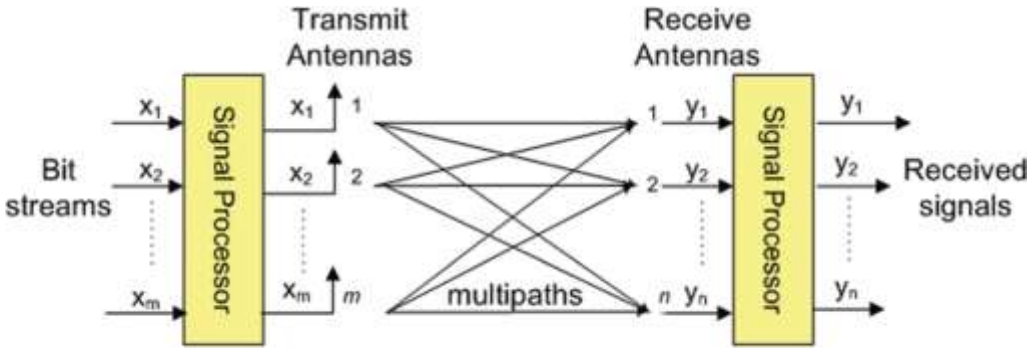

Fig:1 MIMO System

OFDM

'Orthogonal frequency division multiplexing', also known as OFDM. In this technique data transmission takes place in parallel by using a large number of modulated sub-carriers. A higher bit rate channel is converted from time domain to frequency domain and divided into many orthogonal sub-channels in the frequency domain which have lower bit rates. The Orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Because of this, the spectrum of each carrier has a null at the centre frequency of each of the other carriers in the system. Hence there is no interference between the carriers, although their spectrums overlap. The separation between carriers is kept minimal in order to increase the spectral utilization. The sub-carriers are modulated at a very low symbol rate, making the symbols much longer than the channel impulse response. By this process OFDM systems mitigates the inter symbol interference or ISI, introduced by a frequency selective multipath fading in a wireless environment. The other way of overcoming this difficulty is by introducing a guard interval between consecutive OFDM symbols, the effects of ISI can be diminished. However we must ensure that the guard interval is longer than the multipath delay. Even if each sub-carrier operates at a very low data rate, a total high data rate is achieved by using large number of sub-carriers. Since ISI has a very negligible effect on the OFDM systems, equalizers are not needed at the receiver side. The subcarriers have a minimum frequency separation necessary to maintain orthogonality of their corresponding time domain waveforms, still the signal spectra corresponding to the different subcarriers overlap in frequency domain. This Orthogonality can be completely maintained with a minute reduction in SNR, even though the signal passes through a time dispersive fading channel, by introducing a cyclic prefix .We need to take care that the length of the cyclic prefix is at least equal to the length of the multipath channel. The size of cyclic prefix is usually taken as one fourth the symbols. It is very easy to achieve accurate symbol synchronization. Even though the spectra of sub carriers overlap each other, individual sub carriers can be removed by base band processing. This overlapping property of OFDM improves its spectral efficiency than the conventional multicarrier communication scheme. The nowadays solution of taking advantages by combining both these technologies will significantly improve the overall system.

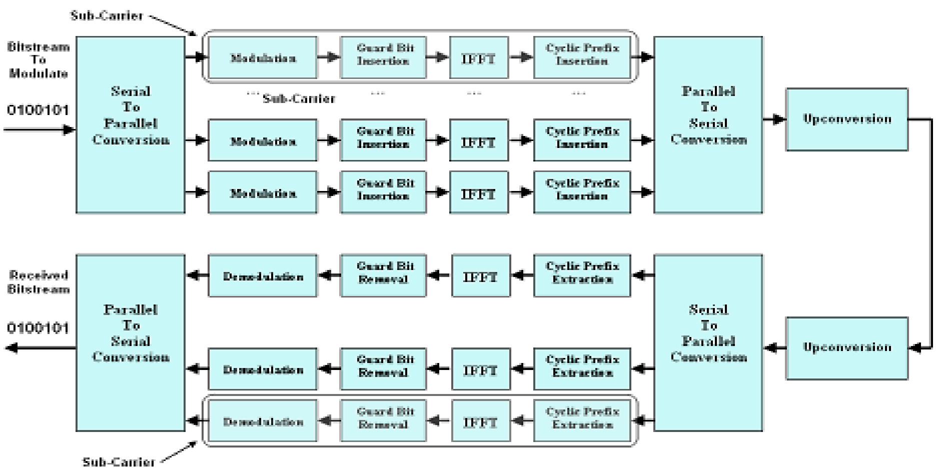

Fig: 2 OFDM

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MIMO-OFDM

There are two different signalling schemes used in MIMO systems which can be roughly categorized into spatial multiplexing and space-time coding. Spatial multiplexing helps in achieving capacity gain and space-time coding, which improves link reliability by using diversity gain. Most multi-antenna signalling schemes, in fact, realize both spatial-multiplexing and diversity gain. Spatial multiplexing is accomplished in MIMO-OFDM system by transmitting autonomous data streams on a tone-by-tone basis with the total transmit power split uniformly across antennas and tones. Even though the use of OFDM eliminates ISI, the computational complexity of MIMO-OFDM spatial-multiplexing receivers can still be high. This is because the number of data-carrying tones typically ranges between 48 (IEEE 802.11a/g standard) and 1728 (IEEE 802.16e standard) and spatial separation has to be performed for each tone. Computational complexity reductions are obtained by performing a QR factorization in a sphere decoder on a subset of tones only and computing the remaining inverses or channel inversion in the case of a MMSE receiver, respectively, through interpolation. The resultants when compared to QR decomposition or brute-force tone-by-tone channel inversion, are proportional to the number of tones divided by the product of the number of transmit antennas and the channel order (upper-bounded by the length of the CP). The main advantages of using a MIMO-OFDM system are low BER, increases the range and reliability, It Increases diversity gain and enhance system capacity on a time-varying multipath fading channel improving power-spectral efficiency in wireless communication systems and Optimizes the power efficiency. This technology guarantees each user's quality of service requirements, including bit-error rate and data rate at the same time ensures fairness to all active users.

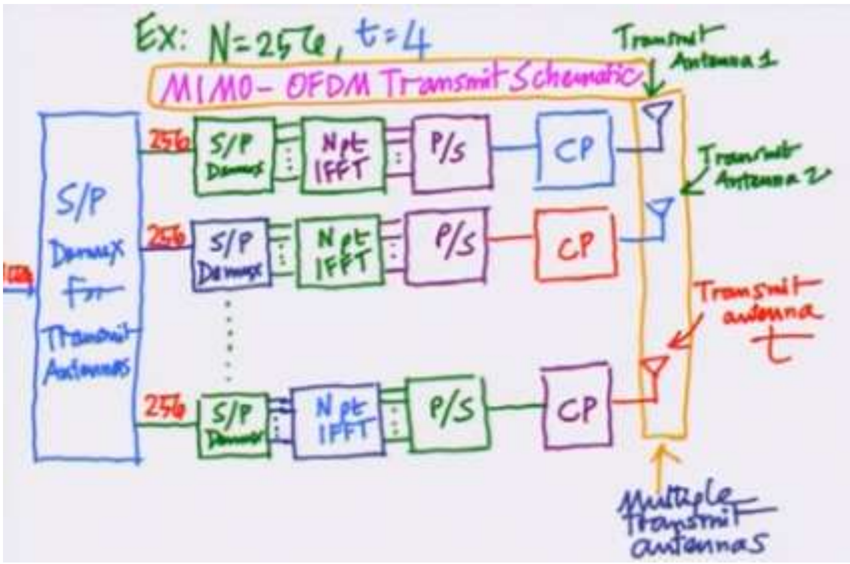

Fig: 3 MIMO-OFDM System

MATLAB Code

Initially we took 64 data bits and 4 subcarrier channel , which makes the total amount of data being transmitted through transmitter 256 ,with an OFDM block size of 16 . We decided the length of cyclic prefix by using the command [cp_len = floor(0.1 * block_size)]. Then we used and inbuilt function to generate random data and applied QPSK modulation on the input stream of data. The serial data was converted into parallel stream of data Using the four sub carriers we initially made. After QPSK modulation IFFT was performed on each of the sub carriers to convert the signal from the frequency domain to the time domain. Finally cyclic prefix was added and the signals were transmitted .At the receiver the cyclic prefix was first removed then FFT was performed in order to convert the signal back to frequency domain. Finally the different sub- carriers were combined into one stream of data . A BER-SNR graph was made using the received data and compared with a system that only used MIMO .

```
% Transmitter
NFDB = 64;
A =4; %Number of subcarrier channel  (M)
B=256;%Total number of bits to be transmitted at the transmitter (n)
block_size = 16;
cp_len = floor(0.1 * block_size);
sgma=sqrt(1/snr)/2;
```

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```
index=1;
data = randsrc(1, NFDB, 0:A-1);
figure(1),stem(data); grid on; xlabel('Data Points'); ylabel('Amplitude')
title('Original Data ')
qpsk_modulated_data = pskmod(data, A);
figure(2),stem(qpsk_modulated_data);title('QPSK Modulation ')
S2P = reshape(qpsk_modulated_data, NFDB/A,A);
SC1 = S2P(:,1);
SC2 = S2P(:,2);
SC3 = S2P(:,3);
SC4 = S2P(:,4);
figure(3), subplot(4,1,1),stem(SC1),title('Subcarrier1'),grid on;
subplot(4,1,2),stem(SC2),title('Subcarrier2'),grid on;
subplot(4,1,3),stem(SC3),title('Subcarrier3'),grid on;
subplot(4,1,4),stem(SC4),title('Subcarrier4'),grid on;
NMB_OF_SC=4;
cp_start=block_size-cp_len;
ifftSC1 = ifft(SC1);
ifftSC2 = ifft(SC2);
ifftSC3 = ifft(SC3);
ifftSC4 = ifft(SC4);
figure(4), subplot(4,1,1),plot(real(ifftSC1),'r'),
title('IFFT on all the sub-carriers')
subplot(4,1,2),plot(real(ifftSC2),'c');
subplot(4,1,3),plot(real(ifftSC3),'b');
subplot(4,1,4),plot(real(ifftSC4),'g');
for i=1:NMB_OF_SC,
ifftSC(:,i) = ifft((S2P(:,i)),16);
for j=1:cp_len,
cyclic_prefix(j,i) = ifftSC(j+cp_start,i);
end
Append_prefix(:,i) = vertcat( cyclic_prefix(:,i), ifftSC(:,i));
end
A1=Append_prefix(:,1);
A2=Append_prefix(:,2);
A3=Append_prefix(:,3);
A4=Append_prefix(:,4);
figure(5), subplot(4,1,1),plot(real(A1),'r'),title('Addition of Cyclic prefix to all  sub-carriers')
subplot(4,1,2),plot(real(A2),'c')
subplot(4,1,3),plot(real(A3),'b')
subplot(4,1,4),plot(real(A4),'g')

figure(11),plot((real(A1)),'r'),title('Orthogonality'),hold on ,plot((real(A2)),'c'),hold on ,
plot((real(A3)),'b'),hold on ,plot((real(A4)),'g'),hold on ,grid on
 [rows_Append_prefix cols_Append_prefix]=size(Append_prefix);
len_ofdm_data = rows_Append_prefix*cols_Append_prefix;
ofdm_signal1 = reshape(Append_prefix, 1, len_ofdm_data);
ofdm_signal2 = reshape(Append_prefix, 1, len_ofdm_data);
figure(6),plot(real(ofdm_signal1)); xlabel('Time'); ylabel('Amplitude');
title('OFDM Signal');grid on;

%Receiver
channel1 = randn(1,2) + sqrt(-1)*randn(1,2);
after_channel1 = filter(channel1, 1, ofdm_signal1);
awgn_noise1 = awgn(zeros(1,length(after_channel1)),SNRindb);
recvd_signal1 = awgn_noise1+after_channel1;
figure(7),plot(real(recvd_signal1)),xlabel('Time'); ylabel('Amplitude');
```

```
title('OFDM Signal after passing through channel');grid on;
channel2 = randn(1,2) + sqrt(-1)*randn(1,2);
after_channel2 = filter(channel2, 1, ofdm_signal2);
awgn_noise2 = awgn(zeros(1,length(after_channel2)),SNRindb);
recvd_signal2 = awgn_noise2+after_channel2
figure(7),plot(real(recvd_signal2)),xlabel('Time'); ylabel('Amplitude');
title('OFDM Signal after passing through channel');grid on;
for i=1:length(recvd_signal1)
recvd_signal(i)=max(recvd_signal1(i),recvd_signal2(i));
end
recvd_signal_paralleled = reshape(recvd_signal,17, 4);
recvd_signal_paralleled(1:cp_len,:)=[];
R11=recvd_signal_paralleled(:,1);
R21=recvd_signal_paralleled(:,2);
R31=recvd_signal_paralleled(:,3);
R41=recvd_signal_paralleled(:,4);
figure(8),plot((imag(R11)),'r'),subplot(4,1,1),plot(real(R11),'r'),
title('Cyclic prefix removed from the four sub-carriers')
subplot(4,1,2),plot(real(R21),'c')
subplot(4,1,3),plot(real(R31),'b')
subplot(4,1,4),plot(real(R41),'g')
for i=1:NMB_OF_SC,
fft_data(:,i) = fft(recvd_signal_paralleled(:,i),16);
end

F1=fft_data(:,1);
F2=fft_data(:,2);
F3=fft_data(:,3);
F4=fft_data(:,4);
figure(10), subplot(4,1,1),plot(real(F1),'r'),title('FFT of all the four sub-carriers')
subplot(4,1,2),plot(real(F2),'c')
subplot(4,1,3),plot(real(F3),'b')
subplot(4,1,4),plot(real(F4),'g')
Recieved_Serial_Data = reshape(fft_data, 1,(16*4));
qpsk_demodulated_data = pskdemod(Recieved_Serial_Data,4);
figure(10)
stem(data)
hold on
stem(qpsk_demodulated_data,'rx');
grid on;
xlabel('Data Points');
ylabel('Amplitude');
title('Recieved Signal with error')

counter=0;
for i=1:64

    if (data(i)~=qpsk_demodulated_data(i))
       counter=counter+1;
    end
end
   pb=counter/length(data)
 end
```

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RESULTS

Following are the results that have been simulated using MATLAB. The graph below was plotted only by using a MIMO system and we observed that for an BER of 10^(-4) we get a SNR of 8.(FIG-4)

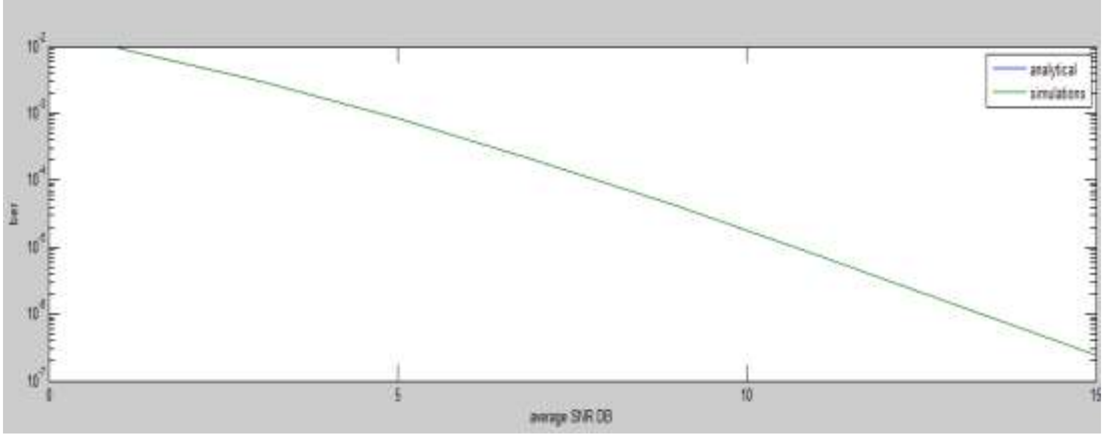

Fig: 4 MIMO System

Whereas in the case of a MIMO-OFDM system for a BER of 10^(-4) we get an SNR of 15 .(FIG-5)

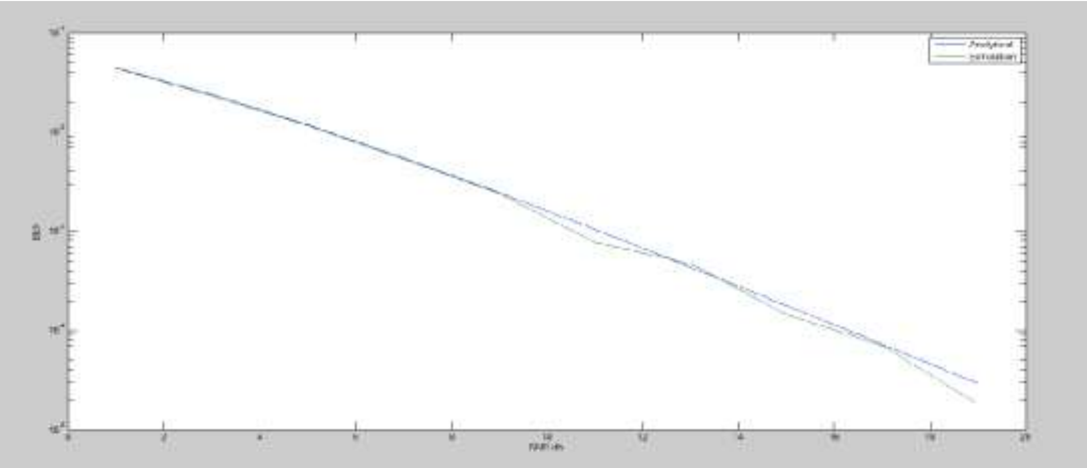

Fig: 5 MIMO-OFDM

Different output at the end of each block in a MIMO-OFDM system.

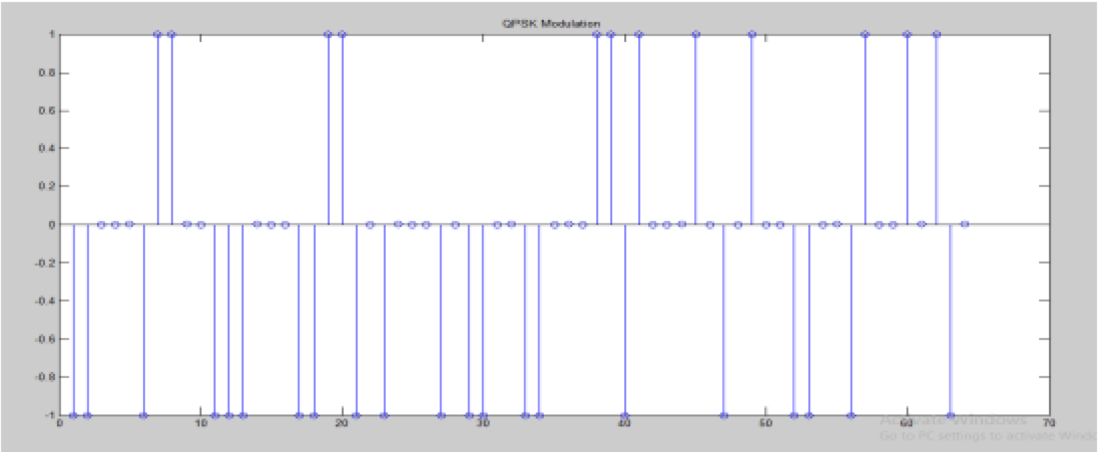

Fig: 6 QPSK modulated signal

The data is initially modulated by using the QPSK modulation technique.
The modulated signal is then superimposed onto 4 different sub-carriers.(FIG-7)

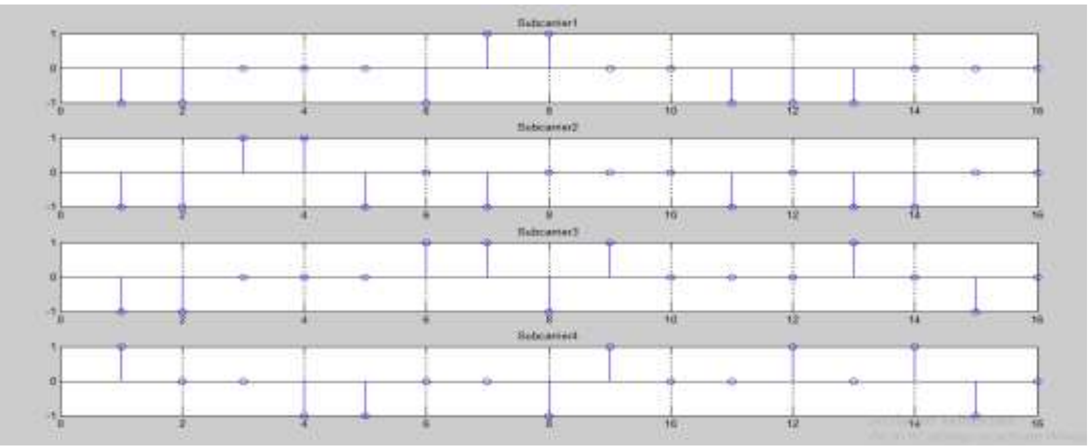

Fig: 7 Different sub-carriers

The application of IFFT on these sub-carriers converts them from a frequency domain to time domain ,this maps the complex data symbols to a Time Domain OFDM symbol..(FIG-8)

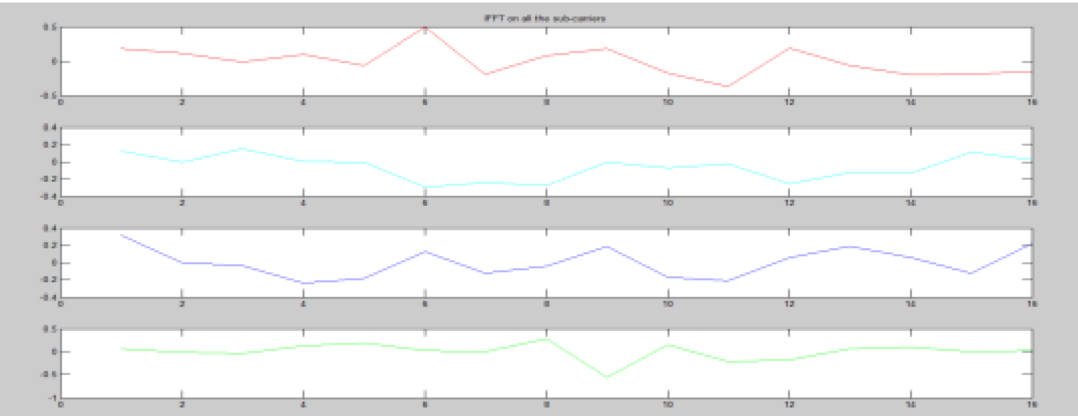

Fig: 8 Performing IIFT on sub carriers

Cyclic prefix are added to these four sub-carriers (FIG-9).

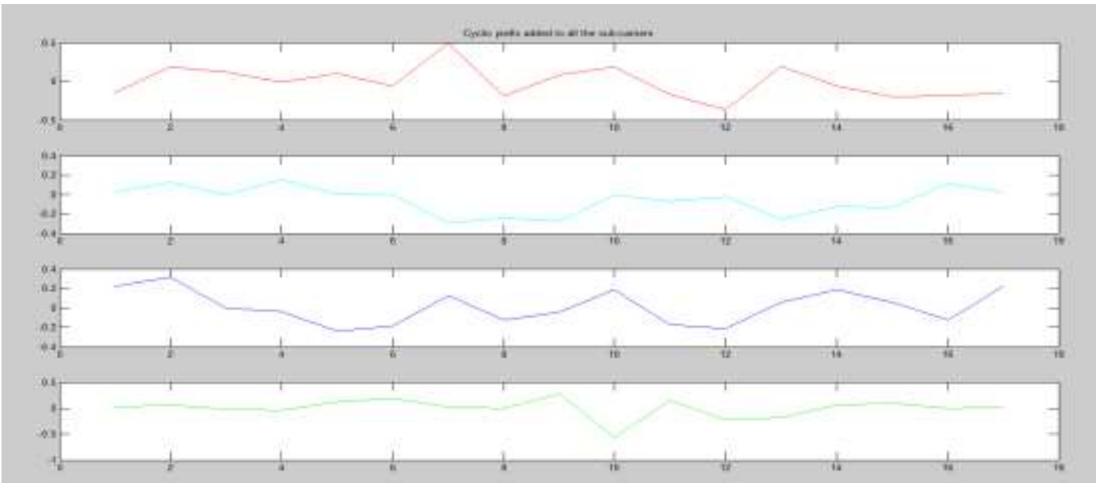

Fig: 9 Adding cyclic prefix

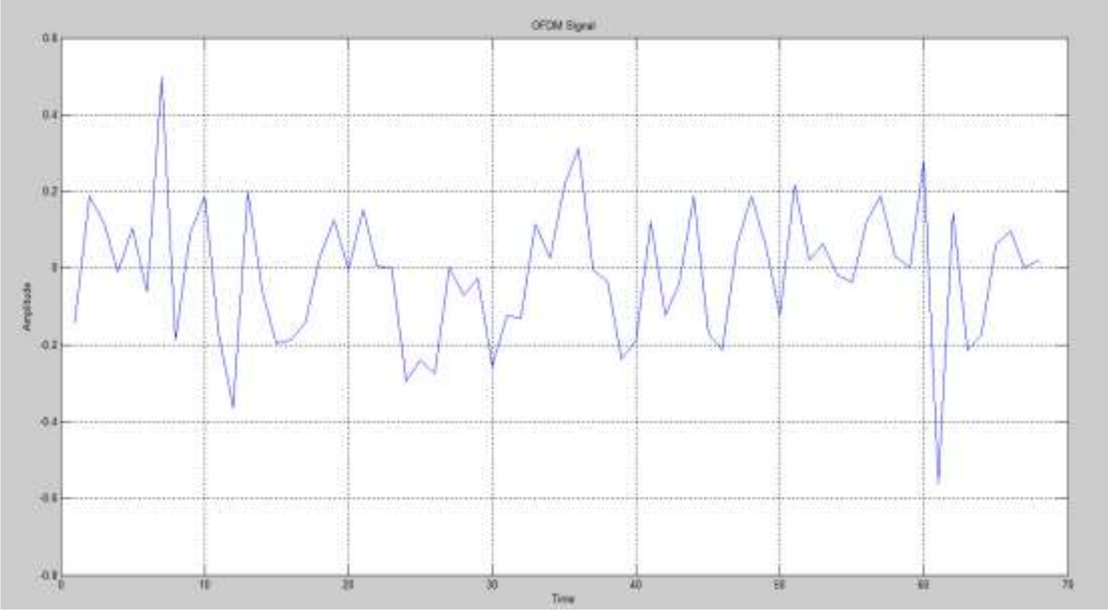

Fig: 10 Final OFDM signal

CONCLUSION

Hence by using a MIMO-OFDM system the overall SNR of the system can be drastically improved.
Different antenna configurations were used for analysis and in all the cases there was an improvement in SNR as and when compared with systems that only used MIMO system One important advantage of MIMO OFDM system is data capacity, as it combines advantages of both MIMO and OFDM.

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