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Simulation of 16 QAM OFDM Modulator using MATLAB

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Abstract— In this paper the 16 QAM (M=16) Modulator is simulated for OFDM using MATLAB tools. In 16QAM, BER performance is better than 64 QAM [2], [3]. OFDM (Orthogonal Frequency Division Multiplexing) is technology that will certainly play a vital role in next generation wireless communication systems [1].To improve BER performance in OFDM, no frequency diversity is changed. The Orthogonality is shown by the OFDM carriers on a symbol interval if they are spaced in frequency exactly at the reciprocal of the symbol interval, which can be done by utilizing the discrete Fourier transform (DFT)[2].This is acceptable in the presence of fading environment and for high data rate application. Orthogonality of signals is the basic key behind its usage which reduces the interference to a large extent. For direct and quadrature component Filtered and unfiltered scatter plot are generated.

Keywords: — OFDM model, CDMA, MATLAB

1. Introduction

- Wireless industry has already seen a rapid growth in past Ten years. It is still expanding at very high rate as more and more consumer and other applications are being envisaged and developed. The Value of any wireless product depends upon how reliably and efficiently it can transmit digital data from transmitter to receiver in a given bandwidth. Nowadays two prominent technologies driving the wireless industry are CDMA and OFDM, but the basic premise of both technologies depends upon the principle of Orthogonality. CDMA was originally developed for Military applications because of its inherent stealth and anti jamming capabilities. CDMA is a kind of spread spectrum communication where each user uses much more bandwidth than required by Shannon's law to transmit certain amount of information (base-band signal).Users are assigned different codes, generally PN sequences , which are orthogonal to each other. Ideally they are orthogonal at no time delay between them. If there is some relative time shift between them, some cross correlation is there between users. But basic detection and demodulation techniques depends upon the property of orthogonality between different users assigned codes? The other technology being researched and used extensively for wireless Digital communication is OFDM [5]. As name itself implies orthogonal frequencies are used for transmission of digital data which may be from single user or from different users for multiplexing purpose.

2. Proposed Methodology

2.1 OFDM Model: In this OFDM technique uses the concept of fast Fourier transform as a integral part for demodulation and IFFT as modulation part.

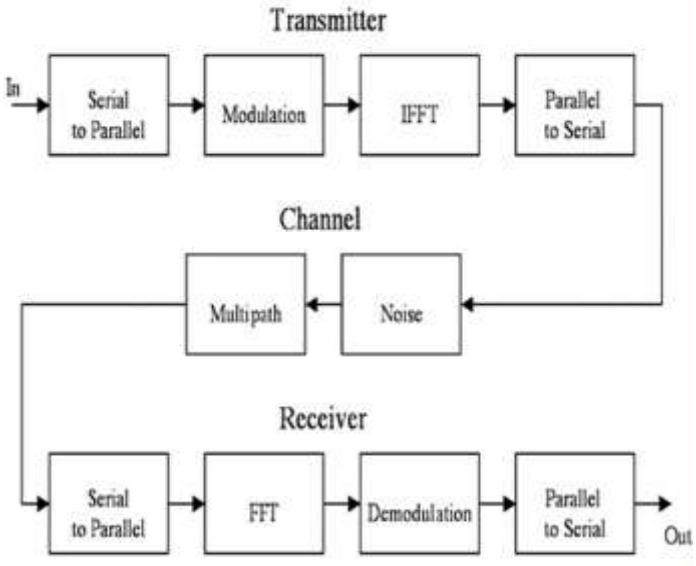
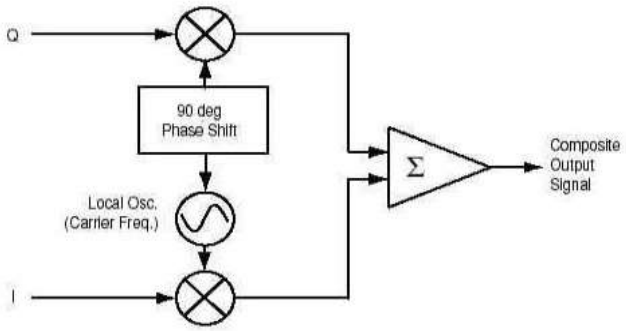


Fig. Basic block diagram for OFDM system

I/Q formats

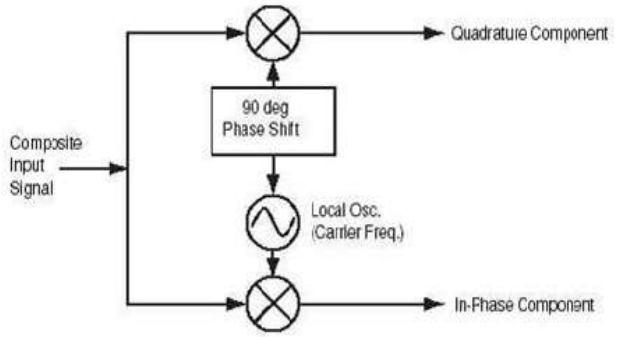
In digital communications, modulation is often expressed in terms of 'I' and 'Q'. This is a rectangular representation of the polar diagram. On

a polar diagram, I axis lies on the zero degree phase reference, and the Q axis is rotated by 90 degrees. The signal vector's projection onto I axis is its "I" component and the projection onto the Q axis is its "Q" component.



I and Q in a radio transmitter

I/Q diagrams are particularly useful because they mirror the way most digital communications signals are created using an I/Q modulator. In the transmitter, I and Q signals are mixed with the same local oscillator (LO). A 90 degree phase shifter is placed in one of the LO paths. Signals that are separated by 90 degrees are also known as being orthogonal to each other or in quadrature. Signals that are in quadrature do not interfere with each other. They are two independent components of the signal. When recombined, they are summed to a composite output signal. There are two independent signals in I and Q that can be sent and received with simple circuits.



I and Q in a radio receiver

The composite signal with magnitude and phase (or I and Q) information arrives at the receiver input. The input signal is mixed with the local oscillator signal at the carrier frequency in two forms. One is at an arbitrary zero phase. The other has a 90 degree phase shift. The composite input signal (in terms of magnitude and phase) is thus broken into an in-phase, I, and a quadrature, Q, component. These two components of the signal are independent and orthogonal. One can be changed without affecting the other. Normally, information cannot be plotted in a polar format and reinterpreted as rectangular values without doing a polar-to-rectangular conversion. This conversion is exactly what is done by the in-phase and quadrature mixing processes in a digital radio. A local oscillator, phase shifter, and two mixers can perform the conversion accurately and efficiently.

The Doppler Effect

If Transmitter or Receiver or both are Mobile and moving at high speed, there will be some significant Doppler shift on the RF signal. This Doppler shift may be varying in nature as Motion Characteristics changes. This shift of frequencies at RF level reflects as varying Carrier frequency offset (CFO) in base band signal as RF signal is down converted to base band using fixed hardware. This CFO is very similar to the CFO induced by Local Oscillator carrier frequency offsets (LOCFO).CFO induced by Doppler may be comparatively high and may exhibit high dynamic behaviour. The CFO has the effect of spectral Leakage in FFT. The Orthogonality between different subcarriers no longer holds and this results in Inter Carrier Interference (ICI).

BPSK/QPSK/QAM Mapping [6]

By selecting Modulation Type in set parameters' we can select one of the four possible modulation techniques that can be employed in the model. Following files are used for the mapping of the signal before it is fed to IFFT. Comp is array of complex numbers of 64 Length. This array is fed to IFFT for each symbol generation. What value each complex number hold defines the amplitude and phase of that particular sub carrier. Hence these complex number values define the Modulation type .These possible values of the various modulation types are depicted by the constellation diagrams.

Comp = I + Q*j

I – real part of complex number

Q – Imaginary part of the complex number.

Constellation diagrams for the various modulation techniques are depicted below.

Time Domain Windowing

In this model no windowing is used to contain the high frequency components. Practical system may use windows in the time domain. Windows tends to smooth out the abrupt changes at the symbol boundaries. Some the popular windows are Hamming, Hanning , Barletta etc.

One other way to smooth the abrupt changes at the symbol boundary is to take average of next expected point, had symbol continued beyond the symbol boundary, and the actual point. This method will reduce the discontinuity at the boundary. Also if there happened to be no change in data to be transmitted between adjacent symbols, the next expected point and actual point will be same and the sub carrier will still remain continuous and hence reducing the high frequency components in the signal.

Gaussian Channel [7]

Since sources of noise may be many in the channel, many Random Processes interact with each other. As per Central Limit Theorem, the final Random Process converges to be Gaussian. Channel does two things on the transmitted signal

1. Adds White Gaussian Noise (WGN)
2. Low pass filtering – Channel filter

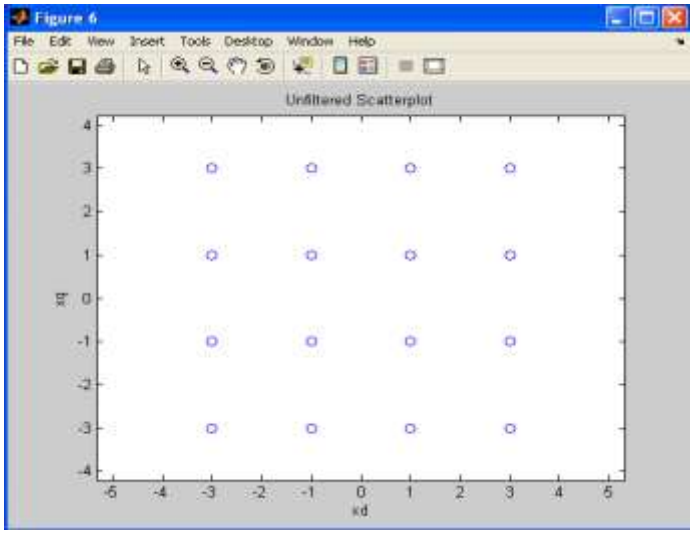
Additionally If the transmitter and Receiver are mobile with respect to each other there will be Doppler on the RF carrier which will reflect at the Base band signal. Effect of Channel on individual sub carrier can be appreciated by the following figure. Data type = 4 is selected. We can see that individual sub carrier has the effect of sampling the Frequency Response of the channel when Data on each sub carrier is same for all OFDM symbols and No Guard Interval is used i.e. Cyclic Prefix is switched off.

Detection and Timing synchronization

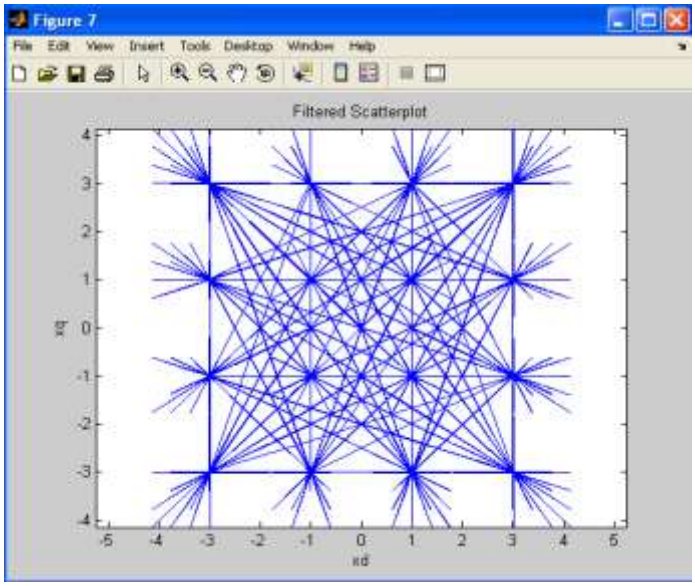
When the Receiver is switched on the very first thing it has to do is to detection. After the detection only proper signal boundaries can be found out and data can be demodulated. As the signal to be looked for is BPSK, be design, it becomes a BPSK signal Detection problem in White Gaussian Noise. Standard Detection Criterions are available for such a detection problem. Two of those are Neaman-Pearson criterion and Minimum Probability Error (MPE) criterion. Both Criterions gives the same optimal solution that is Matched Filter. Matched Filtering is employed for the Detection purpose. Output of Matched filter is shown below. To get clear picture of the Detection peaks, the above figure is zoomed to the actual peaks at the exact difference of 16 samples. Note that no Oversampling is used anywhere in the OFDM system simulated.

3. Result and Discussion

Unfiltered Scatter plot: Following figure shows the unfiltered scatter plot which is also the looking as the constellation diagram, having 4 symbols are taken in both x-axis and y-axis



Filtered Scatter plot



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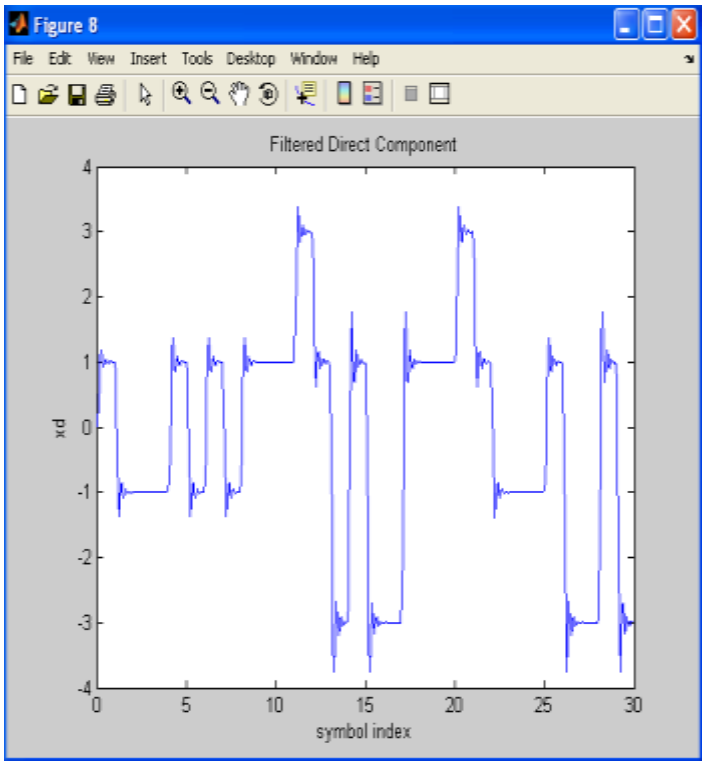
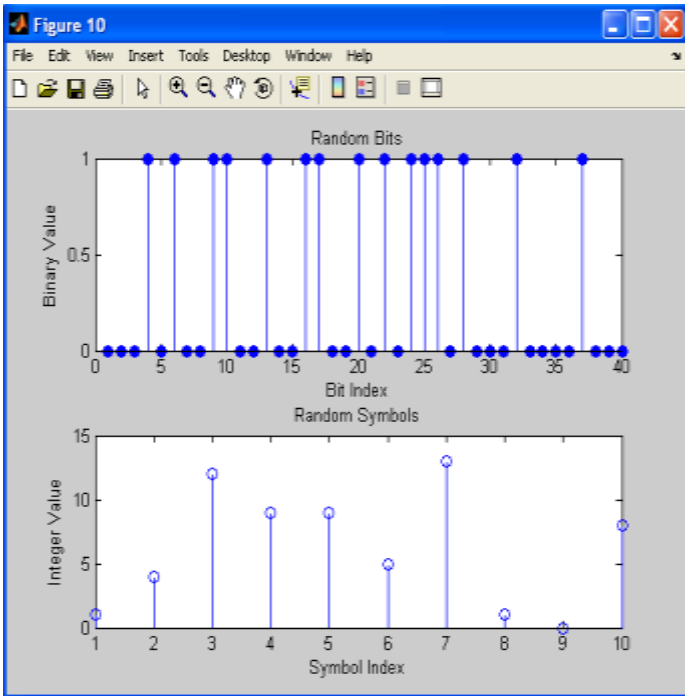
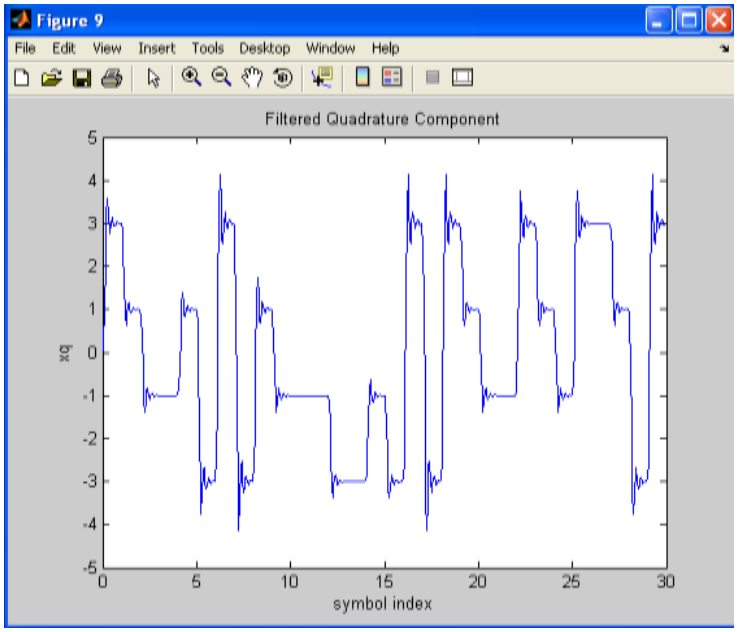
Filtered Direct Component



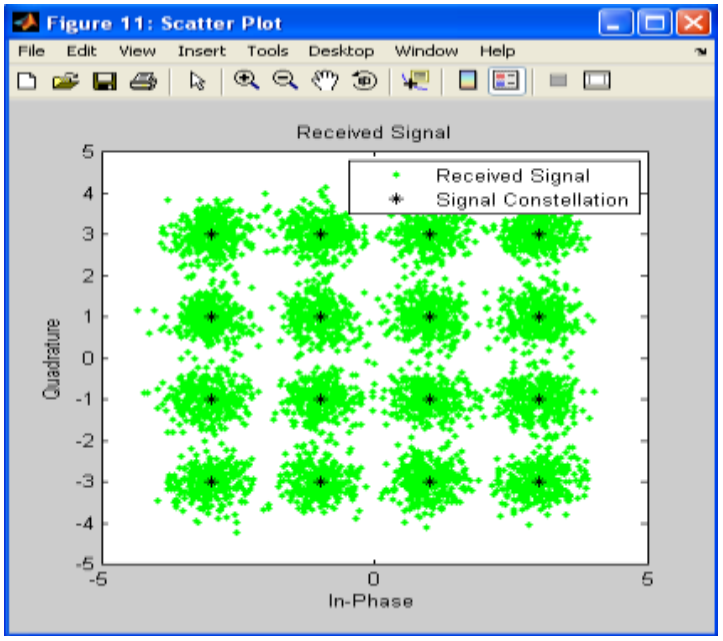
Random Binary Signal and Signal Mapping



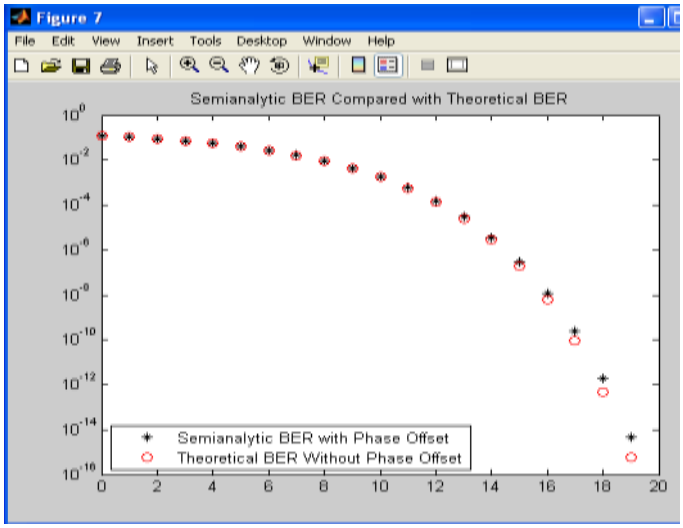
Filtered Quadrature Component



Received Signal with AWGN noise



Bit Error Rate performance



4. Conclusion:

In this project the simulation for the 16QAM modulator is done by using the MATLAB tools. First the scatter plot in unfiltered mode is plotted. This signal is fed to the filter of given parameters. Output of this filter is plotted (direct component xd vs quadrature component xq), which is the filtered Scatter plot. The direct and quadrature waveform are observed when it is passed through a sixth order filter. Signal while travelling through atmosphere is effected by the Gaussian noise so a simulation study is done to observe the modulated output by inserting a Gaussian noise to it. For this a random signal is generated first and then AWG noise is added to it. Communication system design requires the simultaneous conservation of bandwidth, power, and cost. Here I have tried to implement the modulation by software mean which is more reliable and flexible and can easily be implemented by programming the DSP Chips. Because of the orthogonality of signals it is integral tool for the future high data rate and bandwidth applications. It manages the bandwidth in the best possible way keeping the interference level at its minimum. It can improve the working of Cognitive Radios by utilizing the orthogonality concept.

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