International Journal of Advanced Computer Research (ISSN (print):2249-7277 ISSN (online):2277-7970)
Volume-3 Number-2 Issue-10 June-2013

Behaviour of OFDM System using MATLAB Simulation

S.S.Ghorpade[1], S.V.Sankpal[2]

Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is mainly designed to combat the effect of multipath reception, by dividing the wideband frequency selective fading channel into many narrow flat sub-channels. OFDM offers flexibility in adaptation to time varying channel condition by adopting the parameters at each subcarrier accurately. To avoid ISI due to multipath, successive OFDM symbols are separated by guard band. This makes the OFDM system resistant to multi-path effects [1].The idea of using parallel data transmission by FDM was published in mid 60s [2].However, recently the attention toward OFDM has grown rapidly in the field of wireless and wired communication systems. This is reflected by the adoption of this technique in applications such as digital audio/video broadcast, wireless LAN (802.11a and HiperLAN2), broadband wireless (802.16) and xDSL [3]. In this paper design of OFDM system transmitter and receiver is introduced and Simulation is done using MATLAB.

Keywords

FFT, IFFT, OFDM, QAM

1. Introduction

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel.. Here the different carriers are orthogonal to each other, that is, they are totally independent of one another. Orthogonal Frequency Division Multiplexing (OFDM) is a wideband modulation scheme that is designed to cope with the problems of the multipath reception. Essentially, the wideband frequency selective fading channel is divided into many narrow-band sub channels. If the number of sub channels is high enough, each sub channel could be considered as flat.

S.S.Ghorpade, E&TC, DYP College, Kolhapur, India.
S.V.Sankpal, E&TC, DYP College, Kolhapur, India.

This is because we transmit many narrowband overlapping digital signals in parallel, inside one wide band.

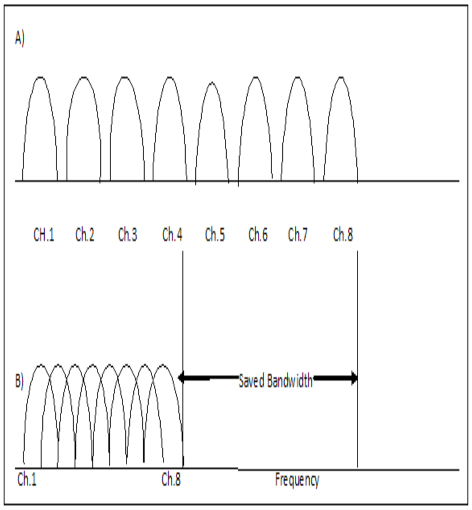

Figure 1: A) Spectrum of FDM showing guard Bands
B) Spectrum of OFDM showing overlapping subcarrier

Increasing the number of parallel transmission channels reduces the data rate that each individual carrier must convey, and that lengthens the symbol period. Therefore the delay time of reflected waves is suppressed to within 1 symbol time. Fig.1 compares the utilization of FDM and OFDM.

The development of OFDM systems can be divided into three parts. They are Frequency Division Multiplexing, Multicarrier Communication and Orthogonal Frequency Division Multiplexing [4]. Frequency Division Multiplexing is a form of signal multiplexing which involves assigning non overlapping frequency ranges or channels to different signals or to each user of a medium. A gap or guard band is left between each of these channels to ensure that the signal of one channel does not overlap with the signal from an adjacent one. Multicarrier Communication involves splitting of the signal to give a number of signals over that frequency range. Each of these signals are individually modulated and transmitted over the channel. At the receiver end, these signals are fed to a demultiplexer where it is demodulated and recombined to obtain the original signal.

2. Implementation

As shown in Fig.2, we have to implement the OFDM System below.

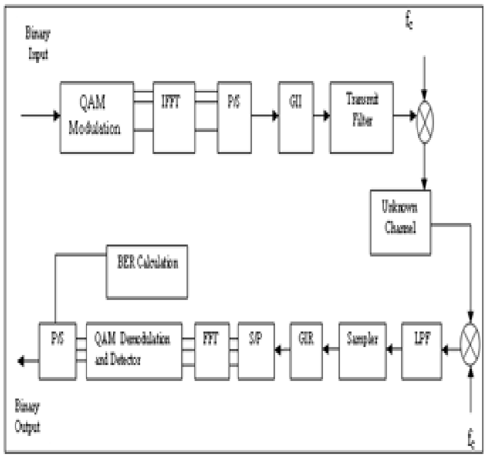

Figure 2: OFDM Block Diagram

Modulation

Modulation is the technique by which the signal wave is transformed in order to send it over the communication channel in order to minimize the effect of noise. This is done in order to ensure that the received data can be demodulated to give back the original data. In an OFDM system, the high data rate information is divided into small packets of data which are placed orthogonal to each other. This is achieved by modulating the data by a desirable modulation technique like Quadrature Amplitude Modulation [7]. After this, IFFT is performed on the modulated signal which is further processed by passing through a parallel to serial converter. Guard Interval Insertion (GII) is done in order to avoid ISI.

Communication Channel

This is the channel through which the data is transferred. Presence of noise in this medium affects the signal and causes distortion in its data content.

Demodulation

Demodulation is the technique by which the original data is recovered from the modulated signal which is received at the receiver end. In this case, the received data is first made to pass through a low pass filter and the Guard Interval Removal (GIR) is done. FFT of the signal is done after it is made to pass through a serial to parallel converter. A demodulator is used, to get back the original signal. The bit error rate and the signal to noise ratio is calculated by taking into consideration the unmodulated signal data and the data at the receiving end.

3. Simulation

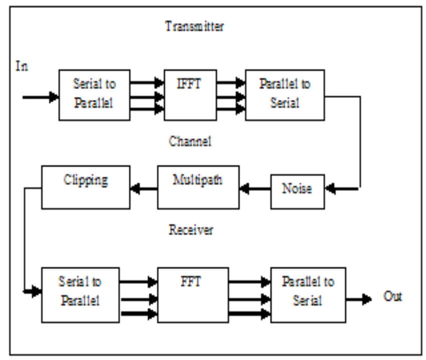

Figure 3: OFDM Simulation Flowchart

OFDM Simulation Process

Simulation flowchart is shown in fig.3. MATLAB code for 256 bits processing is given below.

The transmitter first converts the input data from a serial stream to parallel sets. Each set of data contains one symbol, Si, for each subcarrier. For example, a set of four data would be [S_0 S_1 S_2 S_3].Before performing the Inverse Fast Fourier Transform (IFFT), this example data set is arranged on the horizontal axis in the frequency domain as shown in Fig:4. This symmetrical arrangement about the vertical axis is necessary for using the IFFT to manipulate this data.

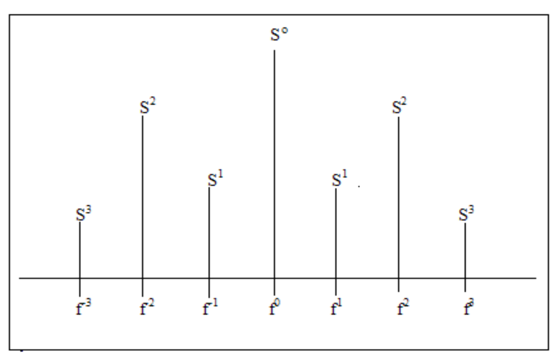

Figure 4: Frequency Domain Distribution of Symbol

An inverse Fourier transform converts the frequency domain data set into samples of the corresponding time domain representation of this data. Specifically, the IFFT is useful for OFDM because it generates samples of a waveform with orthogonal frequency components. Then, the parallel to serial block creates the OFDM signal by sequentially outputting the time domain samples.

The channel simulation will allow examination of the effects of noise, multipath, and clipping. By adding random data to the transmitted signal, simple noise can be simulated. Multipath simulation involves adding attenuated and delayed copies of the transmitted signal to the original. This simulates the problem in wireless communication when the signal propagates on many paths. For example, a receiver may see a signal via a direct path as well as a path that bounces off a building. Finally, clipping simulates the problem of amplifier saturation. This addresses a practical implementation problem in OFDM where the peak to average power ratio is high. The receiver performs the inverse of the transmitter. First, the OFDM data are split from a serial stream into parallel sets. The Fast Fourier Transform (FFT) converts the time domain samples back into a frequency domain representation. The magnitudes of the frequency components correspond to the original data. Finally, the parallel to serial block converts this parallel data into a serial stream to recover the original input data.

MATLAB Code

```
%code for OFDM signal transmission and reception in AWGN channel
% code
n = 256; % Number of bits to process
x = randint(n,1); % Random binary data stream
M = 16; % Size of signal constellation
k = log2(M); % Number of bits per symbol
xsym = bi2de(reshape(x,k,length(x)/k).','left-msb');
% Convert the bits in x into k-bit symbols.
y = modulate(modem.qammod(M),xsym);
% Modulate using QAM
tu=3.2e-6;%useful symbol period
tg=0.8e-6;%guard interval length
ts=tu+tg;%total symbol duration
nmin=0;
nmax=64;%total number of subcarriers
scb=312.5e3;%sub carrier spacing
fc=3.6e9;%carrier frequency
Rs=fc;
tt=0: 6.2500e-008:ts-6.2500e-008;
c=ifft(y,nmax);%IFFT
s=real(c'.*(exp(1j*2*pi*fc*tt)));%bandpass modulation
figure;
plot(real(s),'b');title('OFDM signal transmitted');
figure;
plot(10*log10(abs(fft(s,nmax))));title('OFDM spectrum');
xlabel('frequency')
ylabel('power spectral density')
title('Transmit spectrum OFDM');
snr=10;%signal to noise ratio
ynoisy = awgn(s,snr,'measured');%awgn channel
figure;
plot(real(ynoisy),'b');title('received OFDM signal with noise');
z=ynoisy.*exp(j*2*pi*fc*tt);%Bandpass demodulation
z=fft(z,nmax);%FFT
zsym=demodulate(modem.qamdemod(M),z);%demodulation of bandpass data.
z = de2bi(zsym,'left-msb'); %Convert integers to bits.
z = reshape(z.',prod(size(z)),1);%matrix to vector conversion
[noe,ber] = biterr(x,z) ;%BER calculation figure;
subplot(211);stem(x(1:256));title('Original Message');
subplot(212);stem(z(1:256));title('recovered Message');
```

4. Results

Simulation results for MATLAB code are shown in fig.5, 6, 7, 8.

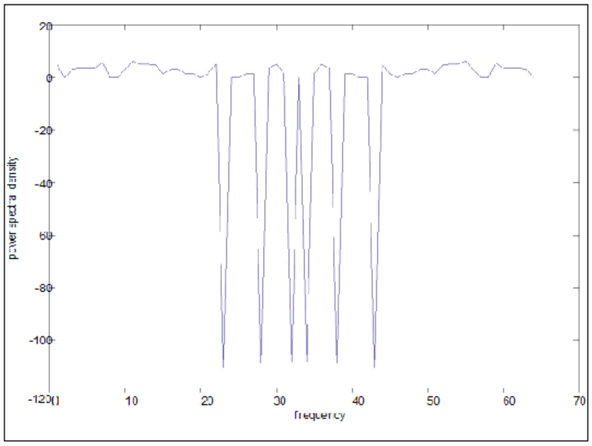

Figure 5: Transmit spectrum of OFDM

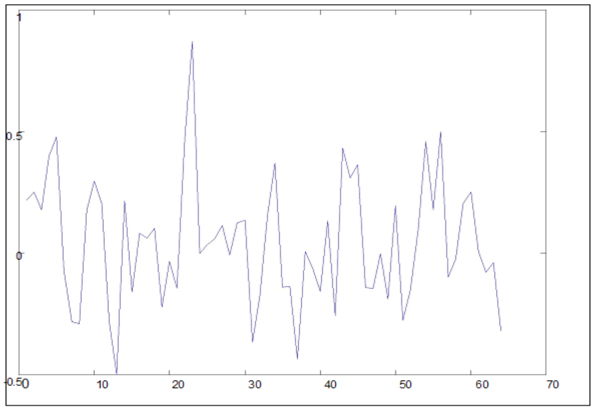

Fig 6: OFDM Signal Transmitted

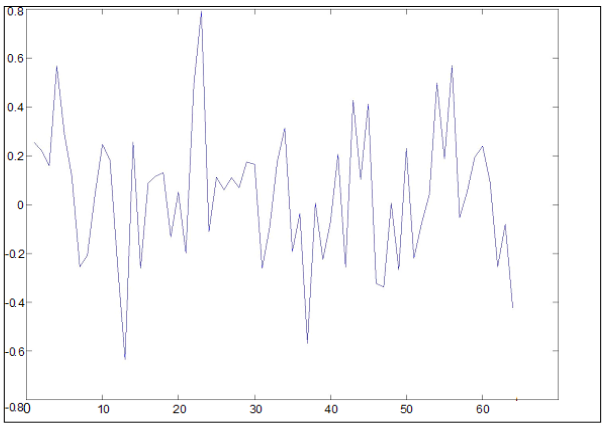

Fig 7: Received OFDM Signal with Noise

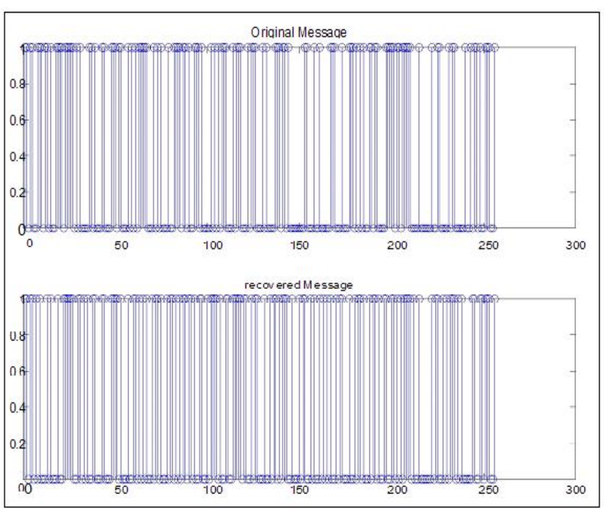

Figure 8: Original message and Recovered Message

5. Conclusion

The main aim of the project is to implement the core signal processing blocks of OFDM system. These blocks are simulated using MATLAB. Design Suite is tested for data patterns and the results are as shown. The results are matching with expected results. In this project OFDM system is simulated using 64 subcarriers. This is very basic implementation and has advantage of less processing time requirement and complexity. The spectral efficiency can be increased by increasing the number of subcarriers. The problem of Peak-to-average ratio can be reduced by using power amplifier with wide linear range at the front end of transmitter. Some other methods like Clipping, Peak Cancellation can be used. Synchronisation can be achieved by using Cyclic extension and Training Sequences.

Acknowledgment

I wish to thank the referee for the careful reading of the paper and giving the valuable suggestions.

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S.S.Ghorpade, received her B.E.(I.E.) degree from Shivaji University.She is student of M.E.(E&TC) in DYP College, Kolhapur.Her research interest include OFDM.She published 1 international conference paper, 1 international journal paper.

Swati V.Sankpal is currently working as associate professor at D. Y. Patil college of Engineering and Techonology, Kolhapur. She has total 28 years of experience. She has completed her B.E .and M.E.in Electronics from Walchand College of Engineering Sangli and earned her Ph.D. from Shivaji University, Kolhapur. She has published totally 28 national conference papers, 29 international conference papers, 25 international journal papers.Under her guidance three students have completed their P.G.(E.&.TC) and ,three students have submitted their thesis and ten are pursuing.