Study & Simulation of O.F.D.M System

Ashok Kamboj[1] Geeta Kaushik[2]
ECE Deptt.M.M.University Mullana (India)

A**BSTRACT**
In this paper, we describe the Orthogonal frequency division multiplexing (OFDM) is an established technique for wireless communication applications. Typical constraints faced during OFDM transmission are: a large peak-to-mean envelope power ratio, which can result in significant distortion when transmitted through a nonlinear device, such as a transmitter power amplifier. We study the effects of clipping and filtering on the performance of OFDM, including the power spectral density, BER, through intensive MATLAB simulation. We have indigenously simulated the effect of multipath fading to ensure that all specifications of OFDM transmission are taken care of. To simulate the modulation of the sub-carriers, we have chosen DQPSK. The way OFDM handles ISI has also been encompassed.

General Terms
Orthogonal frequency division multiplexing (OFDM) for wireless communication.

1. INTRODUCTION
It is valuable to discuss the mathematical definition of OFDM. This allows us to see how the signal is generated and how the receiver must operate, and it gives us a tool to understand the effects of imperfections in the transmission channel. OFDM transmits a large number of narrowband carriers, closely spaced in the frequency domain. In order to avoid a large number of modulators and filters at the transmitter and complementary filters and demodulators at the receiver, it is desirable to be able to use modern digital signal processing techniques, such as fast Fourier transform (FFT) [2]. Mathematically, each carrier can be described as a complex wave

$$s_c(t) = A_c(t) e^{j\left[\omega_c t + \phi_c(t)\right]}$$
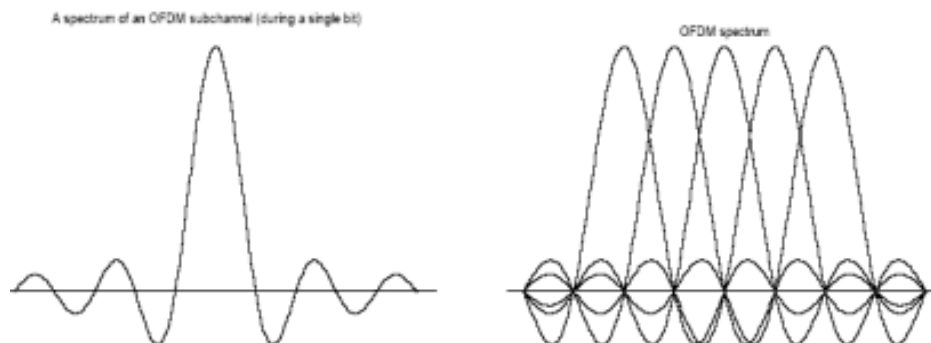
The real signal is the real part of Sc*(t)*. Both *Ac(t)* and *fc(t),* the amplitude and phase of the carrier, can vary on a symbol by symbol basis. The values of the parameters are constant over the symbol duration procedures. The IFFT & FFT operations are naturally performed through easily available commands in MATLABTM

2. OFDM MODEL
All The OFDM system was modeled using MATLABTM to allow various parameters of the system to be varied and tested. The aim of doing the simulations was to measure the performance of OFDM under different channel conditions, and to allow for different OFDM configurations to be tested. Four main criteria were used to assess the performance of the OFDM system, which were its tolerance to multipath delay spread, peak power clipping, channel noise and time synchronization errors.

The OFDM system was modeled using the Communications Toolbox, Signal Processing Toolbox and Simulink of MATLABTM, and is shown in Figure 2.1 A brief description of the model is provided below
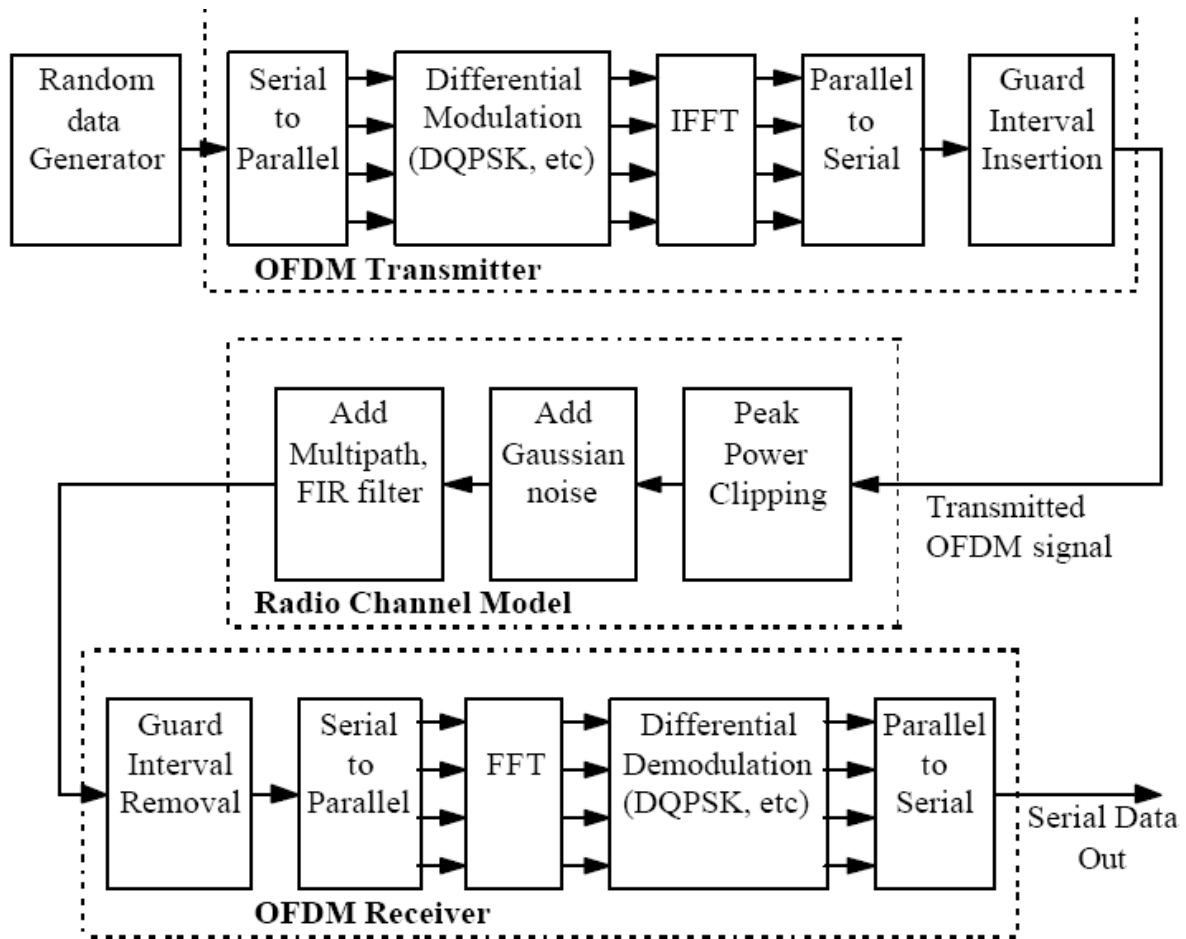
2.1   Fig. OFDM model used for simulation

3. OFDM

3.1 Serial to Parallel Conversion
The input serial data stream is formatted into the word size required for transmission, e.g. 2 bits/word for QPSK, and shifted into a parallel format. The data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

3.2 Modulation of Data
The data to be transmitted on each carrier is then differentially encoded with previous symbols, and then mapped into a PSK format. Since differential encoding requires an initial phase reference an extra symbol is added at the start for this purpose. The data on each symbol is then mapped to a phase angle based on the modulation method. For example, for QPSK the phase angles used are 0, 90, 180, and 270 degrees. The use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to fading.

3.3 Inverse Fourier Transform
After the required spectrum is worked out, an inverse Fourier transform is used to find the corresponding time waveform. The guard period is then added to the start of each symbol.

3.4 Guard Period
The guard period used was made up of two sections. Half of the guard period time is a zero amplitude transmission. The other half of the guard period is a cyclic extension of the symbol to be transmitted. This was to allow for symbol timing to be easily recovered by envelope detection. However it was found that it was not required in any of the simulations as the timing could be

accurately determined position of the samples. After the guard has been added, the symbols are then converted back to a serial time waveform. This is then the base band signal for the OFDM transmission.

3.5 Channel
A channel model is then applied to the transmitted signal. The model allows for the signal to noise ratio, multipath, and peak power clipping to be controlled. The signal to noise ratio is set by adding a known amount of white noise to the transmitted signal. Multipath delay spread is then added by simulating the delay spread using an FIR filter. The length of the FIR filter represents the maximum delay spread, while the coefficient amplitude represents the reflected signal magnitude.

3.6 Receiver
The receiver basically does the reverse operation to the transmitter. The guard period is removed. The FFT of each symbol is then performed to find the original transmitted spectrum. The phase angle of each transmission carrier is then evaluated and converted back to the data word by demodulating the received phase. The data words are then combined back to the same word size as the original data.

3.7 OFDM generation
To generate OFDM successfully, the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by first choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on DQPSK. The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform. In most applications, an Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently, and provides a simple way of ensuring the carrier signals produced are orthogonal.

3.8 Adding a Guard Period to OFDM
One of the most important properties of OFDM transmissions is its high level of robustness against multipath delay spread. This is a result of the long symbol period used, which minimizes the inter-symbol interference. The level of multipath robustness can be further increased by the addition of a guard period between transmitted symbols. The guard period allows time for multipath signals from the previous symbol to die away before the information from the current symbol is gathered. The most effective guard period to use is a cyclic extension of the symbol.

If a mirror in time, of the end of the symbol waveform is put at the start of the symbol as the guard period, this effectively extends the length of the symbol, while maintaining the orthogonality of the waveform. Using this cyclic extended symbol the samples required for performing the FFT (to decode the symbol), can be taken anywhere over the length of the symbol. This provides multipath immunity as well as symbol time synchronization tolerance.

4. Parameters of an actual OFDM System
Following are the parameters of Wi-Fi / IEEE 802.11a which is a system based on OFDM:

- Data Rates   :   6 Mbps to 48 Mbps
- Modulation   :   BPSK, QPSK, 16 QAM and 64 QAM
- Coding   :   Convolution concatenated with Reed Solomon
- FFT Size   :   64 with 52 sub-carriers uses, 48 for data and 4 pilots.
- Subcarrier frequency spacing :   20 MHz divided by 64 carriers or 0.3125 MHz
- FFT Period   :   Also called symbol period, 3.2 μs
- Guard Duration   :   One quarter of symbol time, 0.8 μs
- Symbol Time   :   4 μs

5. IMPLEMENTATION
Implementation refers to the process that bridges the gap between study and simulation. To simulate a system, one needs to obtain some model which can be transferred into the software being used. The model can either be a mathematical model or circuit description or algorithm or anything else which can define the system. The software that we decided to use was Simulink. This software provides a block-diagram approach to simulate systems. Our research/study had also yielded a variety of block diagrams for the OFDM transmitter and receiver. So, the task of implementation became quite easy. The only major task was to search out which blocks were available in the Simulink library that could be used by us. Also, if some blocks were not available, some other blocks with little modifications in their parameters could be used. One may also obtain some blocks by a combination of blocks available in the library. If in case, any of the above mentioned option is not possible, S-functions could be used to model the blocks required.

However, in our implementation process, we did not have to resort the use of S-functions as all the blocks we required were either available directly in the library or were derived from some other blocks available in the library.

Various blocks like QPSK modulators/demodulators, zero pads, AWGN channel, linear binary encoder/decoder, convolution coder/decoder, FFT, IFFT, random binary generator, etc. were available in the Simulink library. For the S/P and P/S blocks we used Buffers. For addition and removal of cyclic prefix, we used Selectors. In making the bock which would add pilots, we used Multiport selector, PN sequence generator and Matrix concatenation blocks. For providing multipath in the channel, we used delay elements and adders.
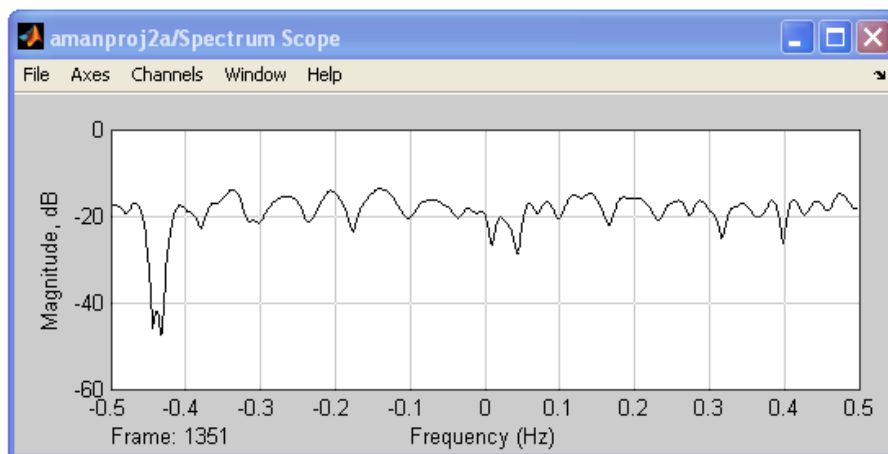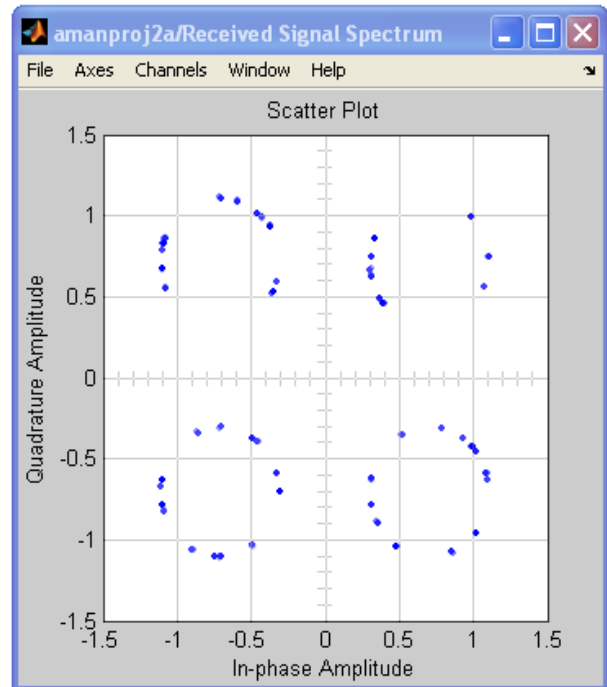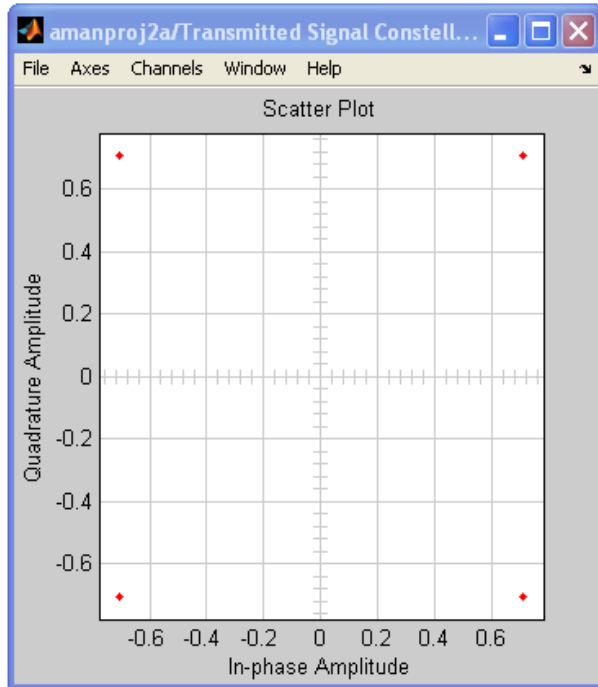
5. Simulation
Simulation of basic OFDM system was studied. In the study the following features have been taken care of

- Encoding (Linear and Convolution)
- Pilot carriers
- Multipath in the channel

For each simulation, observed the following things:

- BER between the transmitted and received signals
- Constellation diagrams for transmitted and received signals
- Frequency spectrum of the channel

5.1 Simulation Results for OFDM with pilots, multipath and codes (convolutional)

5.2 Simulation Results for OFDM with pilots, multipath and codes (linear)
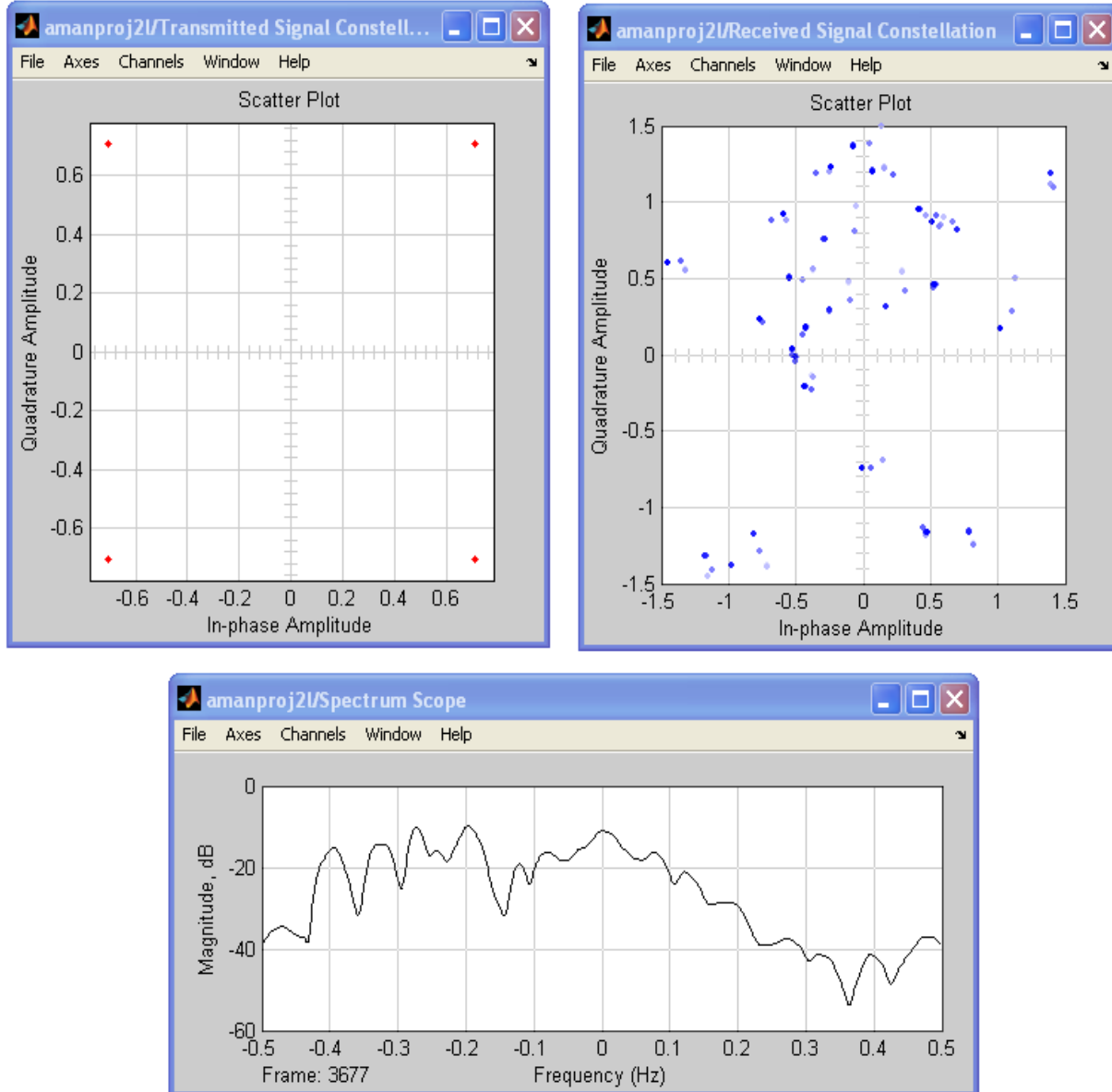
6. CONCLUSION

OFDM has already found wide deployment in various applications such as WLAN [3], vehicular communications [1] [2], etc. An OFDM link has been confirmed to work by using MATLABTM simulations, and some practical tests performed on a low bandwidth baseband signal. Four main performance criteria have been tested, which are OFDM's tolerance to multipath delay spread, channel noise, peak power clipping and start time error. Several other important factors affecting the performance of OFDM have only been partly measured. These include the effect of frequency stability errors on OFDM and impulse noise effects.

Most practical systems would use forward error correction to improve the system performance. Thus more work needs to be done on studying forward error correction schemes that would be suitable for telephony applications, and data transmission.
We can find many advantages in OFDM, but there are still many complex problems to solve.
This MATLABTM simulation proves that OFDM is better suited to a multipath channel than a single carrier

transmission technique such as 16-QAM

REFERENCES

[1] "Measurement Challenges for OFDM Systems", Agilent Technologies

[2] Denis Petrovic, Wolfgang Rave and Gerhard Fettweis, "Phase Noise Suppression in OFDM Using a Kalman Filter", Vodafone Chair for Mobile Communications, Dresden University of Technology, Germany

[3] http://digitalradiotech.co.uk/cofdm.htm [Digital Radio Tech]

[4] http://www.wi-fiplanet.com/tutorials/article.php/1500641

[5] http://www.ert.rwth-aachen.de/Projekte/Theo/OFDM/node1.html

[6] http://en.wikipedia.org/wiki/OFDM [Wikipedia]

[7] http://zone.ni.com/devzone/cda/tut/p/id/3740 [National Instruments]

[8] http://www.radio-electronics.com/info/cellulartelecomms/ofdm/ofdm.php

[9] Ove Edfors, Magnus Sandell, Jan Jaap Van de Beek, Daniel Landstorm and Frank Sjoberg, "An introduction to OFDM", 1996

[10] J.H.Scott, "Explaining some of the magic of COFDM", Proceedings of the 20th International Television Symposium, 1997

[11] "High Speed Wireless OFDM Communication Systems", Whitepaper, Wi-LAN Inc., 2001

[12] Tony Gomez, "OFDM for Mobile Data Communications", Web ProForum Tutorials, The International Engineering Consortium, 2001

[13] K. Panta and J. Armstrong, "Spectral Analysis of OFDM Signals and its Improvement by Polynomial Cancellation Coding", IEEE 2003

[14] Charan Langton, "Orthogonal Frequency Division Multiplexing", Intuitive guide to Principles of Communications, www.complextoreal.com, 2004

[15] Henrik Schulze and Christian Luders, "Theory and Applications of OFDM and CDMA", pp.145-264, 2005, John Wiley & Sons Ltd.

[16] Andreas F. Molisch, "Wireless Communcations", pp.399-424, 2005, John Wiley & Sons Ltd.

[17] L. Henzo and T. Keller, "OFDM and MC-CDMA: A Primer", pp.21-38, 2006, John Wiley & Sons Ltd.