Realization of OFDM Communication System

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Abstract: ***The process of successfully recovering data back after being transmitted is an important task in communication systems. OFDM proves to be a streamlined but complex alternative amidst all the option there are however it also proves to be reliable. In this system, the transmission of information is considered on multiple carriers that is contained within the allocated channel bandwidth. The key motivation for transmitting data is to reduce ISI and thus, eliminate the performance degradation which is incurred to implement the system. The signal undergoes various processes before it is transmitted and then the AWGN is added to corrupt the signal and fed to the receiver unit.***

Keywords: OFDM, AWGN, ISI

1. Introduction

Orthogonal Frequency Division Multiplexing, OFDM is a modulation format that is being used for many latest wireless and telecommunications standards.

OFDM divides high data rate modulating stream and hence places them onto many modulated narrowband subcarriers. It is a form of multicarrier modulation. In standard transmission techniques, the signals must be close to one another so that the receiver unit can separate them and for this it requires guard bands. By transmitting the same information over multiple-channels, it provides signal diversity, which is further exploited by the receiver to recover the information. In the multichannel communications, where the frequency band is subdivided into several sub-channels and information is transmitted on each of the sub-channels. Such channels introduce ISI in non-ideal linear filter channels, which degrades performance compared with the idea channel. Frequency response characteristics determines the degree of performance degradation. Also, the complexity of the receiver increases as we increase the span of ISI.

Although OFDM, is more complicated than other forms of signal format, it provides some unique advantages in terms of data transmission. In the applications where high data rates are needed along with relatively wide bandwidths OFDM is efficient.
In addition to being adopted in the Wi-Fi arena where the standards like 802.11a, 802.11n, 802.11ac and more, OFDM has also been chosen for the cellular telecommunications standard LTE / LTE-A. Further it has been accepted by other standards such as WiMAX and many more.

From [1], this work provides the validation and implementation of OFDM Transceiver on FPGA which is digital, and the whole work is done using VHDL language.

To meet the future needs, new functions should be added to the existing model and this can be implemented on FPGA. It is a better platform and can be easily fabricated to a chip. Thereby FPGA will be a good platform because it gives flexibility to the program design along with the low-cost hardware component comparing to others.

From [2], This project is concerned with OFDM performance when transmitted over an Additive White Gaussian Noise (AWGN) channel only. The OFDM signal was transmitted over this channel for various signal-to-noise ratio (SNR) values. To evaluate the performance, the received signal was demodulated and the received data was compared to the original information for each SNR level.

2. Proposed Method

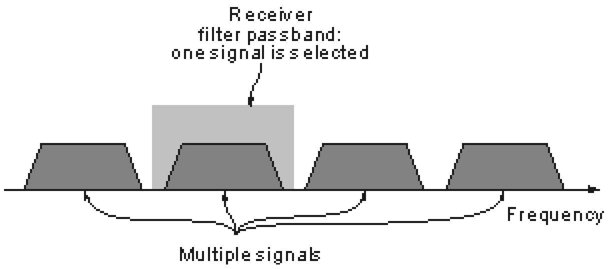
A. OFDM

In QPSK modulation, user requires a band-width of 2-7 kHz but FDMA isn't efficient to handle such band-width and hence TDMA, which uses wider band-width channels, in taken into consideration. Multiple users can handle same frequency at different time slots. Thereby, the spectrum can be used efficiently as many low data rate users can be combined to transmit in a single channel. However, there are some problems with this method as TDMA has a problem with the high symbol-rate, which causes multiple path delay spread.

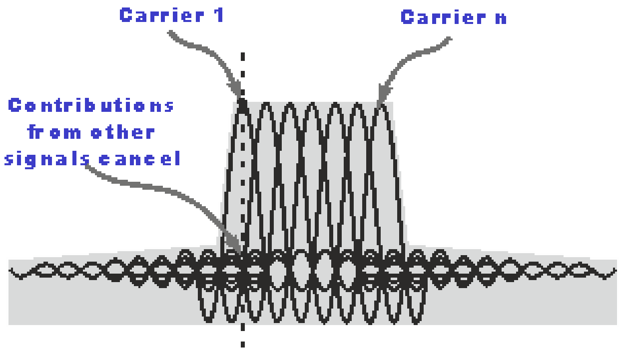
These problems are solved by using OFDM as in this method the sub-carriers are placed close to each other and there is no requirement of overheads. This is because each user has one channel and the channels are integer number multiples of the symbol-period resulting in the orthogonality among the carriers, which results in no inter-symbol interference between the carriers and spacing them as closely as possible [1]. Also, each carrier in an OFDM signal has a very narrow band-width (approx. 1 kHz), which has an advantage of high tolerance to multipath delay spread.

OFDM is a form of multicarrier modulation and an OFDM signal consists of many closely spaced modulated carriers.

When modulation of any form - voice, data, etc. is applied to a carrier, then sidebands spread out either side. It is necessary for a receiver to be able to receive the whole signal to be able to successfully demodulate the data. Thus, when signals are transmitted close to one another they must be spaced so that the receiver can separate them using a filter and there must be a guard band between them. However, in OFDM system, the sidebands from each carrier overlap, they can still be received without the interference that might be expected since they are orthogonal to each other. This is achieved by keeping the carrier spacing equal to the reciprocal of the symbol duration.



Traditional view of receiving signals carrying modulation



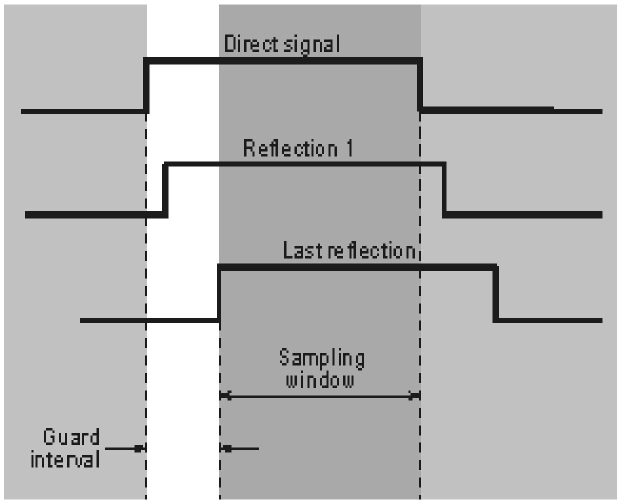
OFDM Spectrum

One requirement of the OFDM communication system is that it must be linear and any anomaly will cause interference between the carriers. This will introduce distortions that would affect the orthogonality of the transmission.

In terms of the equipment to be used, the high peak to average ratio of multi-carrier systems such as OFDM requires the RF final amplifier on the output of the transmitter to be able to handle the peaks whilst the average power is much lower, which leads to inefficiency. Although some distortions are introduced that result in a higher level of data errors, the system can rely on the error correction to remove them. [9]

B. Data in OFDM

In an OFDM signal, the data to be transmitted is spread across the carriers. As each carrier takes part in the payload, the data rate taken by each carrier is reduced. The advantage of these lower data rates is that the interference from reflections is less severe, which can be achieved by introducing a guard band time into the system. Therefore, the data is only sampled when the signal is stable and no new delayed signals arrive that would affect the signal's timing and phase.



Guard Interval

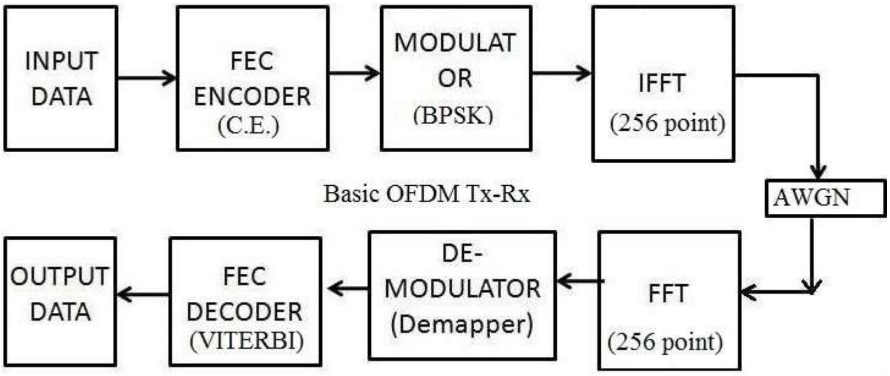
There are further advantages of the distribution of the data across multiple carriers. Only a few carriers are affected by the nulls caused by multi-path effects or interference on a given frequency while the remaining ones are received correctly. Almost all the data is reconstructed by using error-coding techniques.

3. Realisation of the block

- Processing like coding, interleaving and mapping is done on the source data.
- The symbols are modulated onto orthogonal sub-carriers by using IFFT.
- Orthogonality is maintained during channel transmission by adding a cyclic prefix to the OFDM frame which is to be sent. The cyclic prefix consists of the few last samples of the frame, which are copied and placed in the beginning of the frame. The start of each frame is detected by the introduced cyclic prefix. This is done by using the fact that the respective first and last samples are the same and therefore correlated.
- Demodulation of the received signal is done by using FFT.
- Decoding and de-interleaving is performed.

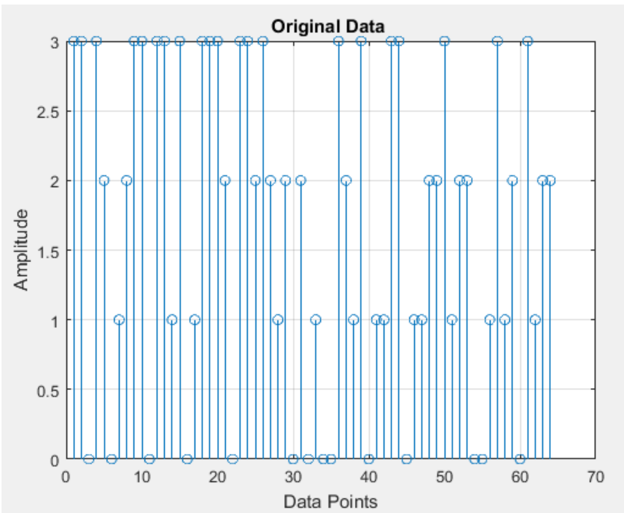
System Block Diagram

System Flow

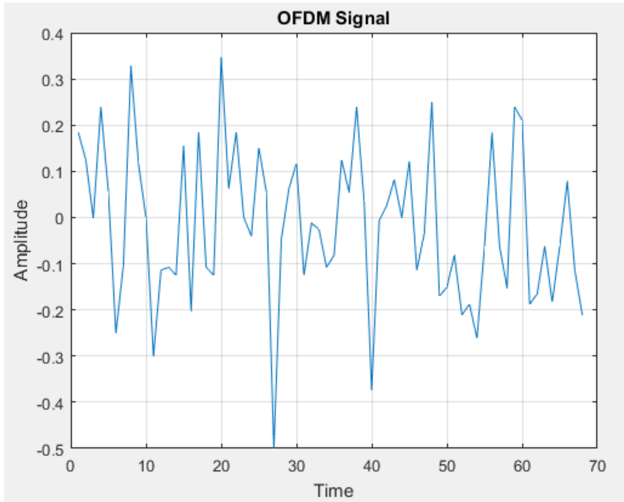


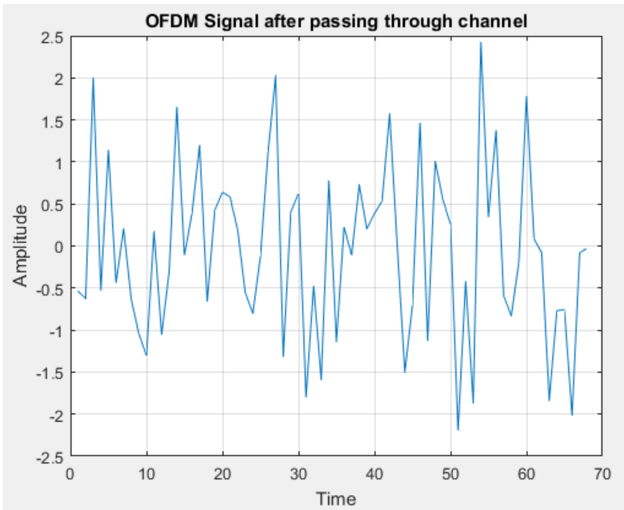
The raw input data is fed to the encoder and processing of the data occurs. This data is then sent for modulation after which Inverse Fourier Transform is done on it. The data is then ready for transmission which is achieved by adding the Additive White Gaussian Noise (AWGN). This compromises of the transmitter block and the data is received by the receiver block. FFT is performed on the received signal and it is sent for demodulation later. This data is then decoded and the original signal is obtained with minimal errors.

4. Results

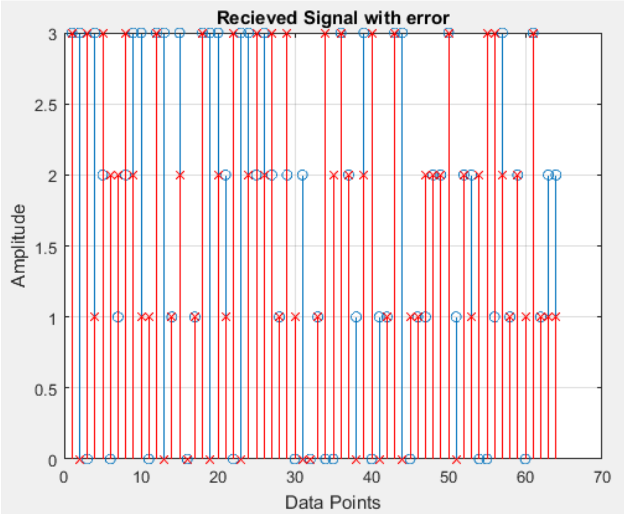


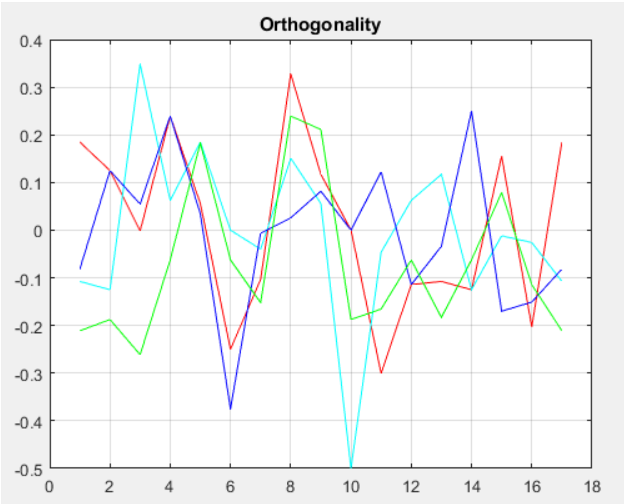
Serial data is fed at the input block and the output obtained is a 2-bit IQ (as shown in 1.) and Input signal is modulated and IFFT is performed to convert the signal into time domain (as shown in 2.)





FFT is performed after passing through AWGN channel (as shown in 3.) and 2 bit IQ from Symbol de-mapper and this generates output bits (as shown in 4.)





Orthogonality provides guard bands which protects from leakage interference. (as shown in 5.)

5. Future Scopes

Forward error correction method is applied to the signal before transmission to overcome the errors during the transmission of signal and this concept is called COFDM (Coded Orthogonal Frequency Division Multiplexing). These errors are introduced in the transmission due to lost carriers from frequency selective fading, noise and interference.

A. OFDM Variants

There are several other variants of OFDM which follow the basic format for OFDM, but have additional attributes:

- COFDM: Coded Orthogonal frequency division multiplexing is a form of OFDM where error correction coding is incorporated into the signal.
- OFDMA: Orthogonal frequency division multiple access is a scheme used to provide multiple access capability for various applications.
- VOFDM: Vector OFDM is a form of OFDM which uses the concept of Multiple Input Multiple Output (MIMO) technology. It uses multiple antennas to transmit and receive the signals so that multi-path effects can be utilized to enhance the signal reception.
- WOFDM: Wideband OFDM is a form of OFDM which uses a degree of spacing between the channels that is large enough so that any frequency errors between transmitter and receiver do not affect the performance.

The basic concept of using close spaced orthogonal carriers is utilized by each of these forms of OFDM. During the demodulation, the data is then combined to get the complete signal.

6. Conclusion

With respect to other multiplexing techniques, there are no guard bands and wastage of spectrum doesn't occur and thus the system becomes more efficient. The quality of the data is not compromised as there are no major distortions in the received signal and is very reliable. Although this technique requires complex calculations, the output efficiency in this method is more and with the help of code correction it is globally used. The input data is almost recovered back with minimal data losses and is used in TV transmission.

The simulation done in MATLAB worked well. However, there are more aspects of OFDM that need to be researched since this simulation was only a basic one. Further improvement can be done by addition of guard interval or coding the original information.

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