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Analysis and Simulation of OFDM system

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Abstract: ***Orthogonal Frequency Division Multiplexing (OFDM) is a special case of multi –carrier modulation which represents a powerful technology with a promising future in next generation wireless communication systems. OFDM signaling has been adopted for use in digital audio broadcasting (DAB) and terrestrial digital video broadcasting (DVB-T) systems, as well as in wireless local area network (W-LAN) standard, such as the IEEE 802.11 a, IEEE 802.11 g, and Hiperlan II. OFDM has also been proposed for packet data systems. The OFDM properties will be studied. The main contribution of this work is at the level of implementation using a Matlab simulation of the transmission and reception of a signal consisting of binary data, as well as mapping and demapping block data using 16 QAM OFDM systems.***

Keywords: OFDM, cyclic prefix, orthogonality, QAM

1. Introduction

In recent years the changing needs from the combined users, an increase in the supply of services for mobile operators, has led to a growing demand for services on mobile devices. This poses new challenges for scientific and industrial research to provide better products to meet this new demand. The most popular services are related to multimedia streaming and downloading [1]. Such applications require a high quality of service, which means a high data rate, reliable communication and efficient use of power. The signal transmitted from the base station to the users is subject to interference due to multipath propagation, which may deteriorate the service. In order to have a system of effective communication that can cope with the difficulties brought by wireless communications, recent communication standards designed to transmit packets over wireless channels using multi-carrier modulations Orthogonal Frequency Division Multiplexing (OFDM) to obtain reliable communication on the downlink.

Communications OFDM (Orthogonal Frequency Division Multiplexing) are a particular type of multi-carrier transmission whose originality is to multiplex information on orthogonal subcarriers. In the event that the bandwidths of these subcarriers are sufficiently close, the distortions caused by frequency selective channel are then limited to a simple attenuation on each [2]. This feature represents an advantage for this modulation face a single carrier transmission, because of the simplicity of the necessary equalization system in reception. Furthermore, the condition of orthogonality of the subcarriers allows their mutual overlap without interference of one over the other and therefore allows high spectral efficiency in the system. Finally, interference between sub-carriers, and interference between the induced channels is severely limited frames, the OFDM modulation is particularly preferred for high-rate transmissions in wireless mobile. OFDM thus has substantial advantages over single carrier systems [3]. Their robustness, efficiency and ease of equalization make a waveform particularly used today.

The rest of the paper is organized as follows. In Section 2, the literature review is presented. Section 3 presents the properties of OFDM. The model of the transmitter and the receiver are described in Section 4. In section 5 we present quadrature amplitude modulation. Simulation results are discussed in Section 6. Conclusions are given in Section 7.

2. Literature Review

OFDM has been proposed in the late 60s allows the user to obtain a better spectral efficiency due to the orthogonality of the carriers and overlapping frequency channels [1]. In 1971 much of the research has focused on developing a multi-carrier transmission of high efficiency, based on carrier "of orthogonal frequency applied the discrete Fourier transform of the parallel transmission systems data as part of the process of modulation and demodulation [3]. Studies were done by different researchers, but no system or final standard was developed. It was not until the 80s that we become aware of the value and applications of OFDM systems. Indeed, these systems bring an effective and practical solution for multipath channels with significant echoes.

3. Properties of OFDM

The OFDM technique is used to avoid having a very high flow rate on one carrier. This technique divides the high flow in several parallel channels of low flows, each fed by its own subcarrier. This means that the technique of OFDM signaling is to randomly distribute digital symbols of duration Tfft modulated on different carriers QAM. OFDM divides the channel into cells along the time axis and frequencies. The channel is constituted by a sequence of sub frequency bands and a sequence of time segments [1]. Each cell frequency / time is attributed a dedicated subcarrier. The information to be conveyed is spread over all the subcarriers modulated each low-flow. An OFDM symbol includes all information contained in the set of carriers at a given time. Each subcarrier is orthogonal to the previous frequency [4]. A same sequence of symbols coming from two different paths is as the same information arriving at two different times and are additive. These echoes cause intersymbol interference.

The fundamental difference between the various conventional modulation techniques multi-carrier and OFDM is that it allows a high spectral overlap between subcarriers, thereby substantially increasing their number or lessen the spectral congestion [5]. However, while the recovery does not have adverse effect, the carrier must comply with an orthogonality constraint, both in time and frequency domains.

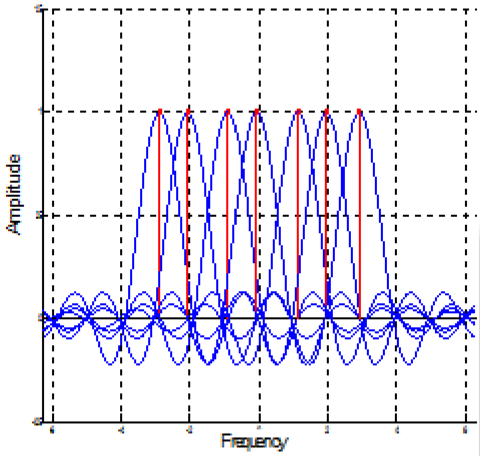

Figure 1: Spectrum of Seven carriers of OFDM Signal

The use of a large number of carriers is almost frightening prospect: it surely takes a lot of modulators and demodulators. It should also have more bandwidth. Fortunately, it is easy to solve these two problems by specifying a strictly regular spacing of Δf = 1/Ts between subcarriers, where Ts is the useful symbol period during which the receiver integrates the demodulated signal [6]. The carrier then forms what mathematicians call an orthogonal set.

4. OFDM transmission and reception

In a chain of transmission, we generate a binary series representing the voice, data, image or analog information resulting from an analog to digital conversion before introduction in the chain of transmission. The binary data is modulated in the following block of modulation in base band. The term commonly used is mapping [7]. The mapping is usually done with M-QAM (M-Quadrature Amplitude Modulation). At the output of the modulator base band information has a very specific constellation [8]. For a 16-QAM mapping, the even distribution of the different symbols can be seen quite easily, and the clarity of their position in the I (in phase) and Q (quadrature phase) as shown in figure 4. The next step is the distribution of the signal on different inputs. Each entry is applied thereafter by a fast Fourier transform [9]. When the final OFDM symbol is obtained, we add the guard interval as cyclic prefix. After the parallel / serial conversion is performed, the assembly is ready for transposition to the transmission frequency.

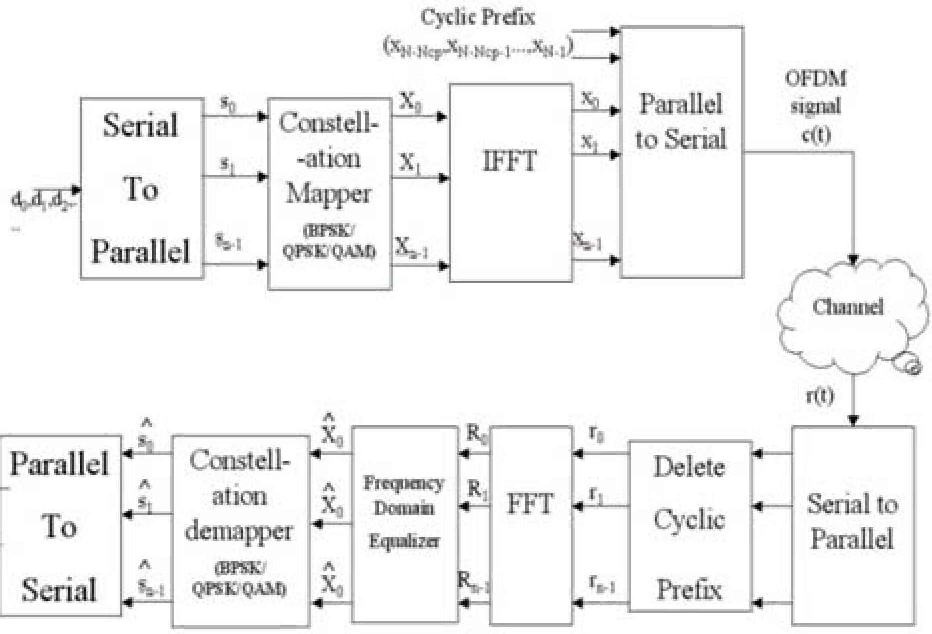

Figure 2: Block Diagram of a Basic OFDM Transceiver

In reception, the reverse process is performed. The received signal to be processed is returned to its starting frequency, it is distributed to go in several different inputs (serial / parallel conversion) for the cyclic prefix is removed. The Fourier transform is applied in order to reduce the signal in the frequency domain, the parallel to serial conversion is applied subsequently [10]. Process information is obtained again, suitable for demodulation in the wireless channel and the signal processing. The binary data is demodulated [11]. The term commonly used is demapping. This is the inverse of the operation performed in transmission. If this is the M-QAM transmission, it also takes M-QAM reception. Found after this step the original signal [12].

Following the same symbol arriving at a receiver via two different paths are present as the same information arriving at two different times, they will thus causing the addition of two types of defects:

- The intra symbol interference: Addition of a symbol with itself slightly out of phase.
- The inter symbol interference: adding a symbol with the following over the preceding slightly out of phase.

Between each transmitted symbol, inserting a guard interval called dead zone [7]. In addition, the useful symbol duration is selected to be sufficiently large compared to spreading echoes. These two precautions will reduce the inter-symbol interference.

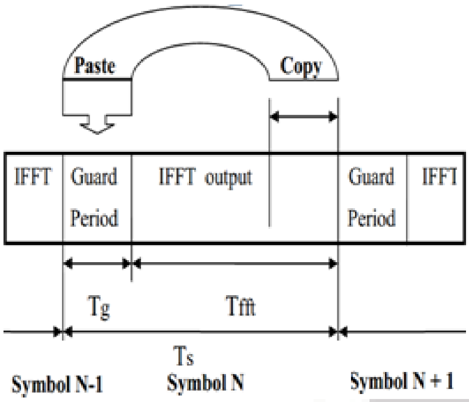

Figure 3: Guard period insertion in OFDM

The time for which the information is transmitted is different from the symbol period because it must be taken into account, between two periods useful, a" call time" which has to eliminate the ISI(intersymbol interference) that continues despite the orthogonality of the carriers [2]. In order to have an effective guard period, its duration should be at least equal to the longest (one that has the maximum delay) significant echo. Between the symbol period, the useful and the guard interval is therefore establish the relation:

$$Ts = Tg + Tfft$$

Figure 3 shows the addition of a guard interval. The symbol period is extended so as to be greater than the integration period Tfft. All cyclic carriers being within Tfft, it is the same for the entire modulated signal [13].

5. Quadrature Amplitude Modulation

Examine the quadrature modulation (QAM) of a digital information carrier by: For each symbol, the transmitted carrier is presented in a particular phase and amplitude, selected from the constellation used. A given symbol conveys a number of information bits equal to the logarithm base 2 of the number of different states in the constellation [4]. For example, a 16QAM modulation is $16 = 2^4$ different states with each symbol with 4 bits. Assume that this signal is received in two ways, with a suitable maximum [14]. In this type of modulation, the constellation is in a uniform distribution on a regular and centered grid as shown in Figure 4.

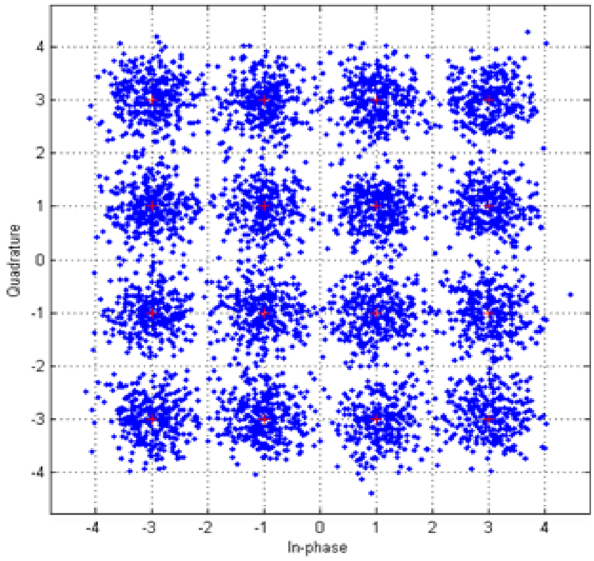

Figure 4: Constellation of the Received Signal -16 QAM

6. Simulation Results

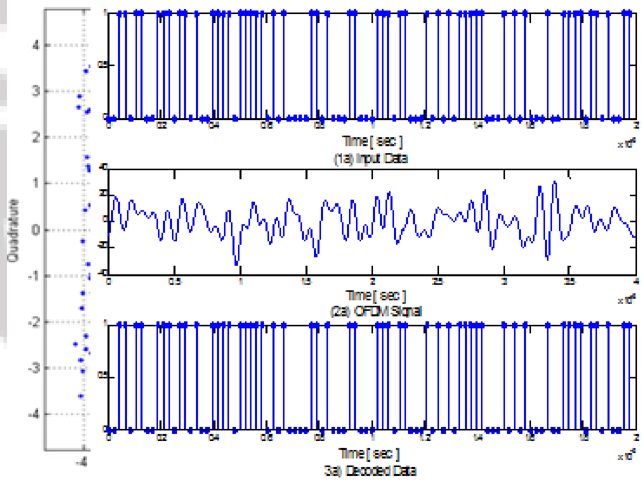

Figure 5: Input output binary data and OFDM signal

Simulation of many physical processes and engineering applications often require the help of a generator of random binary values. The MATLAB simulation accepts inputs of binary data. In this work, the random binary data generator generates random binary data; they are transferred in an OFDM link by using a modulation scheme on each subcarrier. A modulation scheme is a mapping of data to a real (IN phase) and imaginary (Quadrature) constellation, also known as an IQ constellation.

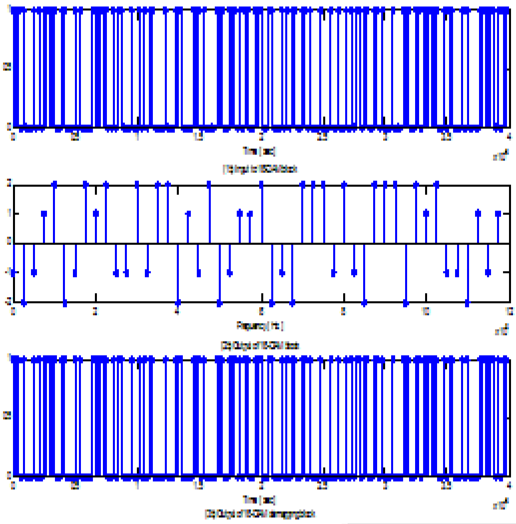

Figure 6: Input output 16-QAM block and output demapping block.

Figure 5 (1a) assume that we want to transmit the following binary data using OFDM: [0100010011……]. Plot (1a) shows this binary data. In practice, the OFDM signal is generated as follows: In Figure 6. (1b), the transmitter binary input data is encoded by a rate ½ convolutional encoder. After interleaving, the binary values are converted to 16-QAM values. The symbol is modulated onto 48 subcarriers by applying the Inverse Fast Fourier Transform (IFFT). In OFDM an IFFT is used to put the binary numbers onto many frequencies. Due to the math involved in an IFFT, these frequencies does not interfere with each other, this is called orthogonality.

The IFFT is now complete; it has generated an OFDM signal that corresponds to the binary data. This OFDM signal can be transmitted through a media and then received, this media could be wireless. Once the signal is received, the reverse process is done to recover the original binary data, the plot Figure 5. (2a) shows the OFDM signal. The constellation demapper takes packets of received constellation points as an input, and outputs data, Figure 6. (3b) shows the constellation demapper. Finally, an FFT is used to recover the binary data as shown in the plot Figure 5. (3a) .note that the FFT is the opposite of the IFFT used to generate the OFDM signal. As long as the channel does not distort the OFDM signal too much, the original binary data can be recovered.

Table1: Simulation parameter

Parameter name	*Parameter value*
Number of data	100
Coding rate	1/2
FFT size /IFFT size	1024
Subcarrier spacing	250 KHz
OFDM symbole duration	4 μs
Data mapping	16 QAM

7. Conclusion

In conclusion, in this work, the basic principle of multi-carrier orthogonal frequency modulation was explained. We have seen that the OFDM modulation technique provides the use of a group of subcarriers for transmission of data in parallel. We also saw that OFDM is useful in wireless high bit rate, since it is effective bandwidth and in addition to being simple to implement due to the fast Fourier transform. Several mechanisms are presented in an OFDM transmission. The guard interval reduces inter-symbol interference due to multipath.

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