REVIEW OF ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING FOR WIRELESS COMMUNICATION

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Abstract- *Orthogonal Frequency Division Multiplexing is a topic of prime importance in the new era of wireless communication field. In few years wireless communication has attracted increasing the attention from both industry and educational areas. The paper introduces the implementation of OFDM. This paper explains one of the multiplexing techniques that helps in efficient use of transmission bandwidth and that speeds up the data transfer, namely Orthogonal Frequency Division Multiplexing. This multiplexing technique overcomes the disadvantages of the traditional Frequency Division Multiplexing of using guard bands between two signals being transmitted to avoid mixing of signals. This article provides an overview of the BPSK modulation in OFDM technology and focuses on BER calculations.*

Keywords*: *Orthogonal Frequency-Division Multiplexing (OFDM), Binary phase shift keying(BPSK), Bit Error Rate.

1. INTRODUCTION

OFDM is a combination of modulation and multiplexing technique. In this technique, the given bandwidth is shared among individual modulated data resources. OFDM is especially suitable for high-speed communication due to its resistance to ISI[1]. As communication systems increase their information transfer speed, the time for each transmission necessarily becomes shorter. OFDM plays vital role in 4G communication leading to various applications in wireless communication. FFT and IFFT are the hearts of OFDM system. This overlapping of subcarriers in frequency domain improves its spectral efficiency than the conventional multicarrier communication scheme[6].OFDM is implemented by using different modulation techniques like BPSK, QPSK, M-ary QAM etc. This Orthogonally can be completely maintained with a minute increase in SNR, even though the signal passes through a time dispersive fading channel, by introducing a cyclic prefix. We need to take care that the length of the cyclic prefix is at least equal to the length of the multipath channel. The size of cyclic prefix is usually taken as one fourth the symbol size.

In this paper, both transmission and reception process of OFDM are analysed by using BPSK modulation. Bit error rate analysis is also carried out. The transmission takes place over Gaussian channel.

2. REVIEW WORK

Orthogonal frequency division multiplexing (OFDM) technology is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers.

Transmission of OFDM signal

Consider that we want to send the following data bits using OFDM: D = {$d_{1,} d_2 d_3$...). The first thing that should be considered in designing the OFDM transmitter is the number of subcarriers required to send the given data. As a generic case,N number of subcarriers are assumed. Each subcarrier is centered at frequencies that are orthogonal to each other (usually integer multiples of frequencies).The second design parameter could be the modulation format that is to be used. An OFDM signal can be constructed using anyone of the following digital modulation, techniques namely BPSK, QPSK, QAM etc. The data (D) has to be first converted from serial stream into parallel stream depending on the number of sub-carriers (N). Since we assumed that there are N subcarriers allowed for the OFDM transmission, the subcarriers are named from 0 to N-1. Now, the Serial to Parallel converter takes the serial stream of input bits and outputs N parallel streams (indexed from 0 to N-1). These parallel streams are individually converted into the required digital modulation format (BPSK, QPSK, QAM etc.)[1]. Once the data bits are converted to required modulation format, they need to be superimposed on the required orthogonal subcarriers for transmission:

This is achieved by a series of N parallel sinusoidal oscillators tuned to N orthogonal frequencies ($f_{0,} f_{1,} f_{N-1}$).

Finally, the resultant output from the N parallel arms are summed up together to produce the OFDM signal. The following figure illustrates the basic concept of OFDM transmission.

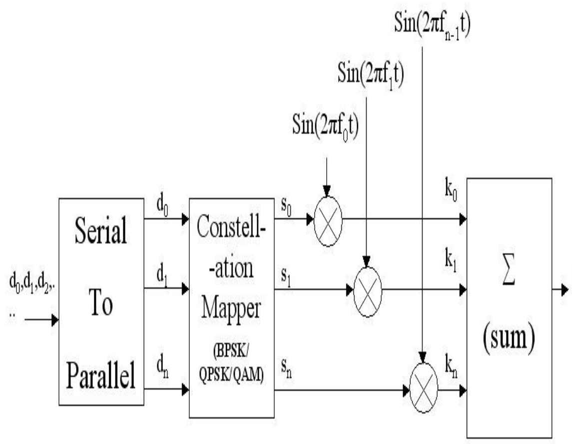


FIG-1: OFDM transmitter

OFDM transmission using BPSK modulation technique
Suppose the data that is to be transmitted be
1,0,1,0,1,1,1,1,0,1,0,0,0,1,0,1,0,0,1,1

Step 1: Initially serial to parallel converter

Time	D0	D1	D2	D3	D4
T1	1	0	1	0	1
T2	1	1	1	0	1
T3	0	0	0	1	0
T4	1	0	0	1	1

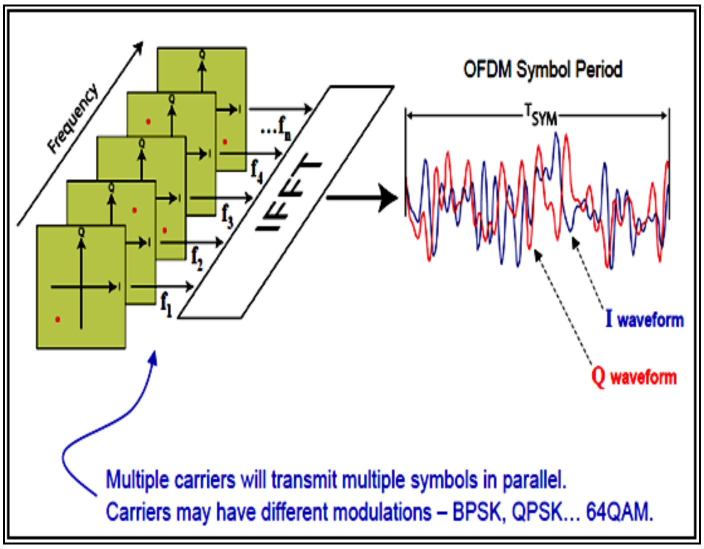
Step2: BPSK mapping

Time	S0	S1	S2	S3	S4
T1	1	-1	1	-1	1
T2	1	1	1	-1	1
T3	-1	-1	-1	1	-1
T4	1	-1	-1	1	1

Step3: Multiplying by orthogonal carrier signal, we get OFDM transmitter signal

Time	K0	K1	K2	K3	K4
T1+ Δ	1*sin2π $f_0 t$	- 1*sin2 $\pi f_1 t$	1*sin2 $\pi f_2 t$	- 1*sin2 $\pi f_3 t$	1*sin2π $f_4 t$
T2+ Δ	1* sin2$\pi f_0 t$	1* sin2$\pi f_1 t$	1* sin2$\pi f_2 t$	-1* sin2$\pi f_3 t$	1* sin2$\pi f_4 t$
T3+ Δ	-1* sin2$\pi f_0 t$	-1* sin2$\pi f_1 t$	-1* sin2$\pi f_2 t$	1* sin2$\pi f_3 t$	-1* sin2$\pi f_4 t$
T4+ Δ	1* sin2$\pi f_0 t$	-1* sin2$\pi f_1 t$	-1* sin2$\pi f_2 t$	1* sin2$\pi f_3 t$	1* sin2$\pi f_4 t$

This multiplication provides OFDM signal.



Generally, an OFDM signal can be represented as

$$C(t) = \sum_{n=0}^{N-1} s_n(t).\sin(2\pi f_n t) \text{.......(i)}$$

This equation can be thought of as an IFFT process The Fourier transform breaks a signal into different frequency bits by multiplying the signal with a series of sinusoids. This essentially translates the signal from time domain to frequency domain. But, IFFT is viewed as a conversion process from frequency domain to time domain. The equation for FFT and IFFT differ by the coefficients they take and the minus sign. Both these operations multiply the incoming signal with a series of sinusoids and separates them into bits. In fact, FFT and IFFT are dual and behave in a similar way.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 frequency components satisfying orthogonality conditions. Then, the parallel to serial converter block creates the OFDM signal by sequentially outputting the time domain samples. The channel simulation allows examination of common wireless channel characteristics such as noise, multipath, and clipping. By adding random noise effect to the transmitted signal, simple noise is 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.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 the frequency domain.

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2. OFDM System

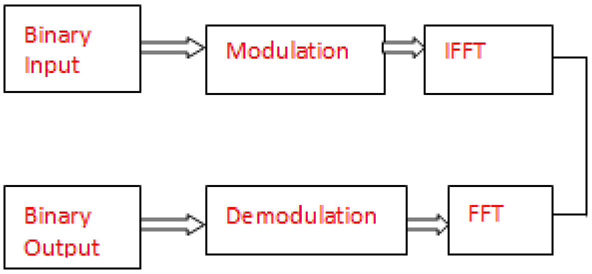

FIG-2: OFDM System

In the typical OFDM system, the serial binary data is encoded into parallel form which reduces bit rate per carrier. This parallel data is mapped by using any suitable modulation technique. As a result, the amplitude of such a signal can have very large values. This large amplitude variation is a big disadvantage of OFDM, which tends to reduce the efficiency of power amplifier[2],since the amplifier is typically rather non-linear for high input amplitudes.In this system, N overlaps orthogonal sub-carriers, each carrying a baud rate of 1/T and spaced 1/ T apart is used, orthogonality of sub-carrier requires that each sub carrier have exactly same integer number of cycles in the interval T. The IFFT block is provided for maintaining orthogonality among the sub carriers which is decoded properly with a FFT block on the receiver side. The above figure shows the block diagram of OFDM system. In the channel, time spread interference is caused between the adjacent OFDM symbols.To mitigate this interference and to preserve the orthogonality between the subcarriers, a CP or guard interval is provided. The length of this CP is kept greater than or equal to the channel length, which introduces redundancy. As a result, inter symbol interference (ISI) is completely eliminated. The resultant symbol is then applied to a power amplifier and subsequently sent over the channel. The binary data input is encoded and converted to parallel data by serial to parallel (S/P) converter. This data is further modulated. The IFFT block receives this data. The IFFT transforms this data into time domain signal maintaining the orthogonality of the OFDM signal. Before adding the CP, data needs to be converted into serial data. Hence the data is converted into serial form then CP is added and the data is transmitted through channel.This data is received at the receiver and the CP or guard interval is removed from the OFDM symbol. Then the data is converted from serial to parallel. This parallel data is transformed by the FFT block and the time domain signal gets converted into frequency domain signal. The signal is further demodulated and decoded. Thus, the received symbol is equalized and detected to retrieve the original transmitted symbol.The use of FFT avoids the complexity in the circuit. It reduces the number of modulators and filters to be used at the transmitter as well as complementary filters and demodulators at the receiver[5].

A spectral spreading and in-band distortion occurs which impairs OFDM signal on passing through a nonlinear device like transmit power amplifier. OFDM is currently used in the wireless system to a large extent and hence it is significant to resolve this problem, which has become an important area of research.

OFDM design parameters for wireless application

Modulation Type	BPSK/QPSK/16QAM
FFT size	64 with 52 subcarriers
FFT period	3.2µs
Data period	6 to 48 Mbps
SubCarriers freq spacing	0.312µs
Symbol time	4 µs

The random binary generator block generates random binary numbers that are applied to BPSK modulator. This modulates using the binary phase shift keying method. The output is a baseband representation of the modulated signal. The input must be a discrete-time binary-valued signal. If the input bit is 0 or 1, then the modulated symbol is exp(θ) or -exp(θ) respectively, where θ is the phase offset parameter. Above figure shows the frequency domain signal is then applied to IFFT block .The IFFT block computes the Inverse Fast Fourier Transform (IFFT) of length-M input, where M must be a power of two. The output is always frame-based, and each output frame contains the M-point Inverse Discrete Fourier Transform (IDFT) of the corresponding input.

Thus IFFT transfers from frequency domain into time domain signal and at the same time maintains the orthogonality among the carriers. The AWGN channel block adds white Gaussian noise to a real or complex input signal. When the input signal is real, then it adds real Gaussian noise and g a real output generates signal. When the input signal is complex, this block adds complex Gaussian noise and produces a complex output signal.

3. Bit Error Rate for BPSK modulation

In digital communication,BER reveals the system behavior and evaluates the systemperformance[3]. Bit error is the number of bits that are altered by factors such as unwanted signal, interference and bit synchronization errors. BER is the ratio of bit errors to the total number of bits of an information signal i.e.

BER = No of bit in errors/ Total no of bits transmitted

It is unitless performance measure, often express as a percentage. BER can beimproved by using appropriate modulation scheme and coding technique[4].

$$P_b = \frac{1}{2}\left(\frac{\frac{Eb}{N0}}{\frac{Eb}{N0}+1}\right)$$

For OFDM, using BPSK Modulation having parameter like

No. of bits transmitted = 12000
No. of carriers used = 6
Bits per each carrier = 2000

SNR	BER(using the above expression)
0	0.0757
1	0.0564
2	0.0388
3	0.0215
4	0.0118

4. CONCLUSION

The paper presents review of OFDM scheme over Gaussian channel. The paper also discusses the basic steps towards the generation of OFDM signal and also the BER-SNR relationship.

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