BER Comparison of DCT-based OFDM and FFT-based OFDM using BPSK Modulation over AWGN and Multipath Rayleigh Fading Channel

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ABSTRACT

In this paper, the Bit Error Rate (BER) performance of Fast Fourier Transform-based Orthogonal Frequency Division Multiplexing system (FFT-Based OFDM) is compared with Discrete Cosine Transform-based Orthogonal Frequency Division Multiplexing system (DCT-Based OFDM) using Binary Phase Shift Keying (BPSK) as a modulation technique over Additive White Gaussian Noise environment (AWGN) and Multipath Rayleigh Fading environment. From the results it is clear that, the BER shift in case of DCT-Based OFDM is less as compared to FFT-Based OFDM. In addition to this we have also compare the BER performance of FFT-Based & DCT-Based OFDM over Additive White Gaussian Noise environment and Multipath Rayleigh Fading environment and it is observed that Bit Error Rate performance of FFT-Based & DCT-Based OFDM over AWGN is better than Multipath Rayleigh Fading environment.

Keywords

BER, FFT, DCT, AWGN, Multipath Rayleigh Fading, OFDM, SNR, BPSK.

1. INTRODUCTION

Multicarrier communication based on Orthogonal Frequency Division Multiplexing (OFDM) principles are increasingly being deployed in broadband wireless communication standards such IEEE 802.11 (Wi-Fi) and IEEE 802.16 (WiMax). In an OFDM scheme a large number of sub channels or sub-carriers are used to transmit digital data. Each sub-channel is orthogonal to every other. They are closely spaced and narrow band. The separation of the sub-channels is as minimal as possible to obtain high spectral efficiency. OFDM is being used because of its capability to handle with multipath interference at the receiver [4]. Because of the orthogonality between each sub channel it is eliminating the need for expensive and complicated time domain equalizers as it is required in conventional single carrier system to overcome the problem of ISI [5].

As the signal strength (SNR) increases in comparison to noise inside the channel the bit error rate (BER) decreases and reaches to zero at some specified value of SNR ideally [6]. Using MATLAB simulation we can implement an OFDM transmission. Using the simulation we can easily change the values of S/N ratio [4], then we can analyze the results of each transmission and see how the BER [1], [2], [4] is changed. In this paper, we have compared the BER performance of DCT-OFDM and FFT-OFDM by considering BPSK modulation techniques over an AWGN channel and Multipath Rayleigh Fading channel. In addition to this we have also considered processing time required for complete simulation and compare the processing time required for FFT-based OFDM and DCT-based OFDM.

2. OFDM SYSTEM- Simulation Flowchart

In this paper, OFDM system is implemented using MATLAB simulation, where each block of OFDM is simulated in scripts file. Figure 1 shows the block diagram of the OFDM. DCT-OFDM is obtained by replacing IFFT at transmitter and FFT at receiver by IDCT and DCT respectively. We have considered AWGN and Multipath Rayleigh Fading Channels for comparing BER of FFT-based OFDM and DCT-based OFDM. For different modulation techniques we have changed the constellation index (M) in the modulation block, modulation block is simulated using modem.psk (M). In addition to this we have simulated simulation time clock for measuring processing time required in each case. The following OFDM system parameters are considered for the simulation:

Data mapping	: PSK
IFFT and FFT Size	: 64-point
IDCT and DCT Size	: 64-point
Channel Used	: AWGN & Multipath Rayleigh Fading
No. Of data sub carrier	: 52
Data symbol duration (Td)	: 64
Cyclic prefix duration (Tcp)	: 16

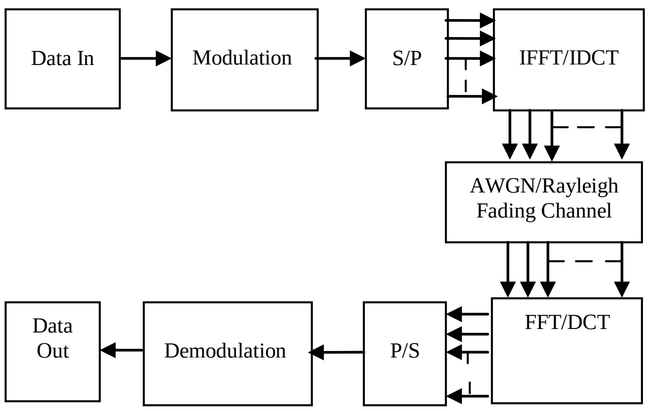


Fig. 1 OFDM System flowchart

3. OFDM SYSTEM- TRANSFORM TECHNIQUES

3.1 FFT-Based OFDM

In OFDM systems, digital modulation and demodulations can be realized with the inverse FFT (IFFT) and FFT, respectively [2], [10]. OFDM employs Ns separate subcarrier to transmit data instead of one main carrier. Input data is grouped in to a block of N bits, where N = Ns × Mn and Mn is the number of bits used to represent a symbol for each subcarrier. In order to maintain orthogonality between the subcarriers, they are required to be spaced apart by an integer multiple of the subcarrier symbol rate Rs. The subcarrier symbol rate is related to overall coded bit rate Rc of the entire system by Rs = Rc/N. The output signal of an OFDM can be written as:

$$X(t) = \sum_{n=0}^{N_s-1} C_k e^{2\pi j\left(n-\frac{N_s}{2}\right)\frac{t}{T_s}}$$

Where Ck are the complex representations of the subcarrier symbols and Ts is the symbol period.

3.2 DCT-Based OFDM

The complex exponential function set is not the only orthogonal basis that can be used to construct baseband multicarrier signals. A single set of co sinusoidal functions can be used as an orthogonal basis to implement the Multi-Carrier Modulation (MCM) scheme, and this scheme can be synthesized using a discrete cosine transform (DCT) [2]. Hence, we will denote the scheme as DCT-OFDM. The output signal of a DCT based OFDM system can be written

$$X(t) = \left[\left(\frac{2}{N_s}\right)^{\frac{1}{2}}\right] \sum_{n=0}^{N_s-1} d_n \beta_n \cos(n\pi t/T_s)$$

Where d0, d1….dN-1 are Ns independent data symbols obtained from a modulation constellation, and

$$\beta_n = \begin{cases} \frac{1}{\sqrt{2}}, & n = 0 \\ 1, & n = 1, 2, \ldots, N_s - 1 \end{cases}$$

4. OFDM SYSTEM- MODULATIONS

4.1 M-array Phase Shift Keying (M-PSK)

In general, M-PSK waveform is represented by

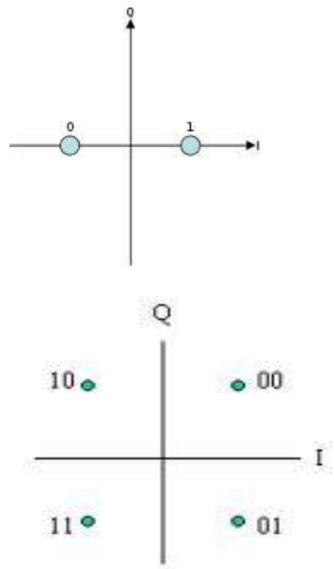
$$s(t) = f(t)\cos\left[\omega_c t + \frac{2\pi}{M}(m-1)\right] \qquad 0 \le t \le T_s$$

Where m = 1,2,…..,M denotes the M possible phase of the carrier $f_c = {}^{\omega_c}/_{2\pi}$ corresponding to M possible data symbols represented by $M = 2^n$ or $n = \log_2(M)$and f(t) is a real valued pulse waveform (normally rectangular). All the M different waveforms have the same energy. In this paper I, have used M=2.

$E_s = \frac{1}{2} E_{f(t)}$ Where $E_{f(t)}$ denotes the energy of basic pulse.

This signal is set is two dimensional. So, PSK waveforms be represented by a linear combination of two basis functions ψ1 (t) and ψ2 (t) [8].

In general, M-PSK schemes are more spectrally efficient. As we go on increasing the number M, the consumption of the spectrum reduces. M is related to the power of 2 values: 8, 16, 32, 64, and so on [9]. In 8-PSK 3 bits/symbol are read together to be mapped into phases. As there are 8 combinations of 3 bits, eight points will be created on the constellation and so on. The constellation diagram of M-PSK is shown in figure2.



(a)

(b) (b)

Figure 2 Constellation diagrams of (a) BPSK (b) QPSK

5. OFDM SYSTEM- COMMUNICATION CHANNEL

5.1 Additive White Gaussian Noise (AWGN) Channel

In reality, transmission is always corrupted by noise whatever may be the type of channel assumed. The simplest mathematical model of the radio channel is the additive white Gaussian noise (AWGN) channel. It is very good model for the physical reality as long as thermal noise at the receiver is the only source of disturbance. Nevertheless, because of its simplicity, it is often used to model human-made noise or multi-user interference. In the study of communication systems, the classical (ideal) additive white Gaussian noise (AWGN) channel, with statistically independent Gaussian noise samples corrupting data samples free of Intersymbol interference (ISI), is the usual starting point for understanding basic performance relationships. An AWGN channel adds white Gaussian noise to the signal that passes through it. The AWGN channel model can be characterized as follows.

1. The noise is additive: In constructing a mathematical model for the signal at the input of the receiver, the channel is assumed to corrupt the signal by the addition of white Gaussian noise, therefore the transmitted signal, white Gaussian noise and received signal are expressed by the following equation with s(t), n(t) and r(t) representing those signals respectively:
$$r(t) = s(t) + n(t)$$
The symbol r(t) represent the received signal and it is equal to the sum of transmitted signal through AWGN channel s(t) and white noise added with the signal n(t).
2. The noise is white: The power spectral density is flat or constant power spectral density. So, the autocorrelation of the noise in time domain is zero for any non-zero time offset. The one sided PSD is usually denoted by No. Thus, No/2 is the two sided PSD and WNo is the noise inside the noise bandwidth W. Where n(t) is a sample function of the AWGN process with probability density function (pdf) and power spectral density as follows:
$$\varphi_{nm}(f) = \frac{1}{2}N_0\left[\frac{W}{Hz}\right]$$
Where N0 is a constant and called the noise power density.
3. The noise sample have a Gaussian distribution: The Gaussian probability density function with variance σ^2 is given by
$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}}e^{\frac{-(x-m)^2}{2\sigma^2}}$$

5.2 Multipath Rayleigh Fading Channel

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal such as that used by wireless devices. It assumes that the power of a signal that has passed through such a transmission medium (also called a communications channels will vary randomly or fade according to a Rayleigh distribution – the radial component of the sum of two uncorrelated Gaussian random variables. It is reasonable model for troposphere and Ionospheric signal propagation as well as the effect of heavily built up urban environment on radio signals. Rayleigh fading is most applicable when there is no line of sight between the transmitter and receiver [7].

6. SIMULATION RESULTS

From simulation results refer to TABLE I it is observed that:

1. When BPSK is considered as a modulation technique, the BER of DCT-based OFDM and FFT-based OFDM reaches to zero at 10dB of SNR (EbNo) while at lower value of SNR it is observed that the BER in case of DCT-Based OFDM is less as compared to FFT-Based OFDM at same value of SNR.
2. From figure 5, it is observed that BER performance of FFT/DCT-based OFDM in an AWGN environment is better as compared to Multipath Rayleigh Fading channel.
3. we also calculated the processing time required in completion of entire simulation and from TABLE II it is observed that FFT-based OFDM is comparatively require less processing time as compared to DCT based OFDM system.
4. From TABLE II it is observed that, Using AWGN as a communication channel in FFT/DCT-based OFDM takes less processing time as compared to Multipath Rayleigh Fading channel.

TABLE I
BER Comparison

Modulation	Channel	EbNo (dB)	Bit Error Rate (BER) Comparison (dB)		
			Theory	FFT-OFDM	DCT-OFDM
BPS-K	AWGN	0	0.0786	0.0803	0.0802
		5	0.0060	0.0064	0.0063
		10	0.0000	0.0000	0.0000
		15	0.0000	0.0000	0.0000
		20	0.0000	0.0000	0.0000
		25	0.0000	0.0000	0.0000
		30	0.0000	0.0000	0.0000
		35	0.0000	0.0000	0.0000
		40	0.0000	0.0000	0.0000
	Rayleigh Fading	0	0.1464	0.1490	0.1494
		5	0.0642	0.0666	0.0667
		10	0.0233	0.0253	0.0245
		15	0.0077	0.0094	0.0086
		20	0.0025	0.0035	0.0031
		25	0.0008	0.0013	0.0010
		30	0.0002	0.0004	0.0004
		35	0.0001	0.0002	0.0001
		40	0.0000	0.0001	0.0000

TABLE III
Processing time Comparison

Modulation used	Channel	Processing time comparison (Seconds)	
		DCT-OFDM	FFT-OFDM
BPSK	AWGN	7.980013	3.905692
	Multipath Rayleigh Fading	8.636559	6.989547

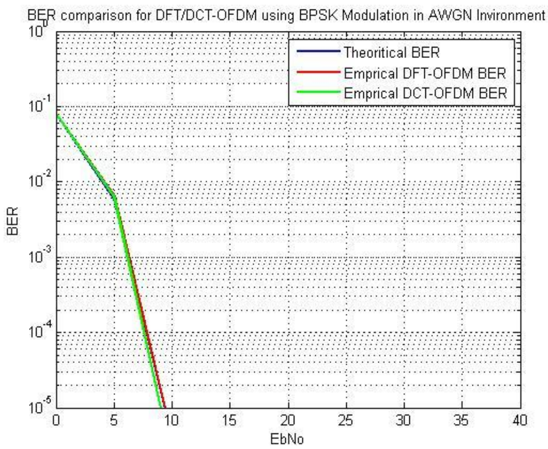


Fig. 3 BER performance of DCT-OFDM and FFT- OFDM using BPSK modulation in presence of AWGN channel

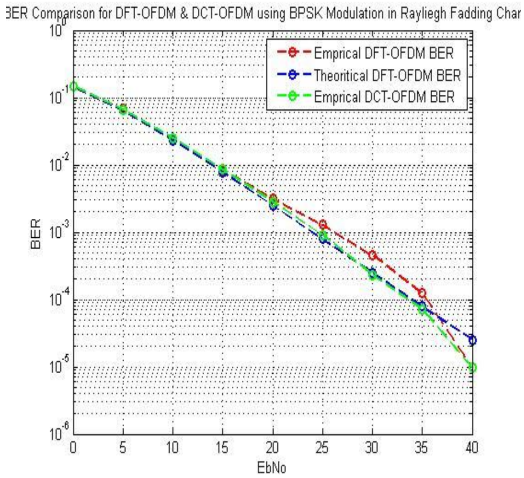


Fig. 4 BER performance of DCT-OFDM and FFT-OFDM using BPSK modulation in presence of Rayleigh Fading Channel

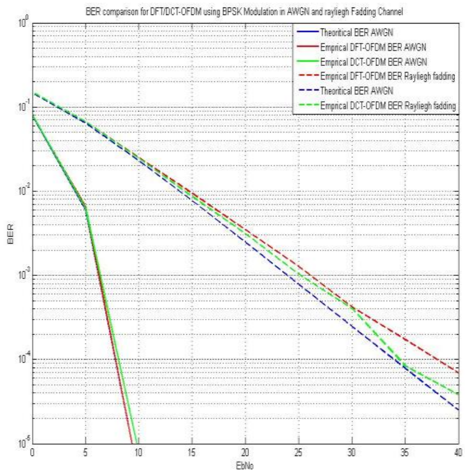


Fig. 5 BER performance comparison of DCT-OFDM and FFT-OFDM using BPSK modulation in presence of AWGN channel and Rayleigh Fading Channel

7. CONCLUSIONS

In this paper, the bit error rate (BER) performance of FFT/DCT-based OFDM is compared using BPSK as a modulation technique over AWGN and Multipath Rayleigh Fading channel. From the simulation results following conclusion can be drawn:

1. DCT-Based OFDM performance is better than FFT-Based OFDM system with BPSK as modulation techniques on AWGN channel and Multipath Rayleigh Fading channel by considering BER as a parameter of comparison.
2. From the simulation results it can be concluded that considering AWGN channel yields better BER performance as compared to Multipath Rayleigh Fading channel.
3. When processing time is considered the, FFT-Based OFDM is faster as compared to DCT-Based OFDM on individual channel.
4. When channel is considered, total processing time taken in case of Multipath Rayleigh Fading channel is comparatively more as taken by AWGN channel.

8. FUTURE STUDY

Proceeding further, our aim is to compare BER of FFT-based OFDM, DCT-based OFDM and DWT-based OFDM with different modulation techniques over different communication channels such as AWGN, Multipath Rayleigh fading channel, Multipath Rician fading channel etc.

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