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Performance Comparison of FFT, DHT and DCT Based OFDM Systems with BPSK as A Modulation Technique

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Abstract: **Today, OFDM has grown to be the most popular communication system in high-speed communications. OFDM is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments. Different type of transform techniques such as Discrete Hartley transform (DHT), Discrete Cosine Transform (DCT), Fast Fourier Transform (FFT) are used to perform the modulation and demodulation operations for the OFDM system. In this paper these three transforms are used in OFDM and study the comparison between these different transforms techniques used in OFDM system based on Bit Error Rate (BER) performances.**

Keywords: **Bit Error Rate (BER), BPSK, DCT, DHT, FFT, Orthogonal Frequency Division Multiplexing (OFDM).**

I. INTRODUCTION

Recently, a worldwide convergence has occurred for the use of Orthogonal Frequency Division Multiplexing (OFDM) as an emerging technology for high data rates. In particular, many wireless standards (Wi-Max, IEEE802.11a) have adopted the OFDM technology as a mean to increase dramatically future wireless communications. OFDM is a particular form of Multi-carrier transmission and is suited for frequency selective channels and high data rates. This technique transforms a frequency-selective wide-band channel into a group of non-selective narrow band channels, which makes it robust against large delay spreads by preserving orthogonality in the frequency domain.

The different transforms used in this paper have their own applications, pons and cons in digital signal processing. These transforms have a wide importance in the orthogonal frequency division multiplexing. These transforms are adopted in OFDM because of their multiplexing and demultiplexing in less computational time. A Fast Fourier Transform (FFT) is an efficient algorithm to compute the discrete Fourier transform (DFT) and it's inverse. The Discrete Fourier Transform (DFT) is used to produce frequency analysis of discrete non-periodic signals. The FFT is a faster version of the Discrete Fourier Transform (DFT). The FFT utilizes some clever algorithms to do the same thing as the DTF, but in much less time. The Discrete Hartley Transform (DHT) is closely related to the Discrete Fourier Transform, but unlike the DFT, the DHT has the advantage of producing real numbers and it is (quasi-)symmetrical. The discrete Hartley transform (DHT) produces real output for a real input, and is its own inverse. It therefore can have computational advantages over the discrete Fourier transform.

II. PAPER PREPARATION GUIDELINES \ OFDM IMPLEMENTATION USING FFT

In the OFDM system implementation Fast Fourier Transform (FFT) and its inverse (IFFT) is used to perform the modulation and demodulation operations. BPSK is used as digital modulation technique. The Fourier transform allows us to relate events in time domain to events in frequency domain. OFDM system Uses discrete Fourier transform (DFT) to

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modulate and demodulate parallel data. The fast Fourier transform (FFT) is merely a rapid mathematical method for computer applications of DFT. In most applications, an Inverse Fast Fourier Transform (IFFT) is used. Both transmitter and receiver can be implemented using efficient FFT techniques that reduce the number of operations from N^2 in DFT, down to NlogN.

It is the availability of this technique, and the technology that allows it to be implemented on integrated circuits at a reasonable price, that has permitted OFDM to be developed as far as it has. The orthogonality of subchannels in OFDM can be maintained and individual subchannels can be completely separated by the FFT at the receiver when there are no intersymbol interference (ISI) and intercarrier interference (ICI) introduced by transmission channel distortion.

IFFT quickly computes the time-domain signal instead of having to do it one carrier at time and then adding. The IFFT performs the transformation very efficiently, and provides simple ways of ensuring the carrier signals precede are orthogonal. The reverse process guarantees that the carriers generated are orthogonal. FFT based OFDM is computationally efficient due to the use of FFT techniques to implement modulation and demodulation functions.

Simulation Results:

Simulation results are noted in Table 1. Fig.1 shows the nature of the BER versus SNR curve. As we go on increasing the SNR value, bit error rate reduces.

Modulation used =BPSK

No. of bits transmitted = 12000

No. of carriers used = 6

Bits per each carrier = 2000

Spacing between the each carrier = 6 KHz

Carrier frequencies are 6 KHz, 12 KHz, 18 KHz, 24 KHz, 30 KHz, and 36 KHz

TABLE 1: BER results for FFT based OFDM

SNR(dB)	BER(using FFT)
0	0.09042
1	0.07660
2	0.06800
3	0.05730
4	0.05042
5	0.04420
6	0.03683
7	0.03090
8	0.02375
9	0.02040
10	0.01308
11	0.01190
12	$6.75x\ 10^{-3}$
13	$5.20x\ 10^{-3}$
14	$2.92x\ 10^{-3}$
15	$6.70x\ 10^{-4}$
16	$4.17x\ 10^{-4}$

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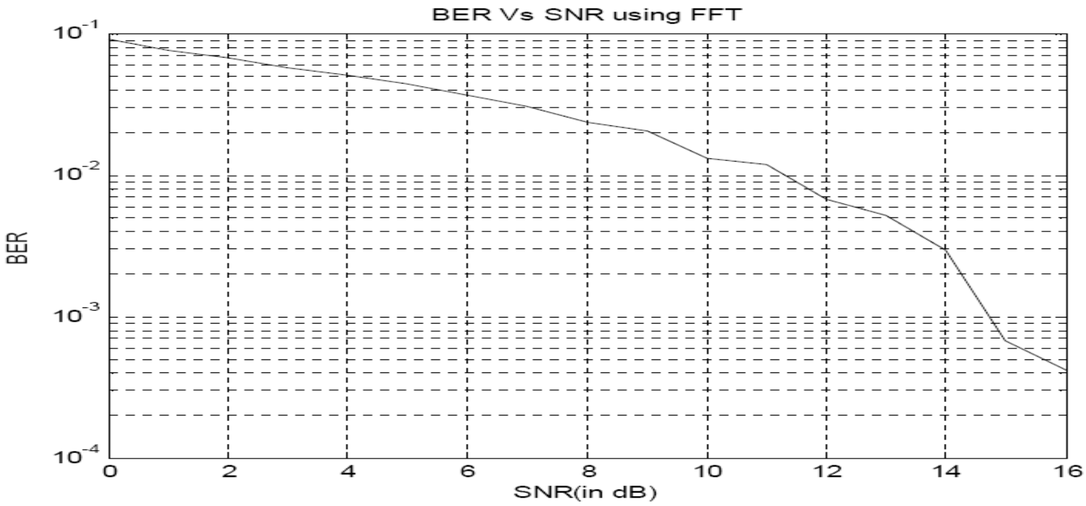

Fig.1: BER versus SNR curve for FFT based OFDM

OFDM IMPLEMENTATION USING DHT:

A discrete Hartley transform (DHT) is a Fourier-related transform of discrete, periodic data similar to the discrete Fourier transform (DFT), with analogous applications in signal processing and related fields. Its main distinction from the DFT is that it transforms real inputs to real outputs, with no intrinsic involvement of complex numbers. Just as the DFT is the discrete analogue of the continuous Fourier transform, the DHT is the discrete analogue of the continuous Hartley transform,

In the OFDM system implementation real-valued discrete Hartley transform (DHT) and its inverse (IDHT) were used to perform the modulation and demodulation operations. BPSK is used as digital modulation technique. Since the DHT and IDHT definitions are identical, we can use the same hardware or program to implement the modulator and demodulator.

For the current OFDM-based transceivers, the modulator needs to compute a long-length inverse discrete Fourier transform (IDFT), and the demodulator needs to compute a long length DFT. For such long-length DFT/IDFT computations, a great number of complex multiplications are required and each of them basically involves four real multiplications and two real additions. Clearly, the complexity of a OFDM-based transceiver would be reduced if the corresponding modulator/demodulator could be implemented using purely real transforms while fast algorithms similar to the fast Fourier transform **(**FFT**)** algorithm can still be applied.

The DHT involves only real-valued arithmetic and has an identical inverse. Like the DFT, there have been a number of fast algorithms and hardware architectures available for the DHT computation. From the results it is seen that the DHT-based OFDM method achieves the same BER performance as the DFT-based OFDM method, but requires less computational complexity.

Simulation Results:

Simulation results are noted in Table 2. Fig. 2 shows the nature of the BER versus SNR curve. As we go on increasing the SNR value, bit error rate reduces.

Modulation technique used is BPSK

No. of bits transmitted = 12000

No. of carriers used = 6

Bits per each carrier = 2000

Spacing between the each carrier = 6 KHz

Carrier frequencies are 6 KHz, 12 KHz, 18 KHz, 24 KHz, 30 KHz, and 36 KHz

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TABLE 2: BER results for DHT based OFDM

SNR(dB)	BER(using DHT)
0	0.1072
1	0.0882
2	0.0775
3	0.0649
4	0.0523
5	0.0447
6	0.0378
7	0.0340
8	0.0246
9	0.0189
10	0.0137
11	0.0106
12	0.0080
13	0.0042
14	$2.6x10^{-3}$
15	$5.0x\ 10^{-4}$
16	$3.3x\ 10^{-4}$

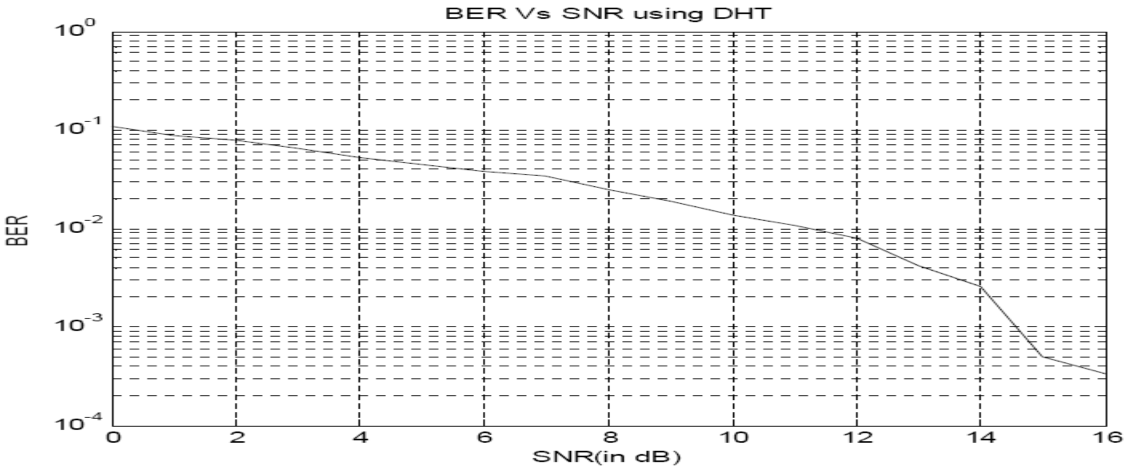

Fig.2: BER versus SNR curve for DHT based OFDM

OFDM IMPLEMENTATION USING DCT:

A discrete cosine transform (DCT) is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry (since the Fourier transform of a real and even function is real and even). In the OFDM system implementation real-valued Discrete Cosine Transform (DCT) and its inverse (IDCT) were used to perform the modulation and demodulation operations. BPSK is used as digital modulation technique. The DCT uses only real arithmetic, as opposed to the complex-valued DFT. This reduces the signal-processing complexity/power consumption. For the current OFDM-based transceivers, the modulator needs to compute a long-length inverse discrete Fourier transform (IDFT), and the demodulator needs to compute a long length DFT, where the transform length is up to 512 or more. For such long-length DFT/IDFT computations, a great number of complex multiplications are required and each of them basically involves four real multiplications and two real additions. The DCT basis is well known to have excellent spectral compaction and energy concentration properties.

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Simulation Results:

Simulation results are noted in Table 3. Fig.3 shows the nature of the BER versus SNR curve. As we go on increasing the SNR value, bit error rate reduces.

Modulation technique used is BPSK

No. of bits transmitted = 12000

No. of carriers used = 6

Bits per each carrier = 2000

Spacing between the each carrier = 6 KHz

Carrier frequencies are 6 KHz, 12 KHz, 18 KHz, 24 KHz, 30 KHz, and 36 KHz

TABLE 3: BER results for DCT based OFDM

SNR(dB)	BER(using DCT)
0	0.0237
1	0.0210
2	0.0162
3	0.0109
4	0.0083
5	0.0050
6	0.0028
7	0.0014
8	4.167x 10
9	1.667x 10
10	0

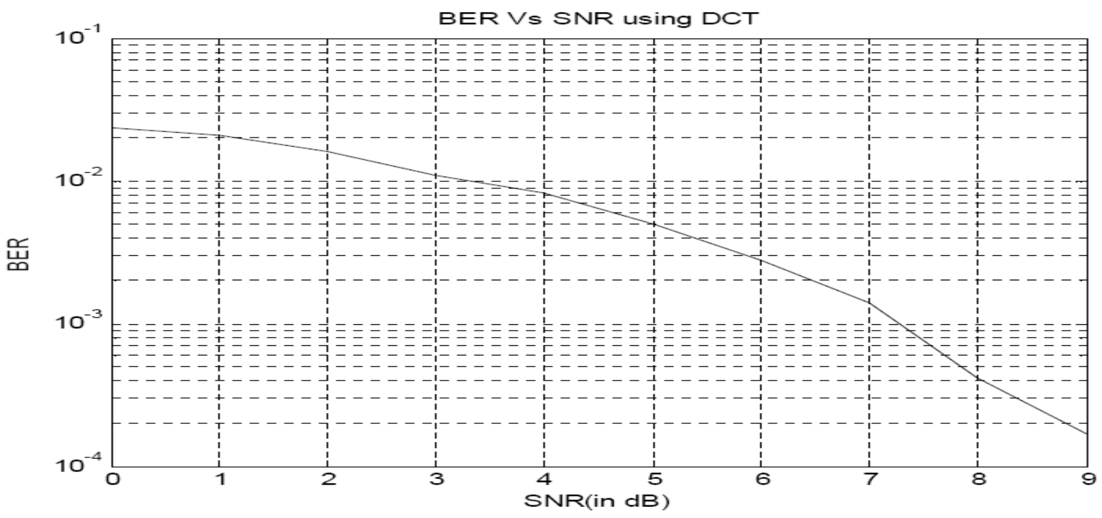

Fig.3: BER versus SNR curve for DCT based OFDM

COMPARISON OF PERFORMANCE OF OFDM SYSTEMS:

Fig.4 shows the comparison of the BER versus SNR curves obtained in the FFT, DHT, and DCT based OFDM systems with BPSK as a modulation technique. It is observed that for all the systems BER is getting reduced as SNR increases. The BER performance of FFT and DHT is almost same. It is also observed that the DCT based BER curve is always below the curves of other two systems.

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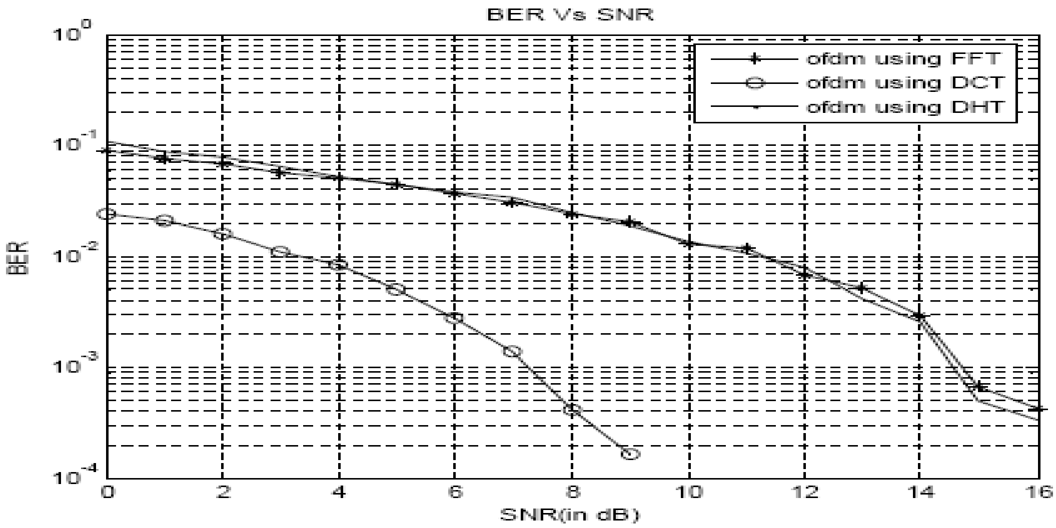

Fig.4: Comparison of Bit Error Rates of FFT, DHT, and DCT based OFDM systems

III. CONCLUSION

It has been seen that the OFDM is a powerful modulation technique that is capable of high data rate and is able to eliminate ISI. It is computationally efficient due to the use of FFT techniques to implement modulation and demodulation functions. Using MATLAB software, the performance of OFDM system is taken for three different transform techniques namely FFT, DHT, and DCT. By simulation results, it observed that BER is improved in noisy channel by using BPSK at maximum data transmission capacity. DCT implies different boundary conditions than the DFT or other related transforms because of real valued nature and strong energy compaction property. DHT based OFDM, due to its real valued, t require less computation complexity and implementation cost.

From the results it is also observed that the DHT-based OFDM achieves the same transmission performance as the DFT-based OFDM from the BER vs SNR point of view, but requires less computational complexity with reduced implementation cost, because it is purely based on the real valued DHT. The DCT based OFDM has better BER performance compared to the DFT and DHT based OFDM methods, because of its strong "energy compaction" property and real valued nature.

So, from the BER vs SNR results, we conclude that form the implementation and performance points of view DHT and DCT transform techniques may be alternatives to DFT for the designing of OFDM-based communication systems.

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