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Improvement of OFDM Transmitter Using Parallel 2D FFT Algorithm

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Abstract. **The demand for high-speed wireless communications is rapidly growing, in this paper a new technique is proposed to improve the performance of OFDM. The new technique is use the Parallel 2D FFT algorithm instead Fast Fourier transform (FFT) in order to reduce the level of interference in the flat and selective fading channels, where the improvement was 3-4 dBs.**

Keywords: *FFT, 2D FFT, OFDM*

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1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is very similar to the well-known and used technique of Frequency Division Multiplexing (FDM). OFDM uses the principles of FDM to allow multiple messages to be sent over a single radio channel. It is however in a much more controlled manner, allowing an improved spectral efficiency. The Fourier transform (or other transform) data communication system is a realization of FDM in which discrete Fourier transform are computed as part of modulation and demodulation process. In addition to eliminating the banks of subcarrier oscillators and coherent demodulators usually required in FDM system, a completely digital implementation can be built around a special-purpose computer performing the fast Fourier transform [1].

OFDM has recently been applied widely in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and its robustness to multi-path delay. It has been used in wireless LAN standards such as American IEEE802.11a and the European equivalent HIPERLAN/2 and in multimedia wireless services such as Japanese Multimedia Mobile Access Communications. A dynamic estimation of channel is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time- varying for wideband mobile communication systems [2].

The block diagram of the given system for OFDM is depicted in Figure 1 and The OFDM modulator and demodulator of FFT- based OFDM are shown in Figure 2.

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First of all, the input serial data stream is formatted into the word size required for transmission e.g. 2 bit/word for QPSK and 4 bit/word for 16-QAM, and shift into a parallel format. The data is then

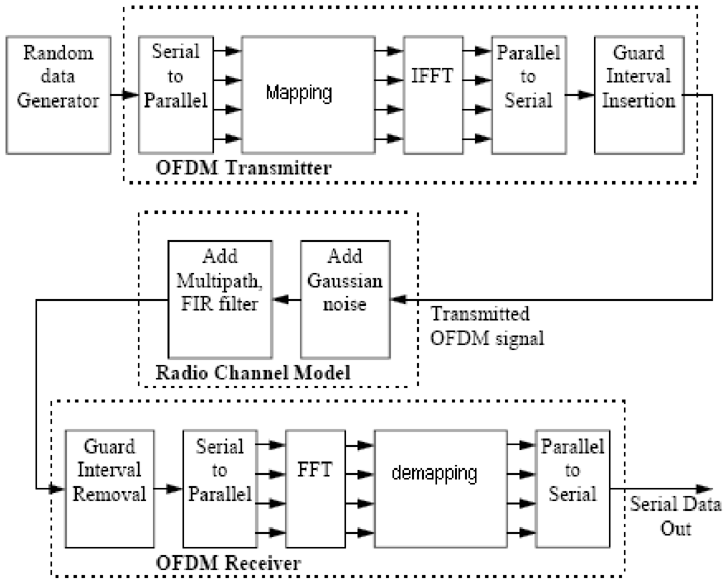
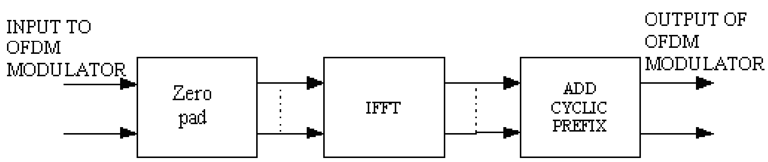
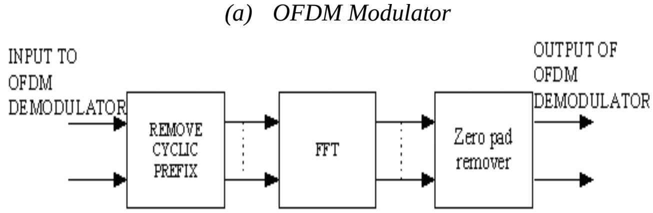


Figure 1. Block Diagram of OFDM System

transmitted in parallel by assigning each word to one sub-carrier in the transmission. After that, the data to be transmitted on each sub-carrier is then mapped into QPSK or 16- QAM constellation format. This process will convert data to corresponding value of M-ary constellation which is complex word, i.e. real and imaginary part. The training frame (pilot sub-carriers frame) will be inserted and sent prior to information frame. This pilot frame will be used for channel estimation that's used to compensate the channel effects on the signal. After that, the complex words frame and pilots frame will pass to IFFT to generate an OFDM symbol. Zeros will be inserted in some bins of the IFFT in order to make the transmitted spectrum compacts and reduce the adjacent carrier's interference.



(a) OFDM Modulator



(b) OFDM Demodulator

Figure 2. The OFDM modem system

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2. Proposed System

The system model is shown in Figure 3; the overall system of OFDM is the same as in Figure 1. The only difference is there are two paths (Corridor) in FFT as shown:

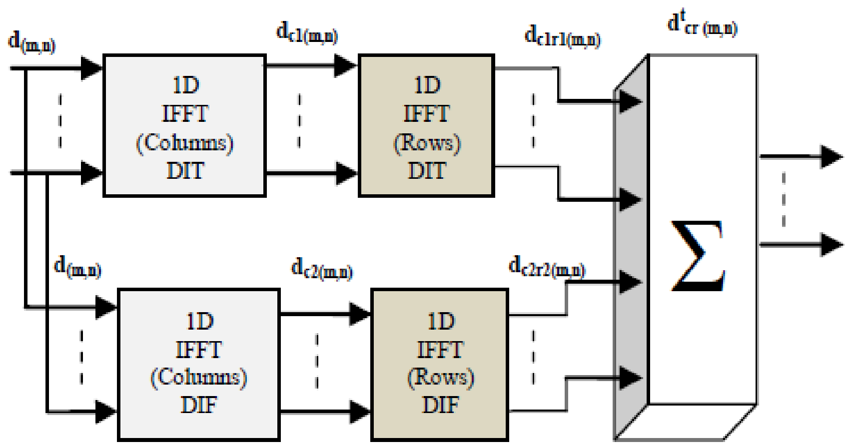
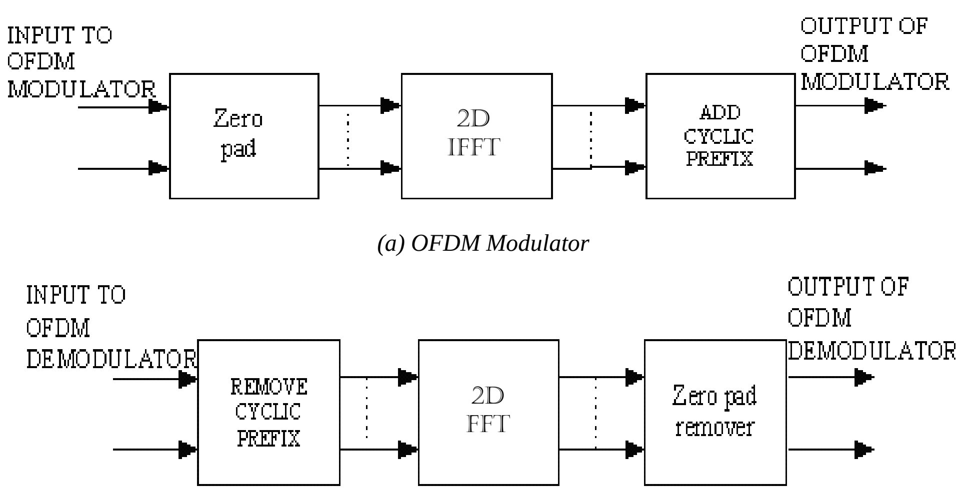


Figure 3. The 2D FFT Parallel System

Rather than 2D FFT Modulated Signal in [6] and which is verified in the search by name 2DFFT OFDM without Parallel (**2DFFTWOP**) (I suggest to make sure of it), as shown in the drawing Figure 4.



(a) OFDM Modulator

(b) OFDM Demodulator

Figure 4. The 2D FFT Modulated Signal OFDM modem system

In Figure3 after zero padding , the data d(m,n) make a copy for two paths ,first path make 1D IFFT for columns and rows both are made by decimation in time (DIT) and the second path make also 1D

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IFFT for columns and rows but both by decimation in frequency ,then for transmitter as equations.1,2 and 3.

$$d_{c(m,n)} = \frac{1}{M}\sum_{m=0}^{M-1} d_{(m,n)} e^{j\frac{2\pi mk}{M}} \quad \text{......} \quad (1)$$

$$d_{cr(m,n)} = \frac{1}{N}\sum_{n=0}^{N-1} d_{c(m,n)} e^{j\frac{2\pi nk}{N}} \quad \text{......} \quad (2)$$

$$d^{t}{}_{cr(m,n)} = \sum_{j=1}^{n}\sum_{i=1}^{m}\left\{d_{c_1r_1(m_i,n_j)} + d_{c_2r_2(m_i,n_j)}\right\} \text{......} (3)$$

Where M and N in equation (1), (2) and (3) are the number of Rows and number of Columns, After all that we can now add cyclic prefix (about 20%-25% from the data).

The reason using this method, because the energy of the piece will be a reference for less if we use the original method 1D FFT , And this is exactly opposite the proposed from the source number [6] as shown in the following figures 5,6 and 7,

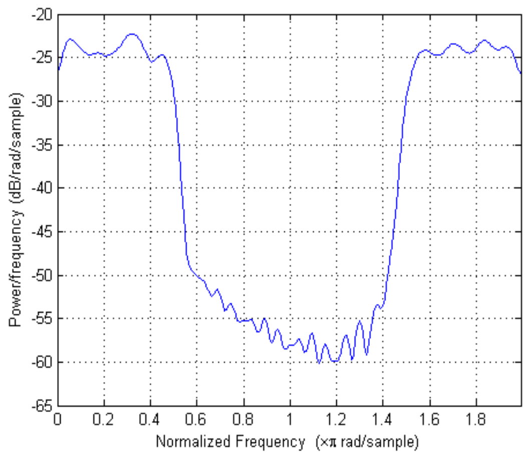

Figure 5. The Welch Power Spectral Density Estimate for 1DFFT OFDM

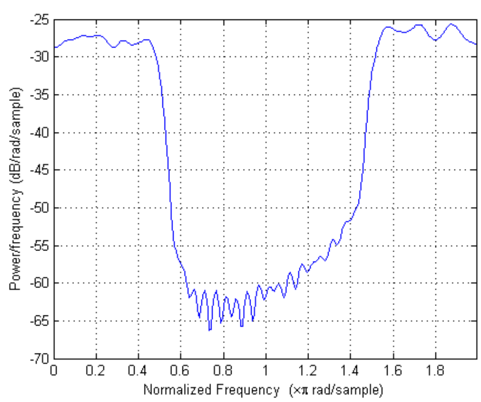

Figure 6. The Welch Power Spectral Density Estimate for 2DFFT OFDM without Parallel (2DFFTWOP)

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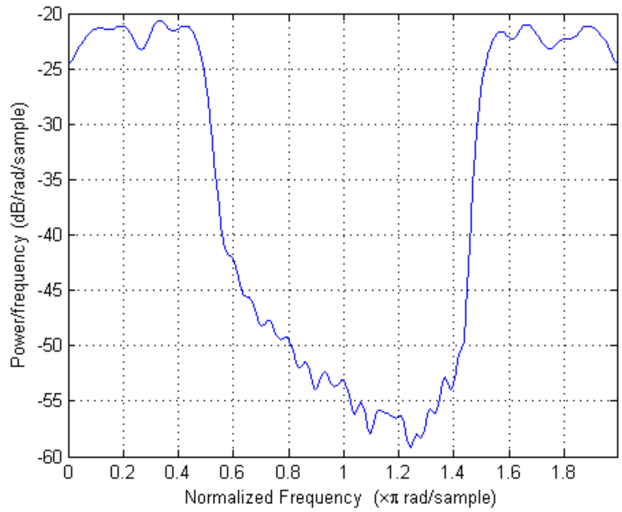

Figure 7. The Welch Power Spectral Density Estimate for 2DFFT OFDM with Parallel (2DFFT)

The energy difference shown in the drawings figures 5,6 and 7 is what led us to pursue this method; Where we note that the amount of energy for the second way (proposed) without parallel leads to weak performance (as noted in the results), and therefore that will increase the error and to solve this problem we propose to double the capacity of the signal before transmission and almost equal reference or the ability of original reference as shown in figure 6, This method has objected maybe, but, not being able to manipulate directly and will be presented the results of cases, figure 8 show the 2D IFFT without parallel (2D IFFTWOP).

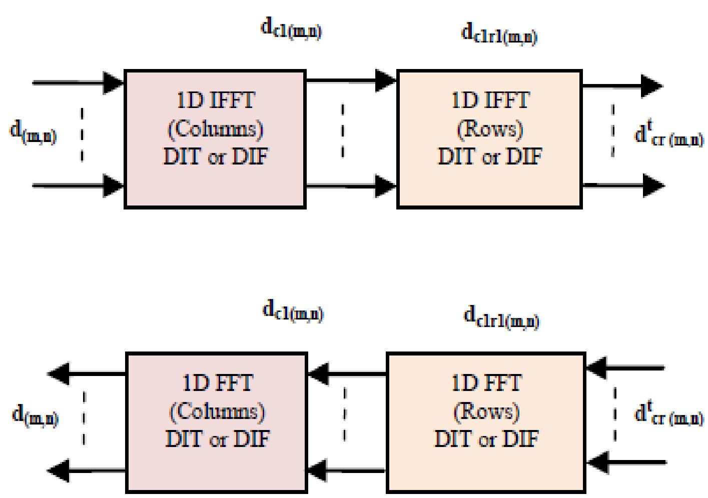

Figure 8. The 2D IFFT without parallel system forward (2D IFFTWOP).

3. Analytical System

The purpose of this method is to enhancement the enrage level of the data before transmitter and is done through by doubling the energy, figures 5, 6 and 7 show the Welch Power Spectral Density Estimate for all systems.

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In reality the inverse Fourier is take the Fourier but divided by number of points as equations 1 and 2 if we note that the $d_{cr}(m,n)$ is divided by n and $d_c(m,n)$ is divided by m then:

$$d_{cr(m,n)} = \frac{1}{N}\sum_{n=0}^{N-1}\left[\frac{1}{M}\sum_{m=0}^{M-1} d_{(m,n)} e^{j\frac{2\pi mk}{M}}\right] e^{j\frac{2\pi nk}{N}} \quad \text{.....(4)}$$

The propose system including The manner in which they will apply applied to a matrix of two dimensions, the First or higher is pilot and the second is the data as shown below:

P_0	P_1	- - - - - - - - - - - - - -	P_{n-2}	P_{n-1}
d_0	d_1	- - - - - - - - - - - - - -	d_{n-2}	d_{n-1}

Figure 9. The 2D Matrix Packets

Where P is the pilot, d is the data and n is integer number power of 2,"in my case n=32 or 64", and The multipath fading channel considered in this model system are:

1. Gaussian channel.
2. Small Scale Fading Channels.
3. Flat Fading Channel.
4. Frequency Selective Fading Channel.

So from Fig.9 the m=2 then equation 4 will be:

$$d_{cr(m,n)} = \frac{1}{2}\frac{1}{N}\sum_{n=0}^{N-1}\left[\frac{1}{M}\sum_{m=0}^{M-1} d_{(m,n)} e^{j\frac{2\pi mk}{M}}\right] e^{j\frac{2\pi nk}{N}} \quad \text{.....(5)}$$

At the end the value of points will be half the energy, but if they use the parallel the enrage return, but from where the improvement become? The improvement become or Consisting from the more Orthogonal between the data and the pilot as shown in Fig.10 below if n and m are both power of 2 then we can use Fast Fourier Transformer:

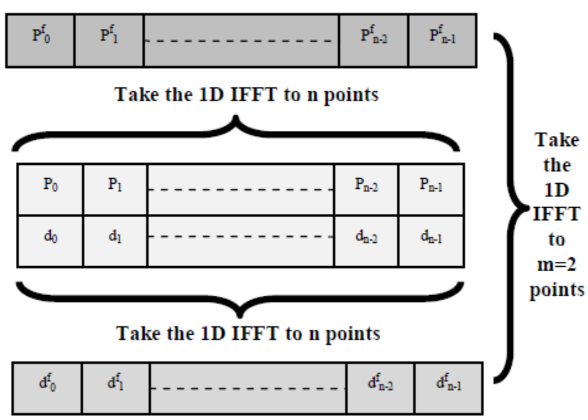

Figure 10. The 2D matrix packets IFFT

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Where P^f_{n-2} the pilot taking IFFT and d_{fn-2} the data taking IFFT, it can be use the Welch Power Spectral Density Estimate, The use of the fast Fourier transform in power spectrum analysis is described [7], it can be seen in figures 5,6 and 7.

Principal advantages of this method area reduction in the number of computations and in required core storage, and convenient application in non-stationary tests. The method involves sectioning the record and averaging modified period grams of the sections [7].

4. Results of the Proposed System

In this part the design of the 2DFFT OFDM systems was given. This part gives the simulations results and evaluation tests of 1DFFT and 2DFFT without parallel (2DFFTWOP) then 2DFFT with parallel (2DFFT) proposed systems using MATLAB® 7.6 the results of both systems in the three types of channels will be examined and compared. The effects of several parameters of wireless channels on the two systems will be investigated. In the OFDM system the two types of the transform 1DFFT and 2DFFT are considered and the PAPR for both transform will be calculated. Table (1) shows the parameters of the systems that are used in the simulation.

Table 1. Simulation Parameters

Modulation types	***4QAM and 16QAM***
Number of sub carriers	32 or 64
Number of IFFT Points	32 or 64
Channel Model	Flat fading+ AWGN Selective fading+ AWGN

1. Performance of 2DFFT & 1DFFT-OFDM Systems in Flat fading AWGN & Selective fading AWGN Channels

In this section the Performance of the OFDM systems. They are compared with both the 1DFFT and 2DFFT Transforms for the possible two types of the channel and as well as for the two types of modulation. The results obtained for AWGN channel in turn are divided into two cases and demonstrated in details in the following subsections:

A. 4QAM modulation in Flat fading & AWGN

Figure 11 illustrates the performance of OFDM systems for 4QAM modulation in Flat fading AWGN channel.

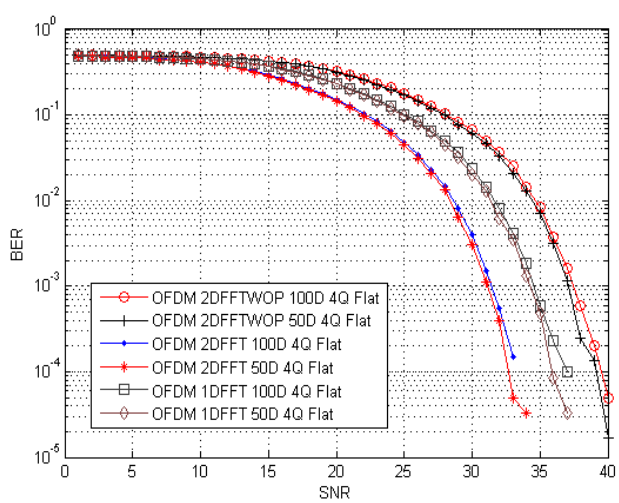

Figure 11. BER performance of OFDM systems for 4QAM modulation in flat fading AWGN channel

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The simulations results contents the effect of the Doppler frequency, It can be seen that the 2DFFT-OFDM is better than the 1DFFT-OFDM, In this case the gain is about 3-4 dB.

B. 4QAM modulation in Selective fading & AWGN

Figure 12 illustrates the performance of 2DFFT-OFDM system for 4QAM modulation in Selective fading AWGN channel .It can be seen that the 2DFFT-OFDM is better than the FFT-OFDM, by 3dB.

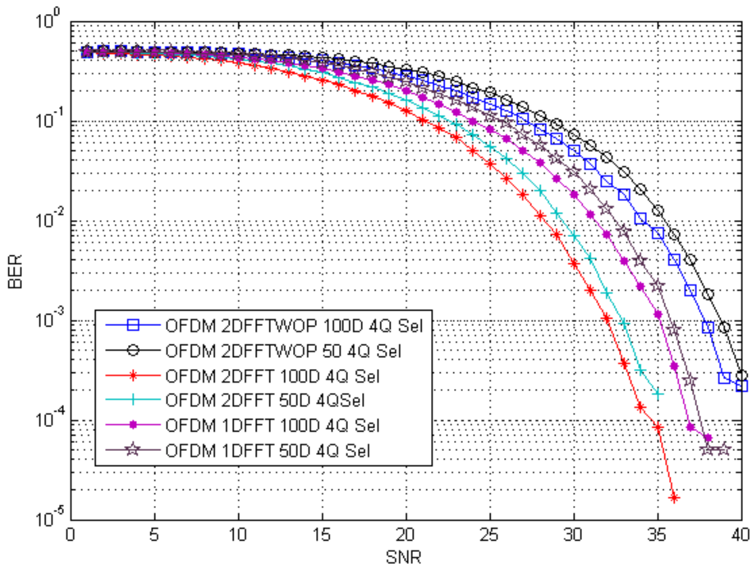

Figure 12. BER performance of OFDM systems for 4QAM modulation in Selective fading + AWGN Channel

C. 16QAM modulation in Flat fading & AWGN

Figure13 show the performance of 2DFFT-OFDM system for 16QAM modulation in Flat fading AWGN channel .It can be seen that the 2DFFT-OFDM is better than the 1DFFT-OFDM, by BER.

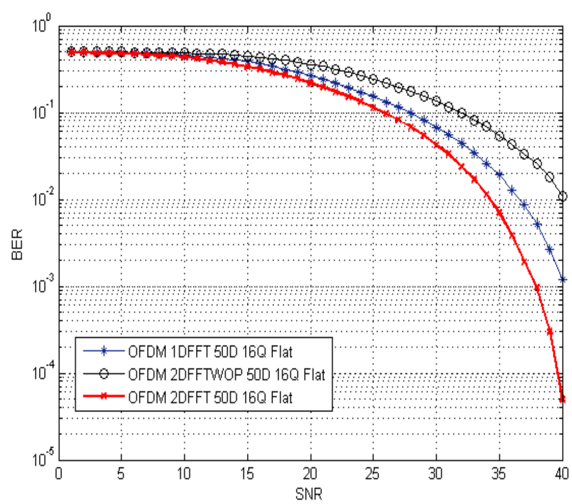

Figure 13. BER performance of OFDM systems for 16QAM modulation in flat fading + AWGN channel

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D. 16QAM modulation in Selective fading & AWGN

Figure14 show the performance of 2DFFT-OFDM system for 16QAM modulation in Selective fading AWGN channel .It can be seen that the 2DFFT-OFDM is better than the 1DFFT-OFDM.

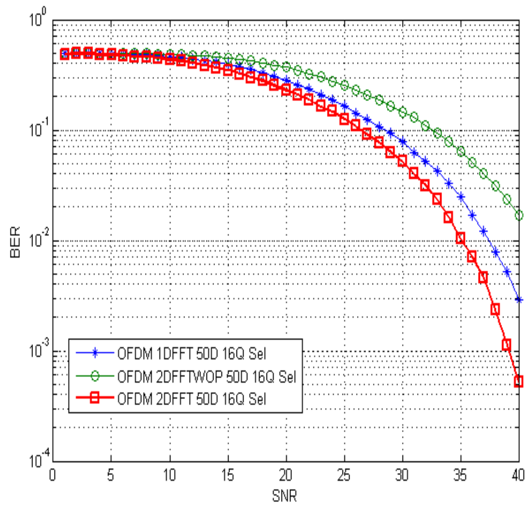

Figure 14. BER performance of OFDM systems for 16QAM modulation in selective fading + AWGN channel

2. The Effect of Doppler Frequency

The Figures below shows the performance of 2DFFT-OFDM system for 4QAM & 16QAM modulation in Flat & Selective fading AWGN channel, it can be seen that the 2DFFT-OFDM is better than the 1DFFT-OFDM. As the maximum Doppler frequency of the fading channel increases, the inter channel interference between sub carriers becomes worse, which leads to the degradation of the system Performance [6].

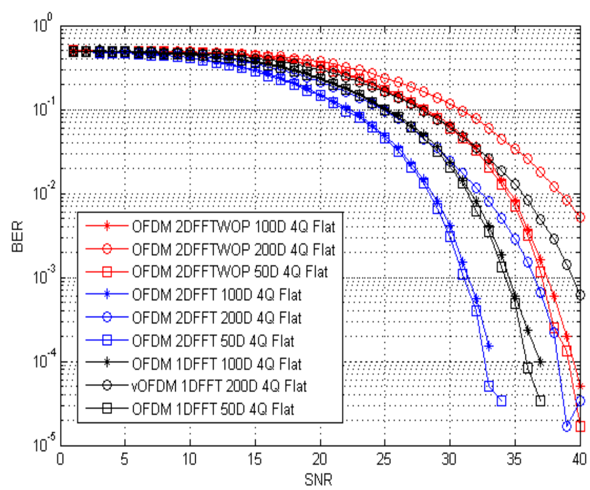

Figure 15. The Effect of Doppler Frequency 4QAM in flat fading AWGN channel

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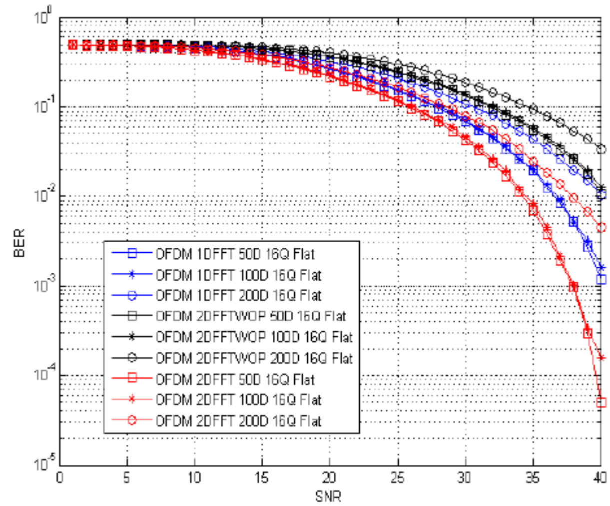

Figure 16. The Effect of Doppler Frequency 16QAM in flat fading AWGN channel

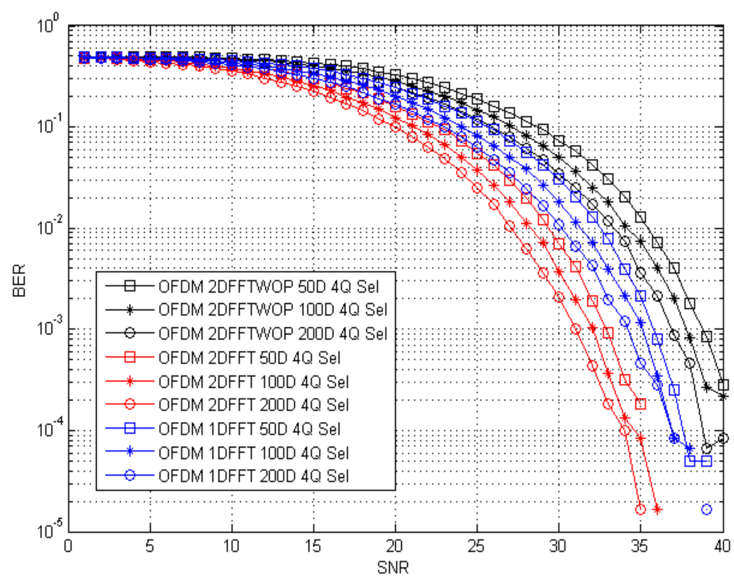

Figure 17. The Effect of Doppler Frequency 4QAM in selective fading AWGN channel

5. Conclusion

In this work, first both the 1DFFT and 2DFFT based OFDM system were realized, the performance of all these schemes, the 1DFFT-OFDM, the 2DFFT-OFDM, and 2DFFTWOP-OFDM, schemes were tested and compared in three types of channels; AWGN flat fading and frequency selective channel. The conclusions drawn from the result obtained can be summarized by the following points:

1. In AWGN and flat fading channel, for all types of the modulation, it was found that the 2DFFT-OFDM was better than the 1DFFT-OFDM. An improvement of about 3-4dB was achieved in 2DFFT-OFDM over that for the 1DFFT-OFDM.
2. In frequency selective fading channel (Multi-Paths case), for all types of the modulation, it was found that the 2DFFT-OFDM was better than the 1DFFT-OFDM. An improvement of about 3-

4dB was achieved in 2DFFT-OFDM over that for the 1DFFT-OFDM.

In both cases can be best performance if using with CDMA or another 2D Transformer [8, 9].

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