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OFDM-DCT ROBUST CHANNEL SIMULATION

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ABSTRACT

Multi-Carrier Modulation is a technique for data-transmission by dividing a high-bit rate data stream is several parallel low bit-rate data streams and using these low bit-rate data streams to modulate several carriers. Multi-Carrier Transmission has a lot of useful properties such as delay-spread tolerance and spectrum efficiency that encourage their use in un-tethered broadband communications. OFDM is a multi-carrier modulation technique with densely spaced sub-carriers that has gained a lot of popularity among the broadband community in the last few years. This report is intended to provide a tutorial level introduction to OFDM Modulation, its advantages and demerits, and some applications of OFDM.OFDM is a multi-channel modulation system employing Frequency Division Multiplexing (FDM) of orthogonal sub-carriers, each modulating a low bit-rate digital stream.

KEYWORDS- Orthogonal frequency division multiplexing(OFDM), Digital audio broadcasting (DAB), Digital video broadcasting(DVB), Inter channel interference(ICI), Inter symbol Interference(ISI), Inverse fast Fourier transform(IFFT), Peak to average ratio(PAR), Bit error rate(BER), Additive white Gaussian noise(AWGN), Inverse discrete cosine transform(IDCT).

INTRODUCTION

Few years back the multi-channel systems used FDM for which the bandwidth was alienated into N non overlapped occurrence sub-channels in entirety. The individual sub-channel gets modulate for an entirely diverse rivulet of cryptogram and so the all N sub-channels got multiplexed on the foundation of the rate of recurrence. Despite the fact that the preclusion of spectral overlapping of the sub-carriers dearth the inter channel infringement, this leads to a clumsy use of spectrum. The safeguard bands on either part of each sub-channels is a misuse of valued bandwidth. To conquer the difficulty of bandwidth depletion, we can as an alternative use N overlapping (but orthogonal) subcarriers, each carrying a baud pace of 1/T and spaced 1/T apart. Because of the frequency spacing preferred, the sub-carriers are all mathematically orthogonal to each other. This authorizes the proper demodulation of the symbol streams exclusive of the obligation of non-overlapping spectrum. Another way of specifying the sub-carrier Orthogonality stipulation is to require that each sub-carrier have precisely integer number of cycles in the interval T. It can be publicized that the modulation of these orthogonal sub-carriers can be represented as an Inverse Fourier Transform (IFT). Alternatively, one could use a DFT procedure followed by low-pass filtering to generate the OFDM signal. The particulars of this method are explained in the next division. It must be illustrious that OFDM can be used either as a modulation or a multiplexing technique.

OFDM

Orthogonal frequency-division multiplexing (OFDM) is a technique of programming digital data on multiple carrier frequencies. OFDM has developed into a well-liked design for wideband digital communication, used in applications such as digital small screen and acoustic broadcasting, DSL Internet access, wireless networks, power line networks, and 4G mobile communications.

OFDM is a frequency-division multiplexing (FDM) design used as a digital multi-carrier modulation technique. An out-sized number of intimately spaced orthogonal sub-carrier signals are used to transmit statistics on several analogous data streams or channels. Each sub-carrier is modulated with a conventional modulation system (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining whole data rates analogous to conventional single-carrier modulation schemes in the identical bandwidth.

The principal benefit of OFDM above single-carrier schemes is its capability to deal with severe channel conditions (for example, attenuation of high frequencies in a stretched copper wire, narrowband intrusion and frequency-selective fading suitable to multipath) devoid of complex equalization filters. Channel equalization is cut down because OFDM may possibly be viewed as using several gradually modulated narrowband signals relatively than

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single rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval sandwiched between symbols reasonable, making it feasible to abolish inter-symbol interference (ISI) and utilize echoes plus time-spreading (on analogue TV these are observable as ghosting and blurring, correspondingly) to accomplish a diversity gain, i.e. a signal-to-noise ratio enhancement. This mechanism besides facilitates the blueprint of single frequency networks (SFNs), where more than a few adjacent transmitters propel the same signal concurrently at the same frequency, as the signals commencing multiple distant transmitters may be combined constructively, rather than interfering as would classically occur in a traditional single-carrier system.

OFDM Generation

Based on the preceding considerations, the technique on behalf of generating an ODFM symbol is as follows.

- First, the N input complex symbols are padded amid zeros to find Ns symbols that are used to compute the IFFT. The productivity of the IFFT is the basic OFDM symbol.
- Based on the delay spread of the multi-path channel, a specific guard-time must be chosen (say Tg). A number of illustrations subsequent to this guard time must be taken from the establishment of the OFDM symbol and appended at the end of the symbol. Likewise, the same number of samples must be taken from the end of the OFDM symbol and must be introduce at the beginning.
- The OFDM symbols have to be multiplied with the raised cosine window to eliminate the power of the out-of-band sub-carriers.
- The windowed OFDM symbol is subsequently added to the output of the previous OFDM symbol with a delay of Tr, so that there is an overlap region of bTr between each symbol.

OFDM System Design

OFDM system design, as in any supplementary system design, engages a lot of trade-offs and incompatible requirements. The following are the most vital design parameters of an OFDM scheme. The following parameters could enhance the general OFDM system generation and specifications:

- **Bit Rate requisite for the system**: The overall system ought to be capable to sustain the data rate essential by the users. For example, to sustain broadband wireless multimedia communication, the system should operate at more than 10 Mbps at slightest.
- **Bandwidth available:** Bandwidth is constantly the insufficient resource, so the mother of the system blueprint should be the accessible bandwidth for operation. The amount of bandwidth co-operates an important role in determining number of subcarriers, because with a large bandwidth, we can effortlessly fit in a large number of subcarriers with practical guard space.
- **BER requirements. (Power efficiency)**
- **RMS delay spread of the channel:** Acceptable delay spread will depend on the user surroundings. Measurements demonstrate that indoor environment experiences maximum wait spread of few hundreds of ns at most, where as outdoor environment can experience up to 10μs. So the length of CP should be determined according to the acceptable delay spread.
- **Doppler values:** Users on a high-speed medium will experience higher Doppler shift, whereas pedestrians will experience smaller Doppler shift. These considerations must be taken into account.
- **Guard time (CP interval) and symbol duration:** A fine ratio among the CP interval and symbol duration should be establish, so that all multi-paths are determined and as a result, not a considerable amount of energy is gone astray due to CP. As a thumb rule, the CP interval ought to be two to four epoch larger than the root mean square (RMS) delay spread. Symbol interval should be much larger than the guard time to diminish the loss of SNR, but within rational and coherent amount. It cannot be arbitrarily immense, because larger symbol time means that more subcarriers can fit within the symbol time. More subcarriers increase the signal processing load together to transmitter and receiver, increasing the cost and complexity of resulting device.

  Symbol duration
- **Number of Sub-carriers:** Increasing amount of subcarriers will lessen the data rate via each subcarrier, which will make certain that the relative amount of dispersal in time caused by multipath delay will be decreased. But when there are large numbers of subcarriers, the coordination at the receiver side will be extremely complicated.
- **Subcarrier spacing:** Subcarrier spacing must be reserved at that much intensity so that synchronization is attainable. This constraint will largely depend on obtainable bandwidth and the mandatory number of sub channels.

- **Modulation type per subcarrier:** This is insignificant, because different modulation schemes will provide different performances. Adaptive modulation and bit loading might be needed depending on the performance requirement. It is remarkable to note that the performance of OFDM systems with differential modulation, in comparison with systems using non-differential and coherent demodulation performs fairly well. In addition, the computation complexity in the demodulation procedure is quite low down than differential modulations.
- **Modulation and Coding Choices:** Selection of FEC code also plays a crucial role as well; suitable FEC coding will formulate surety that the channel is robust to all the random faults.

PRINCIPLES OF OFDM

The ideologies of orthogonal frequency division multiplexing (OFDM) modulation have been in existence for numerous decades. However, in modern years these techniques have rapidly moved out of textbooks, study, research laboratories and into practice in modern communications systems. The procedures are engaged in data delivery systems over the telephone lines, digital broadcasting radio and television, and wireless networking communication systems.

In digital communications, information is articulated in the form of bits. The expression symbol refers to a collection, in different sizes of bits. OFDM data are produced by captivating symbols in the spectral space using M-PSK, QAM, etc, and then convert the spectrum to time domain by taking the Inverse Discrete Fourier Transform (IDFT). Since Inverse Fast Fourier Transform (IFFT) is additional cost effective to implement, it is typically used instead. The foremost features of a practical OFDM system are as follows:

- Some processing is prepared on the source data, such as coding for correcting mistakes, interleaving and mapping of bits against symbols. An example of mapping used is: QAM.
- The symbols are modulated onto orthogonal sub-carriers. This is done by using IFFT.
- **Orthogonality**: Orthogonality is sustained during channel broadcasting. This can be achieved by adding up a cyclic prefix to the OFDM frame to be sent. The cyclic prefix consists of the L last samples of the frame, which are copied and sited in the beginning of the frame. It should be longer than the channel impulse response.
- Conceptually, OFDM is a dedicated FDM, the additional restriction being: all the carrier signals are orthogonal to each other.
- In OFDM, the sub-carrier frequencies are selected so that the sub-carriers are orthogonal to each other, meaning that cross-talk between the sub-channels is eradicated and inter-carrier guard bands are not required. This greatly simplifies the design of both the transmitter and receiver; dissimilar conventional FDM, a separate filter for each sub-channel is not mandatory

  OFDM requires very precise frequency synchronization among the receiver and the transmitter; with frequency variation of the sub-carriers will no longer be orthogonal, causing inter-carrier interference (ICI) (i.e., cross-talk between the sub-carriers). Frequency offsets are characteristically caused by incompatible transmitter and receiver oscillators, or by Doppler shift due to movement. While Doppler shift single-handedly may be compensated by the receiver, the circumstances is worsened when combined with multipath, as reflections will emerge at various frequency offsets, which is much harder to accurate. This effect typically worsens as speed increases, and is an important factor off-putting the use of OFDM in high-speed vehicles. In order to mitigate ICI in such scenarios, one can shape each sub-carrier in order to diminish the interference resulting in a non-orthogonal subcarriers overlapping. For example, a low-complexity method referred to as WCP-OFDM [Weighted Cyclic Prefix Orthogonal Frequency-Division Multiplexing] consists in using short filters at the transmitter output in regulate to perform a potentially non-rectangular pulse shaping and a close to ideal reconstruction using a single-tap for each subcarrier equalization. Other ICI suppression techniques usually boost drastically the receiver complexity.
- **Synchronization**: Cyclic prefix can be used to identify the start of each frame. This is achieved by using the fact that the L first and last samples are similar and therefore correlated.
- Demodulation of the acknowledged signal as a result of using FFT.
- **Channel equalization:** the channel can be anticipated either by using a training progression or sending the known so-called pilot symbols at predefined sub-carriers.
- Decoding and de-interleaving.
- **Simplified equalization:** The effects of frequency-selective channel circumstances, for example fading caused by multipath transmission, can be considered as steady (flat) over an OFDM sub-channel if the sub-channel is adequately narrow-banded (that is if the number of sub-channels is sufficiently large). This

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makes frequency domain equalization probable at the receiver, which is extreme simpler than the time-domain equalization used in conventional single-carrier modulation. In OFDM, the equalizer only has to multiply each detected sub-carrier (each Fourier coefficient) in each OFDM symbol by a constant complex number, or a rarely changed value.

If differential modulation such as DPSK or DQPSK is applied to each sub-carrier, equalization can be entirely omitted, since these non-coherent schemes are insensitive to gradually changing amplitude and phase distortion.

In a logic, improvements in FIR equalization using FFTs or partial FFTs leads mathematically closer to OFDM, [citation needed] but the OFDM technique is easier to comprehend and implement, and the sub-channels can be separately modified in other ways than varying equalization coefficients, such as switching between different QAM assemblage patterns and error-correction schemes to match individual sub-channel noise and interference characteristics.

Some of the sub-carriers in the OFDM symbols might carry pilot signals for the dimensions of the channel conditions (i.e., the equalizer gain and phase shift for each sub-carrier). Pilot signals and training symbols (preambles) may also be used for time synchronization (to avoid inter symbol interference, ISI) and frequency synchronization (to avoid inter-carrier interference, ICI, caused by Doppler shift).

OFDM was primarily used for wired and motionless wireless communications. Conversely, with an increasing number of applications working in highly mobile environments, the consequence of dispersive fading caused by a grouping of multi-path propagation and Doppler shift is more significant. Over the preceding decade, study has been done on how to equalize OFDM transmissions over doubly selective channels.

- **Guard interval for exclusion of inter symbol interference:**

One key standard of OFDM is that since low symbol rate modulation schemes (i.e., where the symbols are relatively long compared to the channel time characteristics) undergo less from inter symbol intrusion caused by multipath propagation; it is beneficial to broadcast a number of low-rate streams in analogous instead of a single high-rate stream. Since the duration of each symbol is protracted, it is reasonable to insert a guard interval between the OFDM symbols, thus eliminating the inter symbol intervention.

The guard interval also eradicates the need for a pulse-shaping filter, and it decreases the sensitivity to time synchronization problems.

A basic example: If one transmits a million symbols per second using conventional single-carrier modulation over a wireless channel, then the duration of every symbol would be one microsecond or fewer. This compels strict constraints on synchronization and demands the elimination of multipath interference. If the equivalent million symbols per second are widen among one thousand sub-channels, the duration of every symbol can be longer by a factor of a thousand (i.e., one millisecond) for Orthogonality with approximately the same bandwidth. Presume that a guard interval of 1/8 of the symbol length is inserted in between each symbol. Inter symbol intrusion can be avoided if the multipath time-spreading (the time between the reception of the first and the last echo) is shorter than the guard interval (i.e., 125 microseconds). This corresponds to a maximum variation of 37.5 kilometers between the lengths of the paths.

The cyclic prefix, which is transmitted during the guard interval, consists of the end of the OFDM symbol copied into the guard interval, and the guard interval is transmitted followed by the OFDM symbol. The reason that the guard interval consists of a copy of the end of the OFDM symbol is so that the receiver will integrate over an integer number of sinusoid cycles for each of the multi-paths when it performs OFDM demodulation with the FFT. In some principles such as Ultra wideband, in the interest of transmitted power, cyclic prefix is skipped and nothing is sent during the guard interval. The receiver will then boast to imitate the cyclic prefix functionality by copying the end fraction of the OFDM symbol and adding it to the beginning segment.

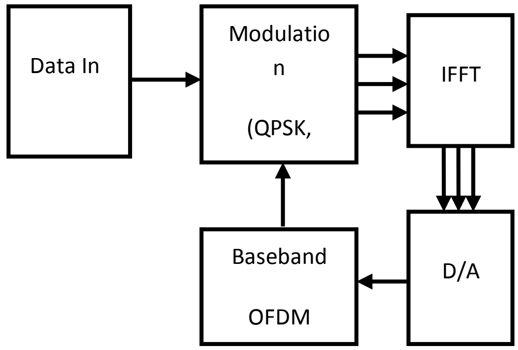

Fig.1. OFDM Transmitter block diagram

OFDM Methodology

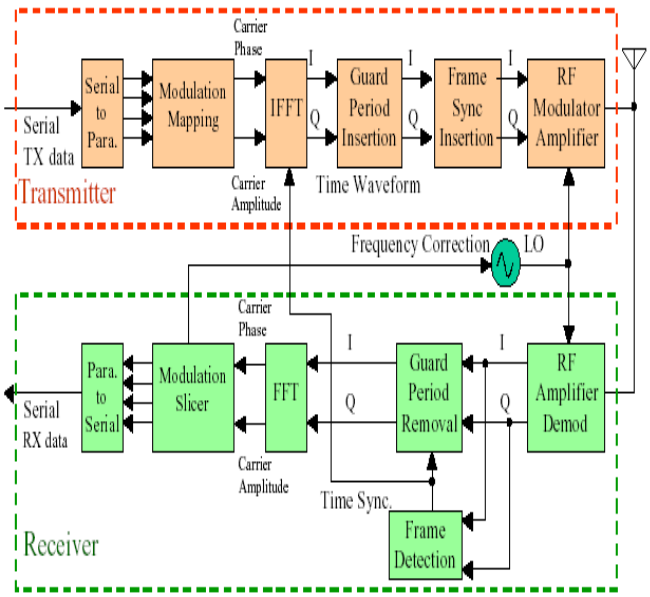

Fig.3. OFDM Methodology

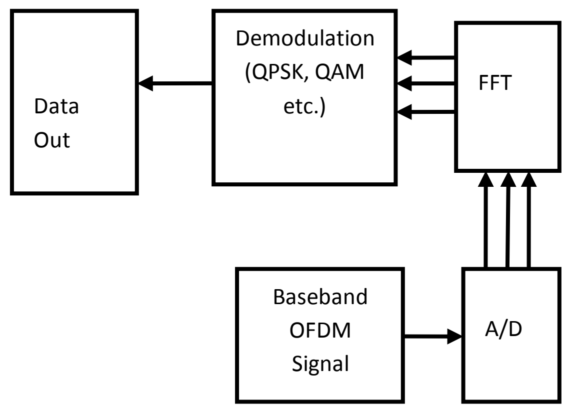

Fig.2. OFDM Receiver block diagram

Basic OFDM System

The OFDM signal generated by the system in Figure 1 & Figure 2 is at baseband; in order to produce a radio frequency (RF) signal at the preferred transmit frequency filtering and mixing is required. OFDM permits for a high spectral efficiency as the carrier power and modulation scheme can be individually controlled for each carrier. However in broadcast systems these are fixed due to the one-way communication. The fundamental principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. The below block diagram shows a simplified configuration for an OFDM transmitter and receiver.

MODELS AND RESULTS

SIMULATION OF OFDM-FFT- Below is the matlab simulink model of OFDM-FFT run at 60db SNR. All results are given below-

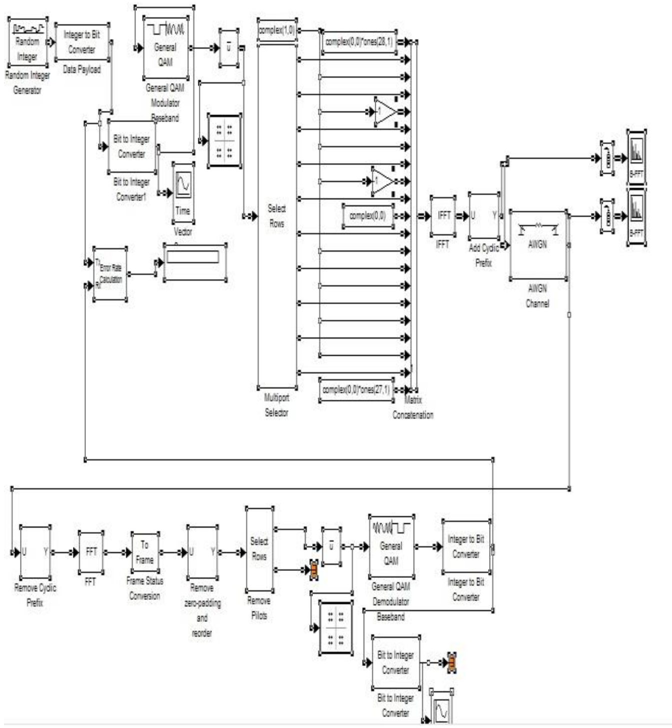

Fig.4. Matlab simulink OFDM-FFT basic design

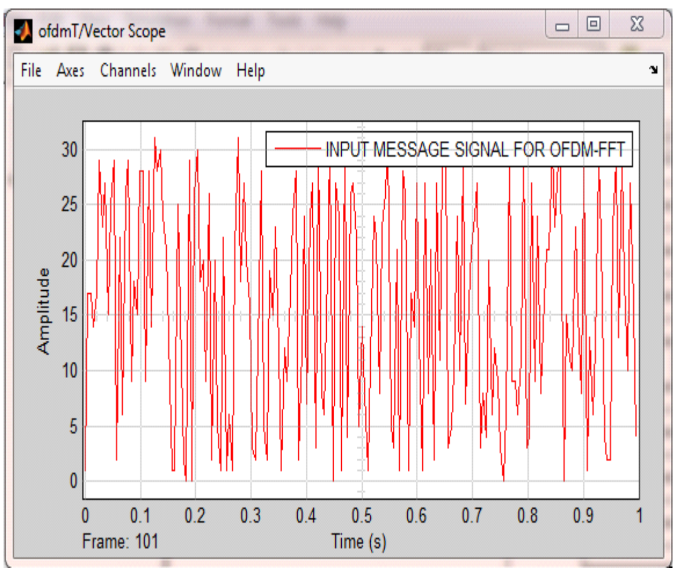

Fig.5. Input message signal.

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RESULT OF FFT SIMULATION

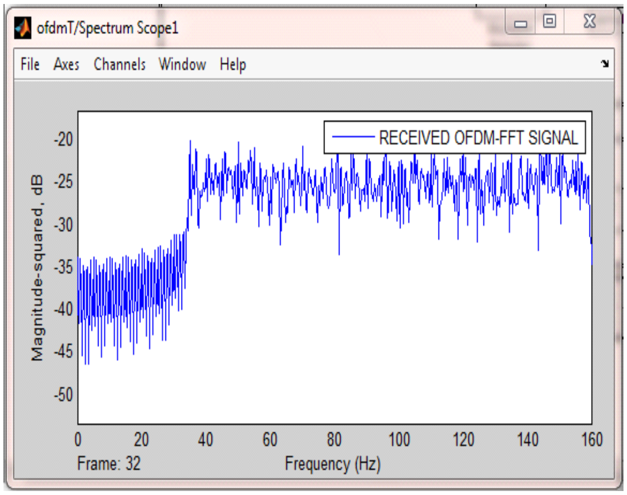

Fig.6. Received OFDM-FFT signal.

Fig.7. Output message OFDM-FFT signal.

SIMULATION OF OFDM-DCT- Below is the matlab simulink model of OFDM-DCT run at 60db SNR. All results are given below

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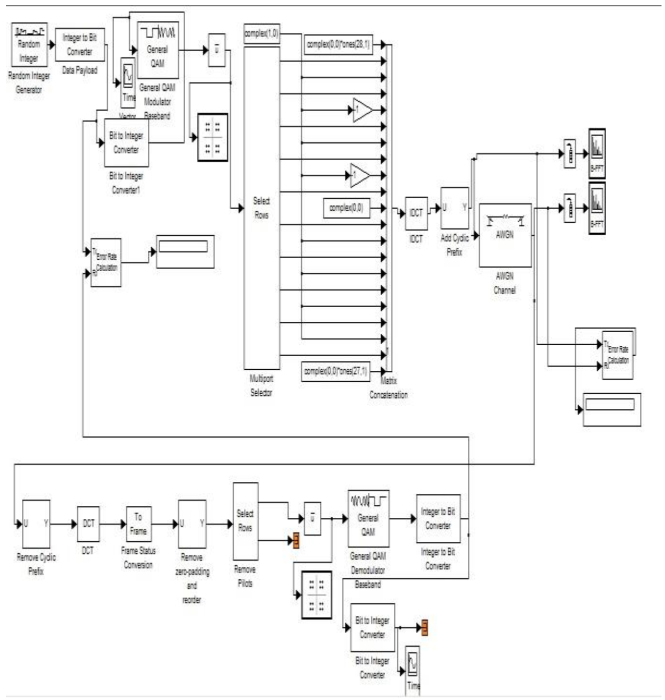

Fig.8. Matlab simulink OFDM-DCT basic design

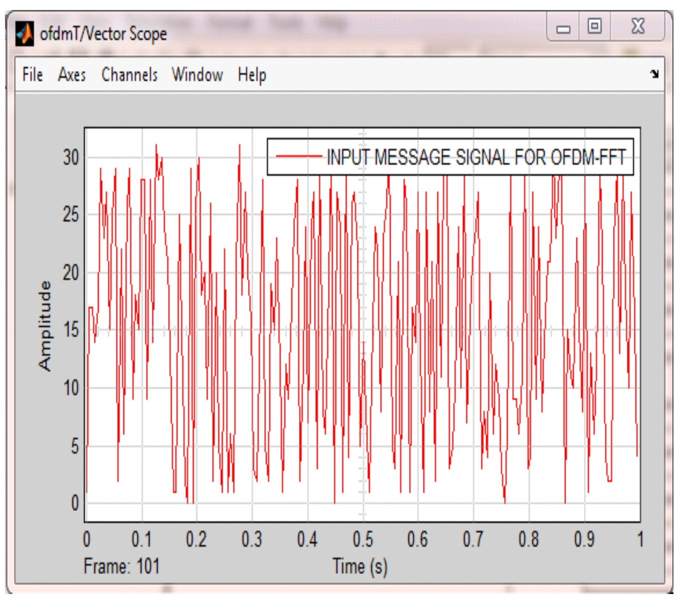

Fig.9. Input message signal.

Result of DCT Simulation:

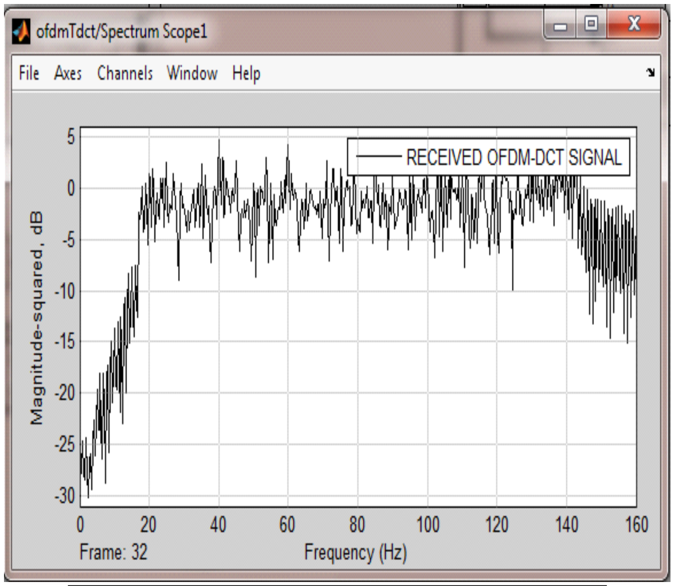

Fig.10. Received OFDM-DCT signal.

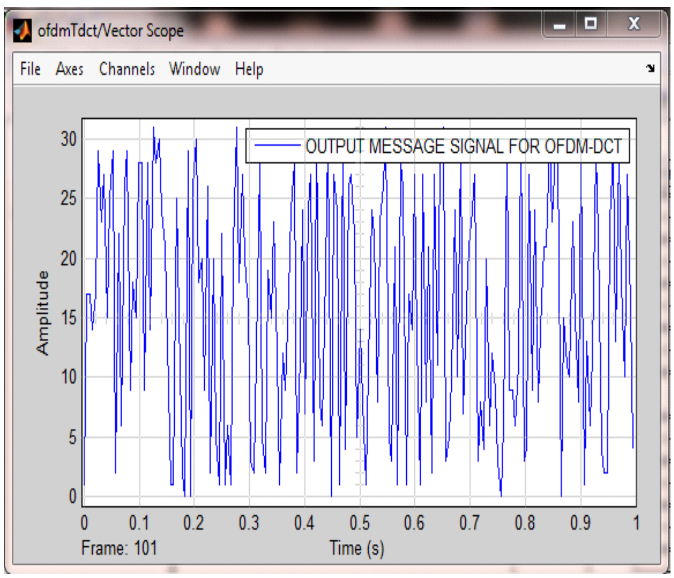

Fig.11. Output message OFDM-DCT signal.

CONCLUSION

OFDM has numerous interesting characteristics that feature its use over Wireless channels and hence lots of Wireless standards have started to make use of OFDM for modulation and multiple accesses. The large range of methods of generation and demodulation of OFDM and specific concerns such as linearity and synchronization were investigated. Relevance of OFDM such as MC-CDMA, DAB, DVB, WLAN etc, were also specified but not discussed in large. Two diverse transforms were used in OFDM generation and results were shown and also has been discussed which one is better.

Multicarrier systems are proving enhanced versions in transmission than single carrier systems. OFDM is a digital multi-carrier modulation technique where a large number of closely spaced orthogonal subcarriers are used to transmit data. One of the somber drawbacks of OFDM systems is that the composite transmit signal can exhibits a very high PAPR when the input sequences are highly interrelated. In this paper, we described several significant aspects related to the PAPR & its overall consequence on the OFDM systems & also mention the names of several techniques adopted by the system according to the requirement. These techniques to reduce PAPR can be used to decrease the PAPR at the cost of loss in data rate, transmit signal power increase, BER performance degradation, computational complexity increase, and so on.

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