OFDM FOR OPTICAL FIBER COMMUNICATIONS BASED ON HARTLEY TRANSFORM

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Abstract— Orthogonal Frequency-Division-Multiplexing (OFDM) is widely used in many digital communication systems due to its advantages such as high bit rate, strong immunity to multipath loss and high spectral efficiency. It is effectively mitigates Inter Symbol Interference (ISI) caused by the delay spread of wireless channels. Therefore, it has been used in many wireless systems and adopted by various standards. Orthogonal frequency division multiplexing (OFDM) schemes are being considered for both optical fiber and wireless optical communications mainly because their ability to cope with the high inter-symbol interference levels associated to dispersive channels. The high PAPR increases the complexity of analogue converters and also reduces the efficiency of High Power Amplifiers. In this paper, we present a Hartley Transform based OFDM for optical communication for reducing the complexity. The performance of Fast Hartley Transform based OFDM is carried out using same input data without using any modulation technique. Also, we present the companding techniques to reduce the PAPR in OFDM.

Keywords— OFDM, Inter Symbol Interference (ISI), Fast Hartley Transform(FHT), PAPR

I. INTRODUCTION

Recently, the demand for multimedia data services has grown drastically which drive us in the age of 4th generation wireless communication system. This requirement of multimedia data service where user are in large numbers and with bounded spectrum, modern digital wireless communication system adopted technologies which are bandwidth efficient and robust to multipath channel environment known as multicarrier communication system. The modern digital multicarrier wireless communication system provide high speed data rate at minimum cost for many users as well as with high reliability. In single carrier system, single carrier occupies the entire communication bandwidth but in multicarrier system the available communication bandwidth is divided by many sub-carriers. So that each sub-carrier has smaller bandwidth as compare to the bandwidth of the single carrier system. These tremendous features of multicarrier technique attract us to study Orthogonal Frequency Division Multiplexing (OFDM). OFDM forms basis for all 4G wireless communication systems due to its huge capacity in terms of number of subcarriers, high data rate in excess of 100 Mbps and ubiquitous coverage with high mobility. OFDM system is very efficient systems for transmission of data than others. Because, in general FDMA systems, we provide the guard interval between two carriers to avoid the interference between carriers, but, due to this, half of the bandwidth of total bandwidth is wasted for Guard band interval. So, by using OFDM system we provide 90^0 phase shift between two adjacent carriers due to these, if two carriers are very adjacent to each other then also they cannot overlap each other because of 90^0 phase shift between two carriers so because of these we can obtain efficient bandwidth utilization and there is no wastage of bandwidth.

II. DRAWBACKS OF OFDM

- **PAPR:** The OFDM signal has a noise like amplitude with a very large dynamic range, therefore it requires RF power amplifiers with a high peak to average power ratio.
- **Frequency offset:** It is more sensitive to carrier frequency offset and drift than single carrier systems are due to leakage of the DFT.

III. DISCRETE HARTLEY TRANSFORM (DHT)

The Discrete Hartley transform (DHT) and the Discrete Fourier transform (DFT) are similar but differ from it in two characteristics of the DFT that are sometimes computation- ally undesirable, Since the inverse DHT is identical with the direct transform, and so it is not necessary to keep track of the +i and -i versions as in the DFT. Also, the DHT has real rather than complex values and thus does not require provision for complex arithmetic operations and separately managed storage for real and imaginary parts.

DHT has been established a potential tool for signal processing applications. It has a real valued and symmetric transform kernel. In this particular work the simulation time for the DFT/IDFT and DHT/IDHT for a given set of data have been obtained. It shows that the computing speed of the DHT/IDHT is faster than DFT/IDFT.

IV. RELATIONS BETWEEN THE FOURIER AND HARTLEY TRANSFORM

In this section some relations between the Hartley and Fourier transform are presented. The analysis will be made based on the continuous time version of these transforms, although the discussion is obviously valid for the discrete time case too. A detailed study of both transforms can be found in expanding the complex exponential in the Fourier transform relations by using the Euler formulas and comparing the result to the Hartley transform relations, it is easy to obtain the following interesting results. The even part of the Hartley transform $E[H_x(f)]$ is the real part of the Fourier transform.

$$E[H_x(f)] = \frac{H_x(f) + H_x\,(-f)}{2} = \int_{-\alpha}^{\alpha} x(t)\cos(2\pi f t)\,dt = \Re\big(F_x(f)\big)$$

Similarly, the odd part of the Hartley transform O [Hz (f) is the imaginary part of the Fourier transform

$$O[H_x(f)] = \frac{H_x(f) + H_x\,(-f)}{2} = \int_{-\alpha}^{\alpha} x(t)\sin(2\pi f t)\,dt = \Im(F_x(f))$$

Thus, the Fourier transform of x(t) can be readily extracted from $H_x(f)$ by simple reflections and additions

$$F_x\,(f) = E[H_x(f)] - iO[H_x(f)]$$

Conversely, given the Fourier transform$F_x\,(f)$, it is possible to obtain $H_x(f)$ by noting that

$$H_x(f) = \Re(F_x f)) - \Im\,(F_x\,(f))$$

It should be noted that Fourier and Hartley transforms are very similar. They are related to one another by equations (3) and (4).Also, it can be observed that both transforms may be expressed as combinations of the sine and cosine transforms. Another important fact is that Hartley and Fourier transform are invertible and consequently they carry the whole information about the original signal but in a different way.

V. FAST HARTLEY TRANSFORM (FHT)

In our project we removed the digital modulation technique, because before transmission we have to perform band pass modulation, so the digital modulation technique before OFDM not giving any additional profit. The other reason is no digital modulation technique which provides higher date rates, higher immune to noise and without complex numbers is available.

For comparison purpose we took general OFDM Mat lab program which is using QAM. Same input, noise function, signal to noise ratio, carrier frequency and symbol duration are considered

In our work before OFDM the raw data of bits are converted into integers. Since the reference OFDM is using QAM, here we considered four bits as one integer. Our focus is, we want to give same size for both DFT and DHT. After conversion of bits into integers we directly used FHT (Fast Hartley Transform) function. For the purpose of band pass modulation we used cosine function only because it gives accurate values at demodulation without using complex terms.

VI. COMPANDING TECHNIQUES

As a matter of fact, companding is non-uniform quantization. It is required to implement to improve the signal to quantization noise ratio of weak signals. We know that the quantization noise is given by

$$N_q = \frac{\Delta^2}{12}$$

This shoes that in uniform quantization, once the step size is fixed, the quantization noise power remains constant. However, the signal power is not constant. It is proportional to square of signal amplitude. Hence signal power will be small for weak signals, but quantization noise power is constant. Therefore, the signal to quantization noise for the weak signals is very poor. This will affect the quality of signal. The remedy is to use companding. Companding is a term derived from two words i.e., compression and expansion as under:

Companding = Compressing + Expanding

In practice, it is difficult to implement the non-uniform quantization because it is not known in advance about the changes in the signal level. Therefore, a particular method is used. The weak signals are amplified and strong signals are attenuated before applying them to a uniform quantizer. This process is called as compression and the block that provides it is called as a compressor.

At the receiver exactly opposite is followed which is called expansion. The circuit used for providing expansion is called as an expander. The compression of signal at the transmitter and expansion at the receiver is combined to be called companding. The process of companding has been shown in the form of a block diagram in the figure

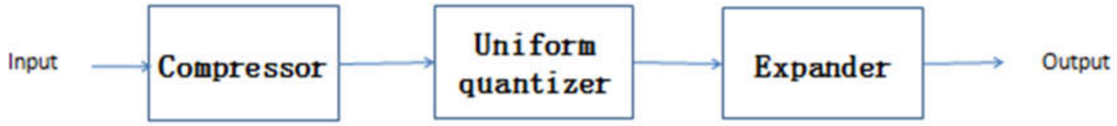


Fig 1: A Companding model

Different types of compressor characteristics

Ideally, we need a linear compressor characteristic for small amplitudes of the input signal and a logarithmic characteristic elsewhere. In practice, this is achieved by using following two methods:

(i) μ-law companding

(ii) A-law companding

(i)μ-law companding

In μ-law companding, the compressor characteristics is continuous. It is approximately linear for smaller values of input levels and logarithmic for high input levels. The μ -law compressor characteristics is mathematically expressed as under:

$$Z(X) = (sgn\ X)\frac{\ln(1+\mu|x|/X_{max})}{\ln(1+\mu)}$$

$$\text{Where} \qquad 0 \le |x|/X_{max} \le 1$$

(ii)A-law companding

In the A-law companding, the compressor characteristic is piecewise, made up of a linear segment for low level inputs and a logarithmic segment for high level inputs. Corresponding to A=1, we observe that the characteristic is linear which corresponds to a uniform quantization. Three practically used value of A is 87.56. The A-law companding is used for PCM telephone systems in Europe. The linear segment of the characteristics is for low level inputs whereas the logarithmic segments is for high level input. It is mathematically expressed as under:

$$\frac{\mathrm{Z(X)}}{\mathrm{X_{MAX}}} = \begin{cases} \dfrac{\mathrm{A|X|/X_{MAX}}}{1+\mathrm{LOG_E}\,\mathrm{A}}\ \mathrm{FOR}\ 0 \le \dfrac{\mathrm{|X|}}{\mathrm{X_{MAX}}} \le 1 \\ \dfrac{1+\mathrm{LOG_E}[\mathrm{A|X|/X_{MAX}}]}{1+\mathrm{LOG_E}\,\mathrm{A}}\ \mathrm{FOR}\ \dfrac{1}{\mathrm{A}} \le \dfrac{\mathrm{|X|}}{\mathrm{X_{MAX}}} \le 1. \end{cases}$$

VII. OFDM USED IN OPTICAL FIBER COMMUNICATION

Despite the many advantages of OFDM, and its widespread use in wireless communications, OFDM has only recently been applied to optical communications. This is partly because of the recent demand for increased data rates across dispersive optical media and partly because developments in digital signal processing (DSP) technology make processing at optical data rates feasible. However another important obstacle has been the fundamental differences between conventional OFDM systems and conventional optical systems.

In typical (no optical) OFDM systems, the information is carried on the electrical field and the signal can have both positive and negative values (bipolar). At the receiver there is a local oscillator and coherent detection is used. In contrast in a typical intensity-modulated direct detection optical system, the information is carried on the intensity of the optical signal and therefore can only be positive (unipolar). There is no laser at the receiver acting as a local oscillator and direct detection rather than coherent detection is used.

A variety of optical OFDM solutions have been proposed for different applications. To understand these different techniques, it is useful to realize what is fundamental in each domain. For an OFDM system to work successfully the system must be (approximately) linear between the transmitter IFFT input and the receiver FFT output. . In other words, ≈ H where Hk is either a constant or is slowly so that it can be tracked at that the receiver. In the optical domain, optical receivers used. A variety of optical OFDM solutions have been proposed for different applications. To understand these different techniques, it is useful to realize what is fundamental in each domain. For an OFDM system to work successfully the system must be (approximately) linear between the transmitter IFFT input and the receiver FFT output. In other words, where is either a constant or is slowly varying so that it can be tracked at that the receiver. In the optical domain, optical receivers use square-law detectors.

VIII. PROPOSED WORK

The importance of multi-carrier communication system has been established in the present communication era. The merits and demerits of OFDM system along with its implication are discussed in first chapter. Multi-carrier communication system especially OFDM has been evolved as one of such potential candidate which are bandwidth efficient and robust to multipath channel condition (frequency selective fading). The research activities in OFDM have grown tremendously during last two decades. Due to its advantageous features like high spectral efficiency, easy equalization and robustness to frequency selective fading channel, the OFDM has been adopted by many broadband wireless communication standards like DAB, DVB-T, IEEE 802.11, 802.16 and UWB communication systems.

Besides so many advantageous and favorable features, there exist some major drawbacks of OFDM which must be resolved for getting all the advantages. Therefore, for overall improvement in the performance of OFDM system, it is required to handle all these issues separately. This project presents a brief review of major problems of OFDM system with proposed solutions. The main focus of work was to provide an appropriate solution to major problems like high PAPR, complexity in Fast Fourier Transform (FFT).

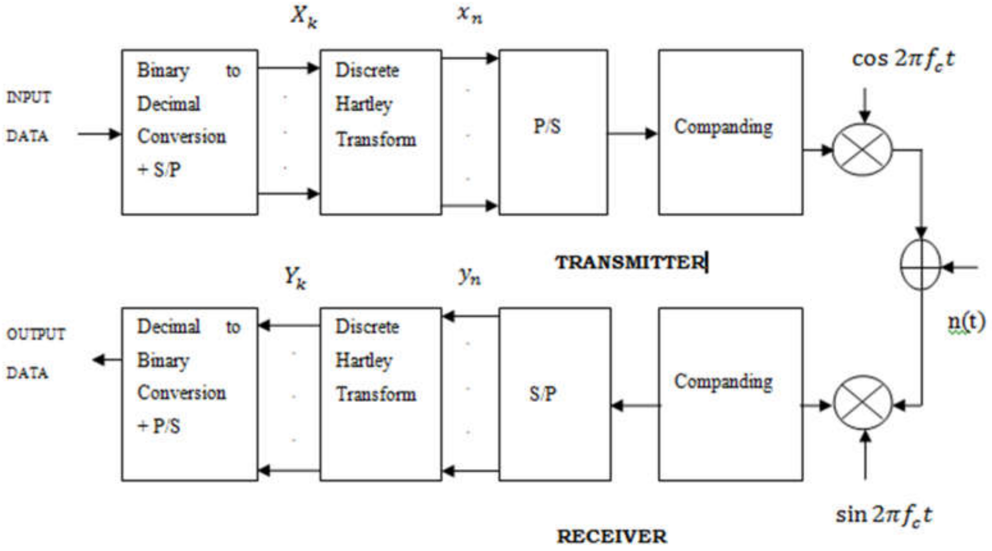


Fig 2: Block diagram of overall proposed technique

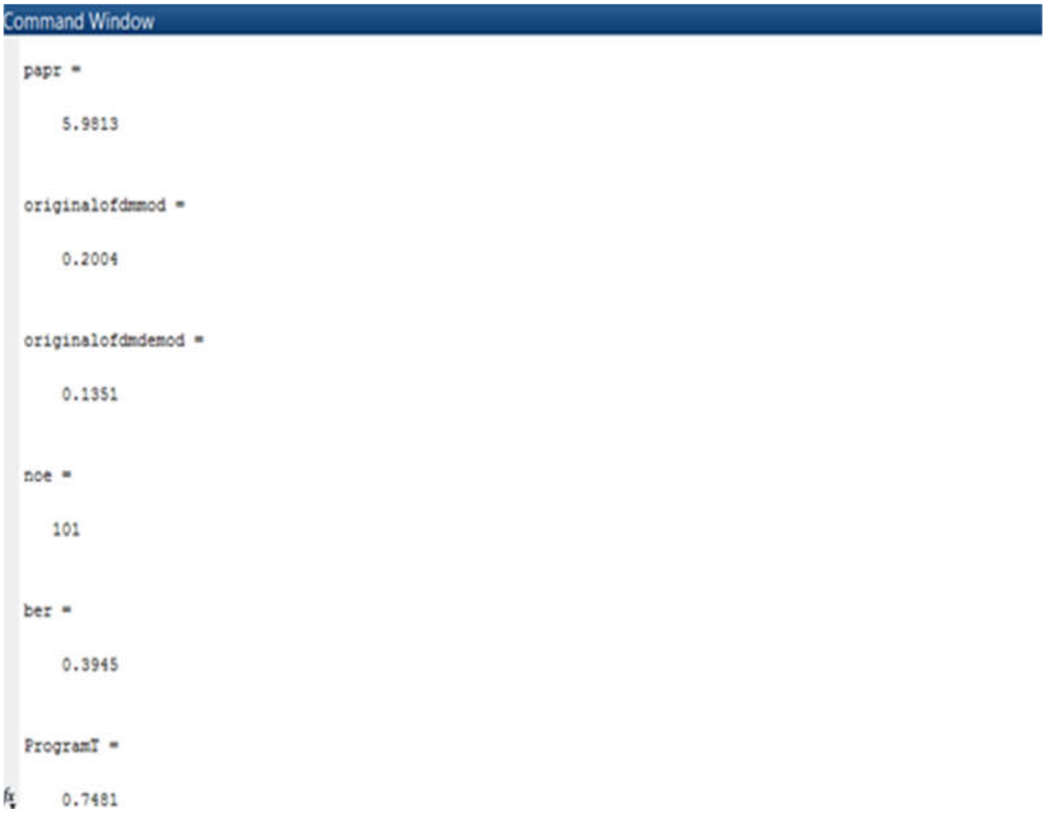
In OFDM, there is a complexity occurs while using the Fast Fourier Transform. In order to avoid that we used Discrete Hartley Transform. The DHT has same formula for transmission and reception.

As per the block diagrams, the given serial input data will be first converted from binary to decimal values then be converted into serial to parallel. The parallel data fed to DHT for getting the orthogonality between the carrier's and again the parallel to serial conversion takes place. We are adding the companding technique, to reduce PAPR problem which means presence of large carriers at the output. At the channel we added the noise i.e., Additive white Gaussian noise (AWGN)) for testing purpose.

In communication, signal to noise ratio is very important because our main focus is on signal but during transmission it got affected by some random noise. At the receiving end we want to get the same transmitted signal, to achieve this noise as minimum as possible. At SNR=50, The OFDM used in optical fiber communication. The OFDM recently used in optical communication which increases the data rates.

IX. SIMULATION RESULTS

The simulated results for basic model of OFDM system with QAM modulation as shown below. The SNR ratio is 10, used in wireless communication. By observing the noe and BER are very high, PAPR is also more. The PAPR is major drawback in OFDM system. The results for basic OFDM system shown in fig(6.1).The fig(6.2),fig(6.3) and fig(6.4) shows the simulated waveforms.



```
papr =

    5.9813


originalofdmmod =

    0.2004


originalofdmdemod =

    0.1351


noe =

   101


ber =

    0.3945


ProgramT =

    0.7481
```

Fig 3: Results of basic OFDM with QAM modulation

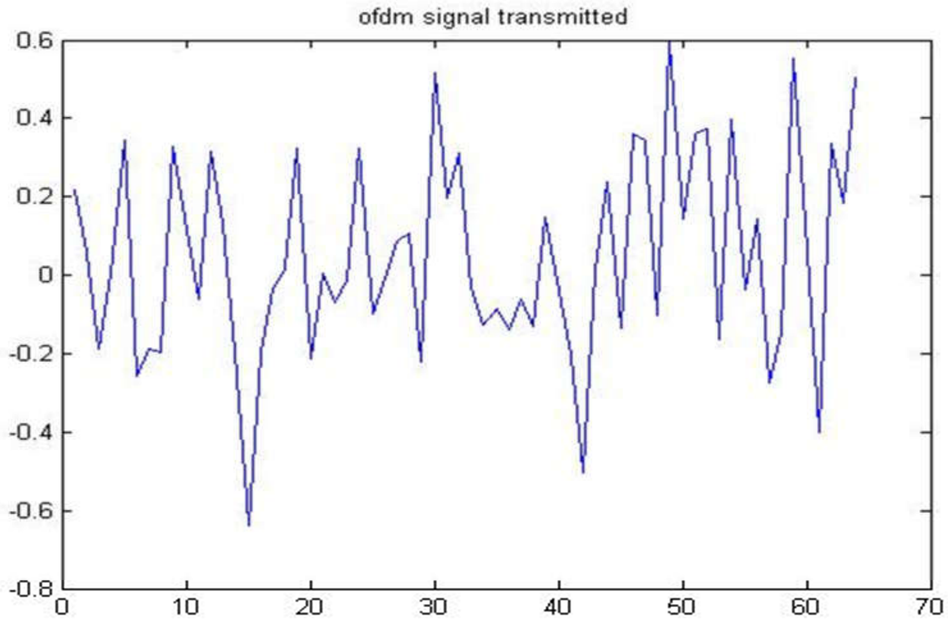


Fig 4: Simulated waveform for OFDM transmitted signal

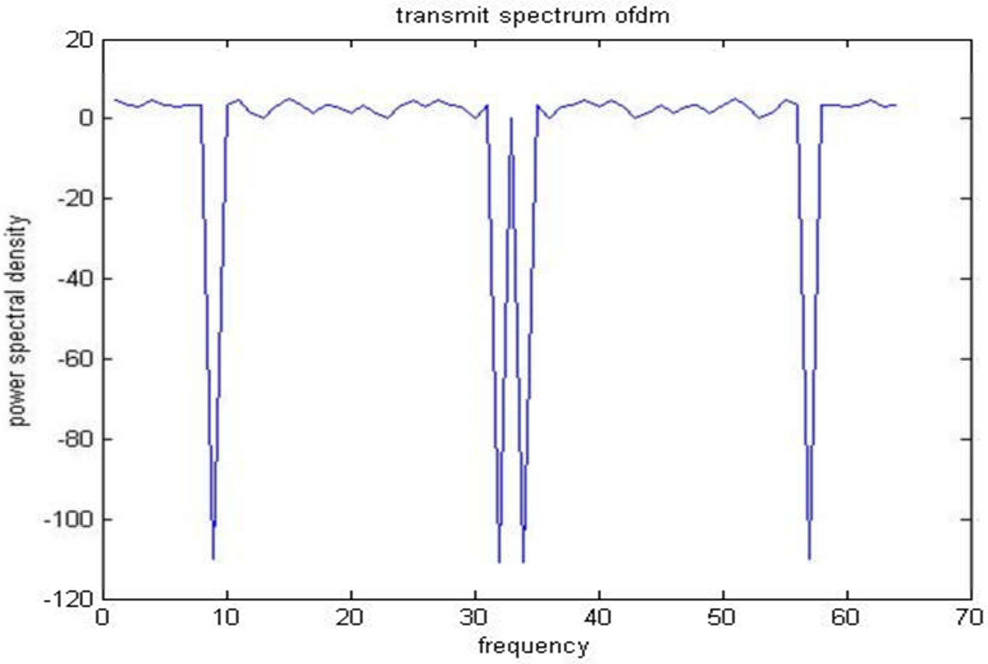


Fig 5: Simulated waveform for OFDM spectrum

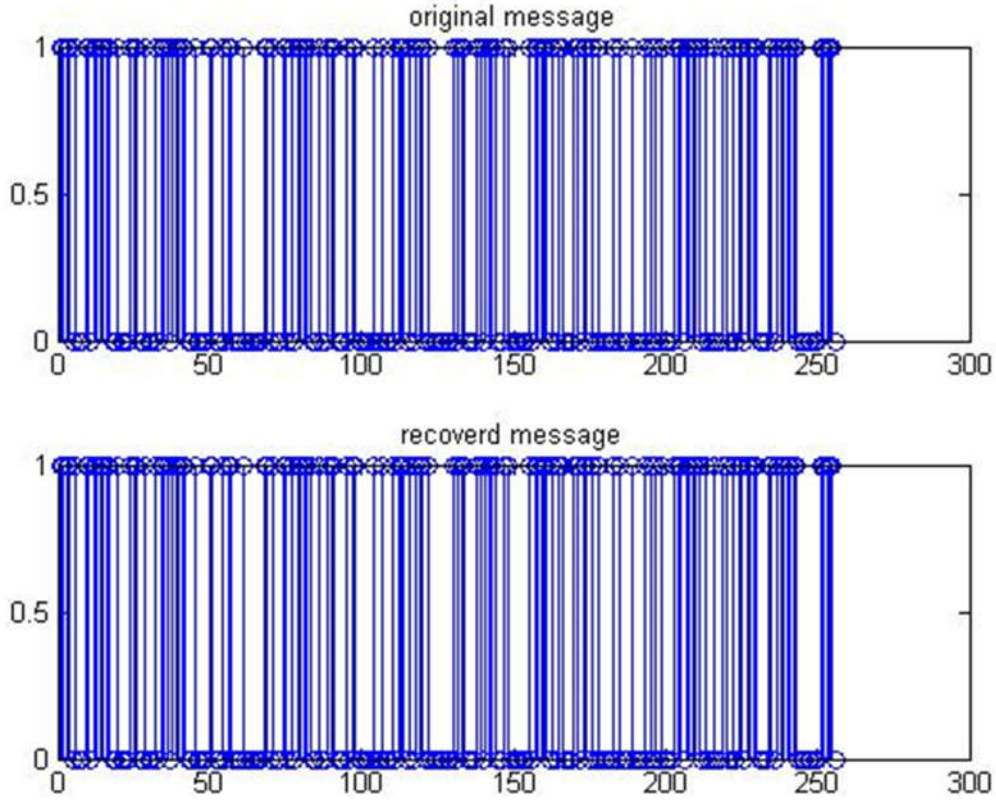
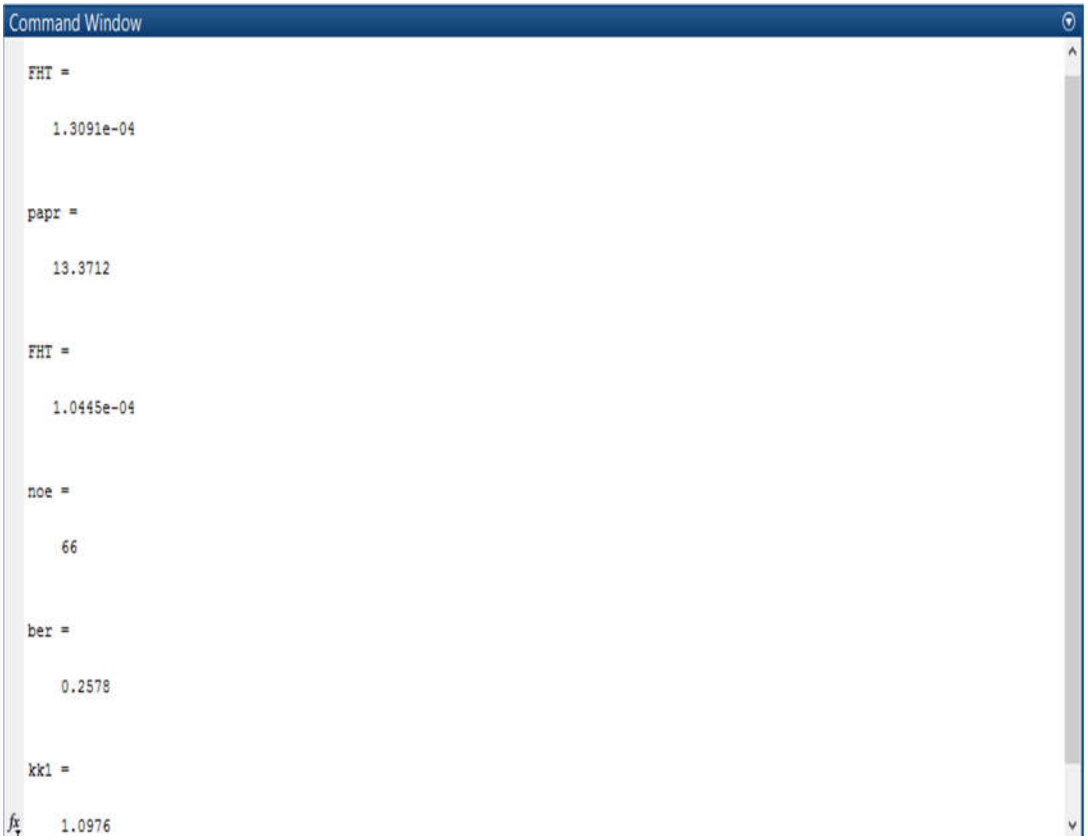


Fig 6: Simulated waveform for original and recovered OFDM bits

Fast Hartley Transform based OFDM results:

By using DHT algorithm, it take more time for calculations. For fast calculations, we introduced new approach called Fast Hartley Transform. When we used FHT, we observed the time and noe are reduced as shown in fig 7.



```
FHT =

   1.3091e-04


papr =

   13.3712


FHT =

   1.0445e-04


noe =

    66


ber =

    0.2578


kk1 =

    1.0976
```

Fig 7: Results of OFDM with Fast Hartley Transform

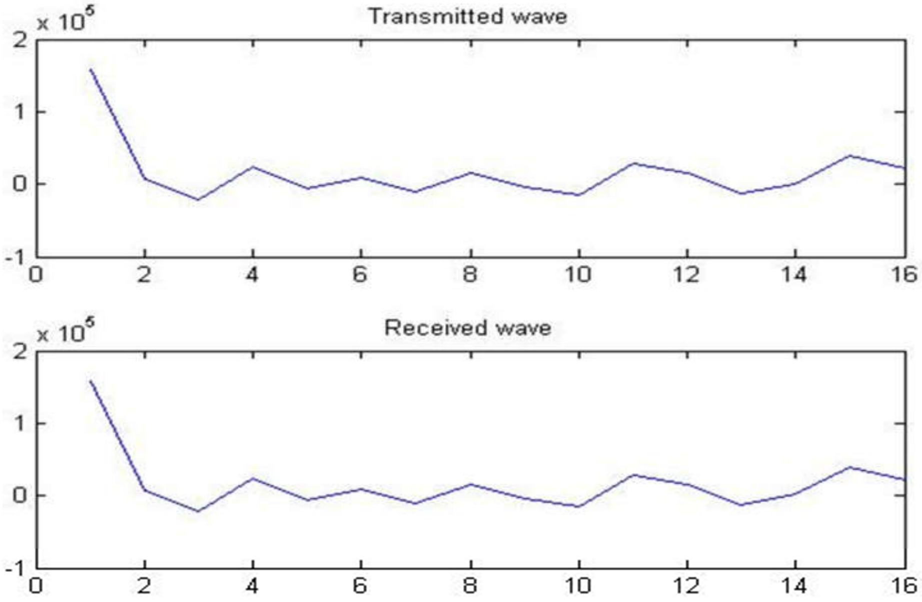


Fig 8:Simulated waveform for OFDM transmitted and received signal

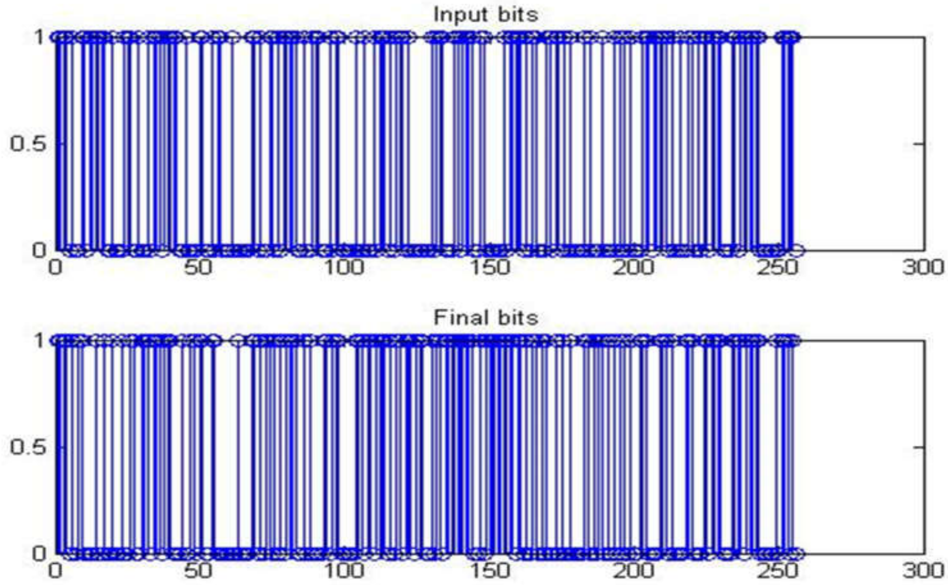


Fig 9: Simulated waveform for OFDM input and final bits

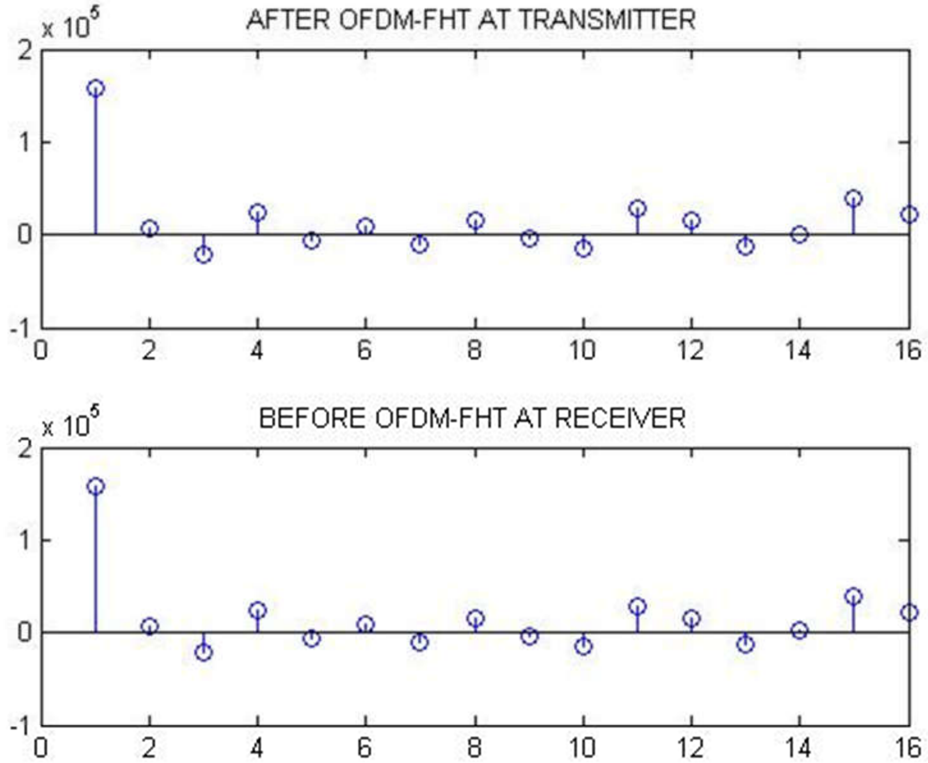


Fig 10: Simulated waveform for OFDM-FHT after transmitter and before receiver signal

OFDM with companding

(i)μ-law companding

We are adding the μ-law comapanding technique to the OFDM with FHT algorithm, then we observed the reduced PAPR compared to basic OFDM system.

```
FHT =

   1.8668e-04


papr_mu =

    2.0510


FHT =

   1.2997e-04


noe =

    80


ber =

    0.3125


ProgramT =

    2.1250
```

Fig 11: Results of OFDM with μ -law companding

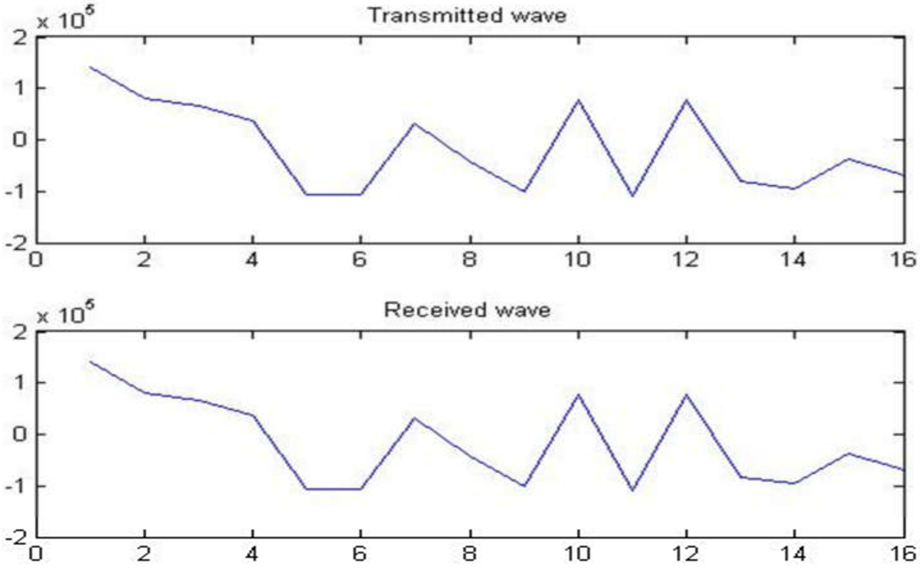


Fig 12 Simulated waveform for OFDM μ - law transmitted and received signal

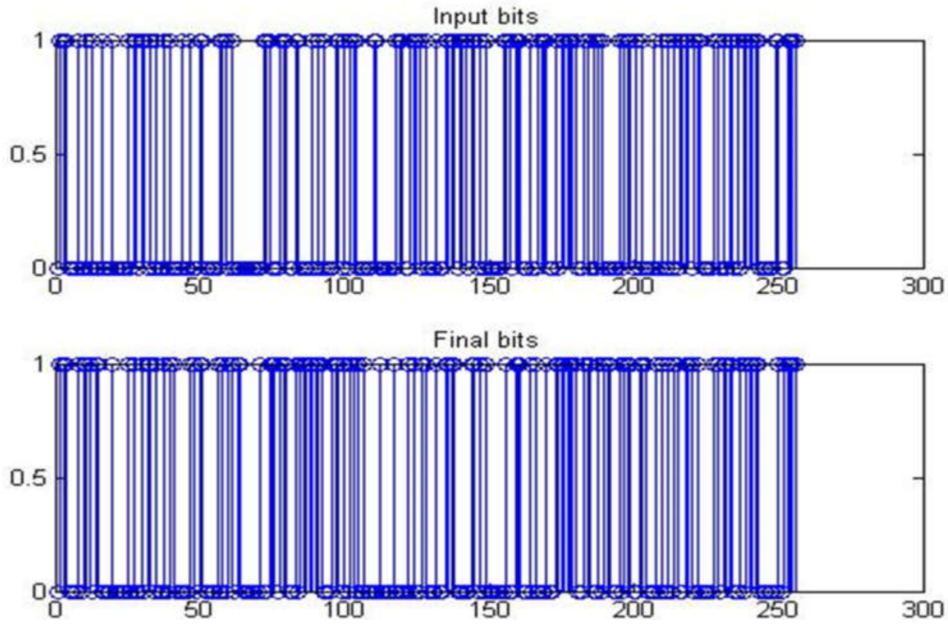


Fig 13: Simulated waveforms for OFDM μ - law transmitted and received bits

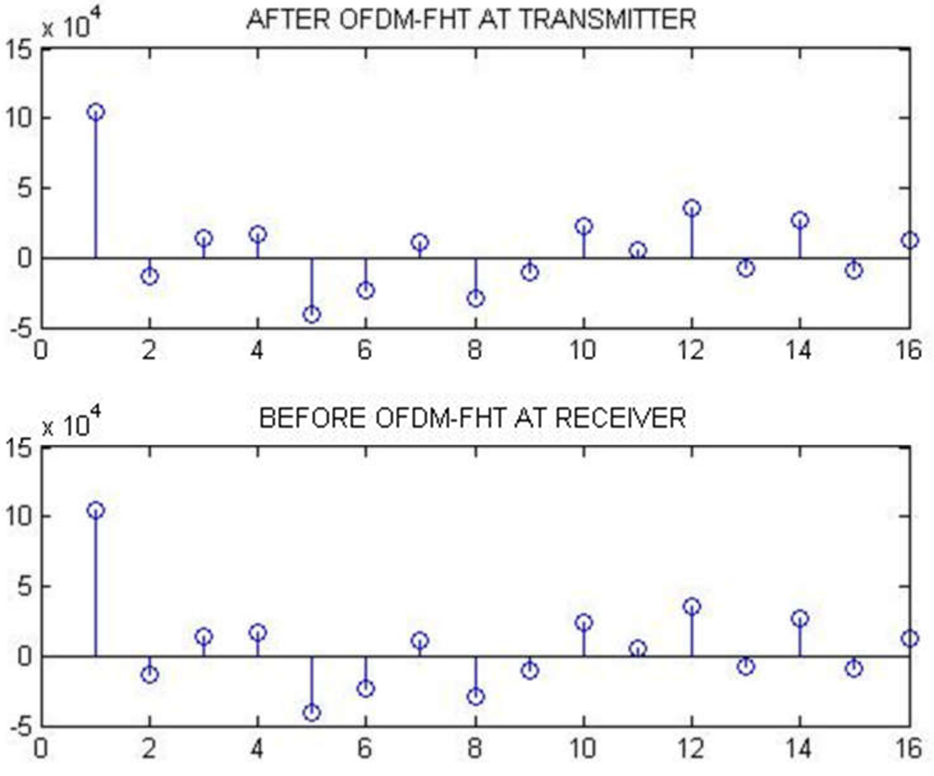
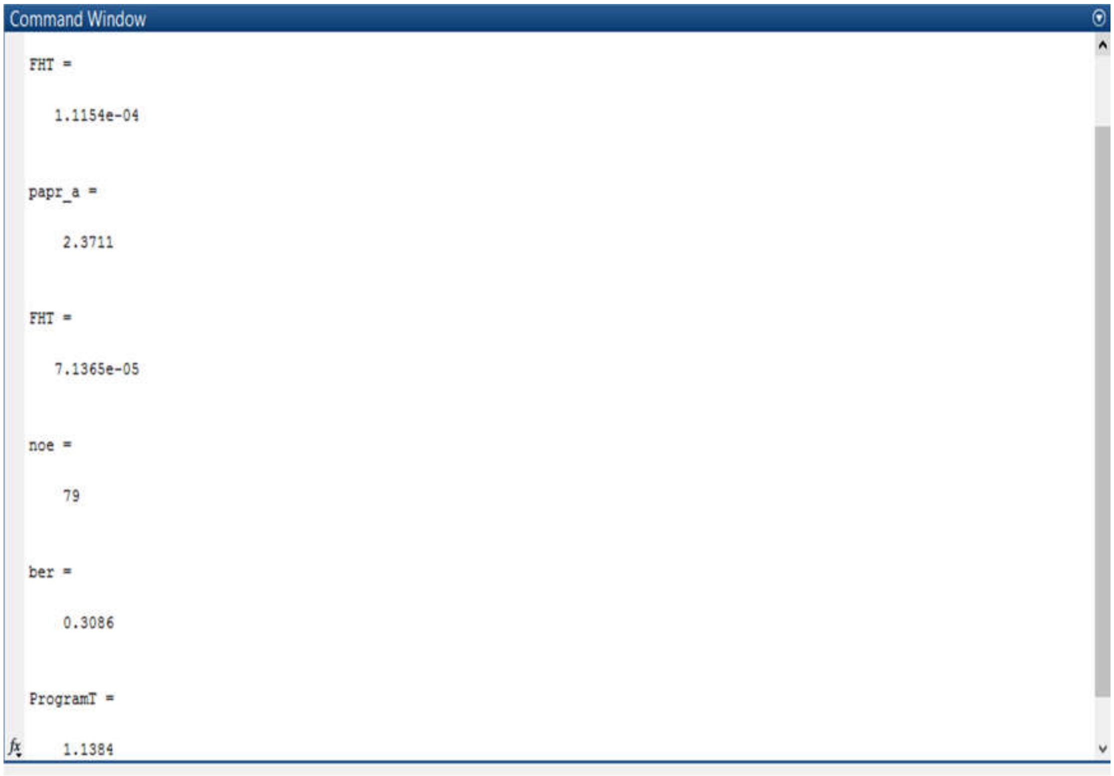


Fig 14: Simulated results of OFDM μ - law after transmitter and before receiver signal

(ii)A-law companding

We are adding the A-law companding technique to the OFDM with FHT algorithm, then we observed the reduced PAPR compared to basic OFDM system.



```
FHT =

   1.1154e-04


papr_a =

    2.3711


FHT =

   7.1365e-05


noe =

    79


ber =

    0.3086


ProgramT =

    1.1384
```

Fig 15: Results of OFDM with A-law companding

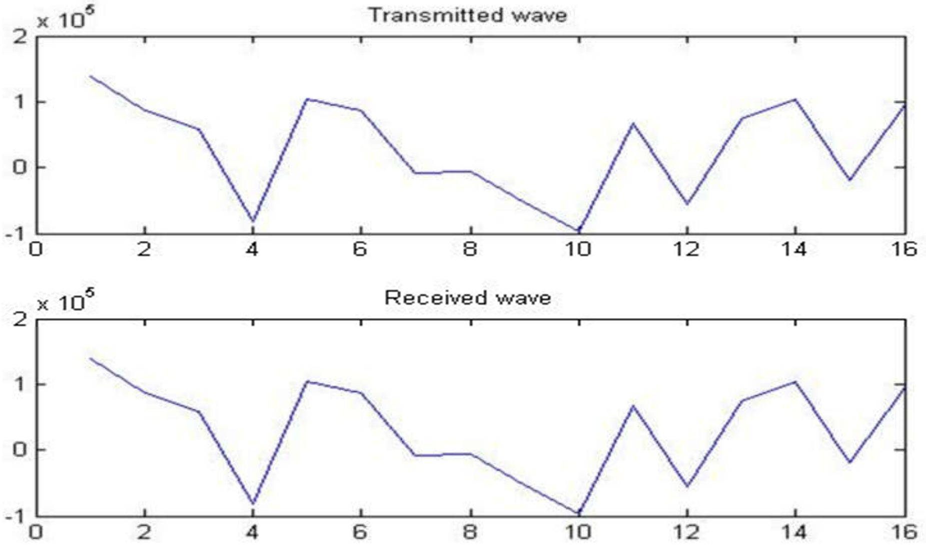


Fig 16: Simulated waveform for OFDM-A law transmitted and received signals

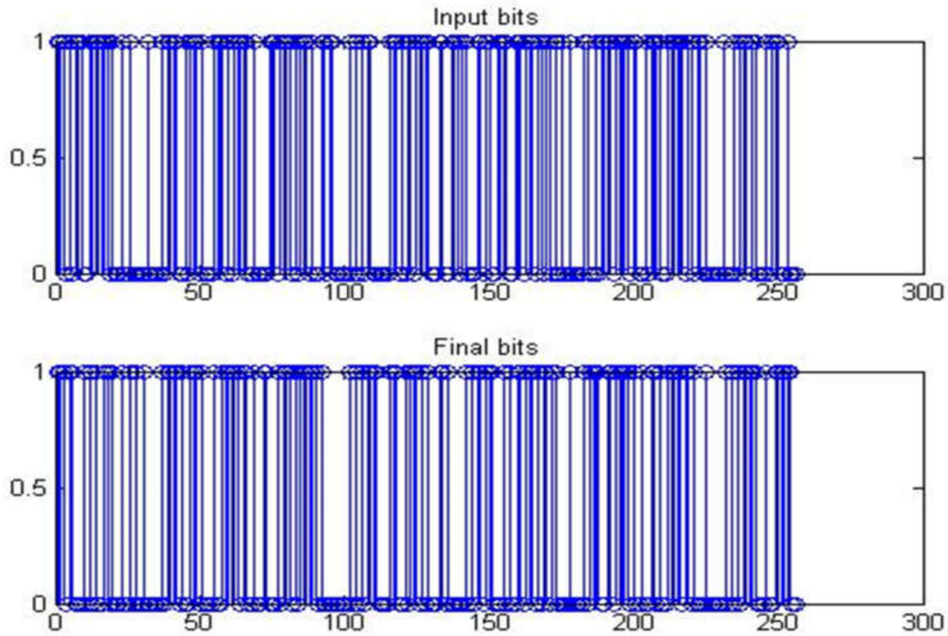


Fig 17: Simulated waveform for OFDM-A law input and output bits

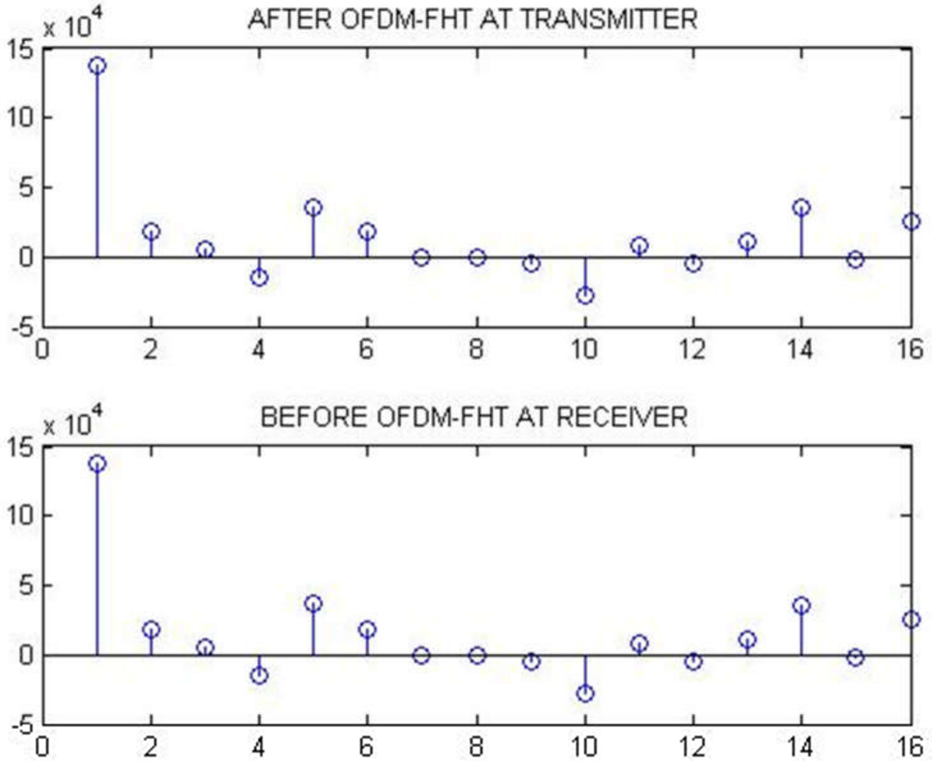


Fig 18: Simulated waveform for OFDM-A law after transmitter and before receiver signal

Comparison between existing OFDM and proposed OFDM

Parameters	**OFDM with FFT (Existing)**	**OFDM with FHT (Proposed)**
Modulation techniques	Used	Not used
Transformation techniques	Fourier transform used	Hartley transform used
Number of errors	101	80
Transmission time	0.2004	1.8668e-04
Reception time	0.1351	1.2997e-04
Bit error rate	0.3945	0.3125
PAPR	5.9813	2.0510

X. CONCLUSION

Orthogonal Frequency Division multiplexing (OFDM) is widely used in many digital communication systems due to its advantages such as high bit rate, strong immunity to multipath loss and high efficiency. In this paper, we presented a Hartley Transform based OFDM for optical communication. In particular, the Hartley Transform is used for reducing the complexity. The performance of Fast Hartley Transform based OFDM is carried out using same input data without using any modulation technique. The simulated result and comparison table shows the improvement in time and number of errors reduction. At the same time, reduced the PAPR using companding techniques also proposed. The overall technique used in optical communication at SNR=50.

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