Genetic Algorithm in Partial Transmit Sequence to Reduce Peak to Average Power Ratio in Orthogonal Frequency Division Multiplexing

A thesis report submitted in partial fulfillment of the requirements

for the award of the degree of

BACHELOR OF TECHNOLOGY

in

ELECTRONICS AND COMMUNICATION ENGINEERING

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DEPARTMENT OF ELECTRONICS AND COMMUNICTION ENGINEERING

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CERTIFICATE

This is to certify that the Main Project entitled **"Genetic Algorithm in Partial Transmit Sequence to Reduce Peak to Average Power Ratio in Orthogonal Frequency Division Multiplexing"** is being submitted by Y. M. Sri Harika (15B01A04H9), M. Divya Shree (15B01A0495), Usha Vanaja Srilakshmi. P (15B01A04G1) N. Bala Durga (15B01A04A5). In partial fulfillment of the requirement for the award of the degree of Bachelor of Technology in ELECTRONICS AND COMMUNICATION ENGINEERING, to Shri Vishnu Engineering College for women (Autonomous), Bhimavaram is a record of bonafide work done by them under our guidance and supervision.

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ABSTRACT

In recent years, OFDM has gained a lot of interest in diverse-digital communication applications. This has been due to its favorable properties like high spectral efficiency and robustness to channel fading. Some of the major drawbacks in OFDM are its high peak-to-average-power ratio (PAPR) of the transmitted signals and the synchronization of signals. OFDM consist of large number of independent subcarriers, as a result of which the amplitude of such signal can have high peak values. Significant reduction in PAPR has been achieved using Partial Transmit Sequence (PTS) which comes under signal scrambling techniques. The genetic algorithm based PTS scheme (GA-PTS) is a novel PAPR reduction method, which has lower computational load than the PTS technique and is a suboptimal PAPR reduction method. GA-PTS, which uses genetic algorithm as the selection mechanism of PTS scheme for finding the proper phase factor to minimize the PAPR of transmitted signal.

Index terms: OFDM – Orthogonal Frequency Division Multiplexing, PTS – Partial Transmit Sequence, PAPR – Peak to Average Power Ratio, Subcarriers, GA – Genetic Algorithm.

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UNIT 1

INTRODUCTION

Since the very genesis of man, communication has been one of the main aspects in human life. Previously various methods like sign languages were implemented for this purpose. As various civilizations started coming into existence, many innovative ideas came into the minds of the people – special birds and human messengers were employed to meet these challenges. As ages rolled by, post system developed and transportation vehicles like trains and ships used to maintain link between people miles apart. But by the turn of the nineteenth century, a great leap in communication system was observed when wireless communication was introduced.

This history of modem wireless communications started in 1896 with Marconi, who demonstrated wireless telegraphy by sending and receiving Morse code, based on long-wave (>> 1 km wavelength) radiation, using high-power transmitters. After the advent of wireless communication huge change has been observed in the life style of people.

Wireless communication which was initially implemented analog domain for transfer has a now-a-days mostly done in digital domain. Instead of a single carrier in the system multiple sub-carriers are implemented to make the process easier.

A simple communication system consists of a transmitter end which send the data and a receiver end at which data is received as shown in Fig 1.1.

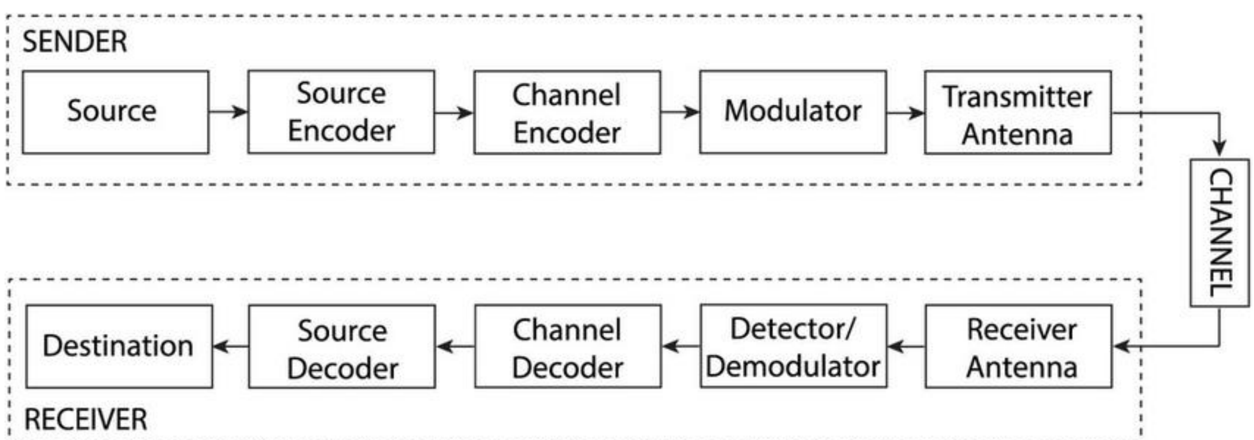

Fig 1.1: Block Diagram of Communication System

1.1 Wireless Networks

Wireless local-area networks use high-frequency electromagnetic waves, either infrared (IR) or radio frequency (RF) to transmit information from one point to another. Wireless Communication doesn't require any physical medium but propagates the signal through space. Sine, space only allows for signal transmission without any guidance, the medium used in Wireless Communication is called Unguided Medium.

It is generally agreed that RF will be more practical than IR in home and office networking, since it can propagate through solid obstacles. Traffic from multiple users is modulated onto the radio waves at the transmitter, and extracted at the receiver.

Multiple radio carriers can coexist in the same physical space, and at the same time, without interfering with each other by transmitting at different frequencies (frequency-division multiple access or FDMA) in different time slots, (time-division multiple access or TDMA), or using specific codes for each message (code division multiple access or CDMA).

1.1.1 Multipath Channels

In Frequency Division Multiple Access (FDMA) systems the communication is done through multiple channels which leads to multipath fading. The wireless environment is highly unstable and fading is due to multipath propagation. Multipath propagation leads to rapid fluctuations of the phase amplitude of the signal.

The presence of reflectors in the environment surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Components may have different channel gain and time delay. This combined effect causes what we known ad multipath fading.

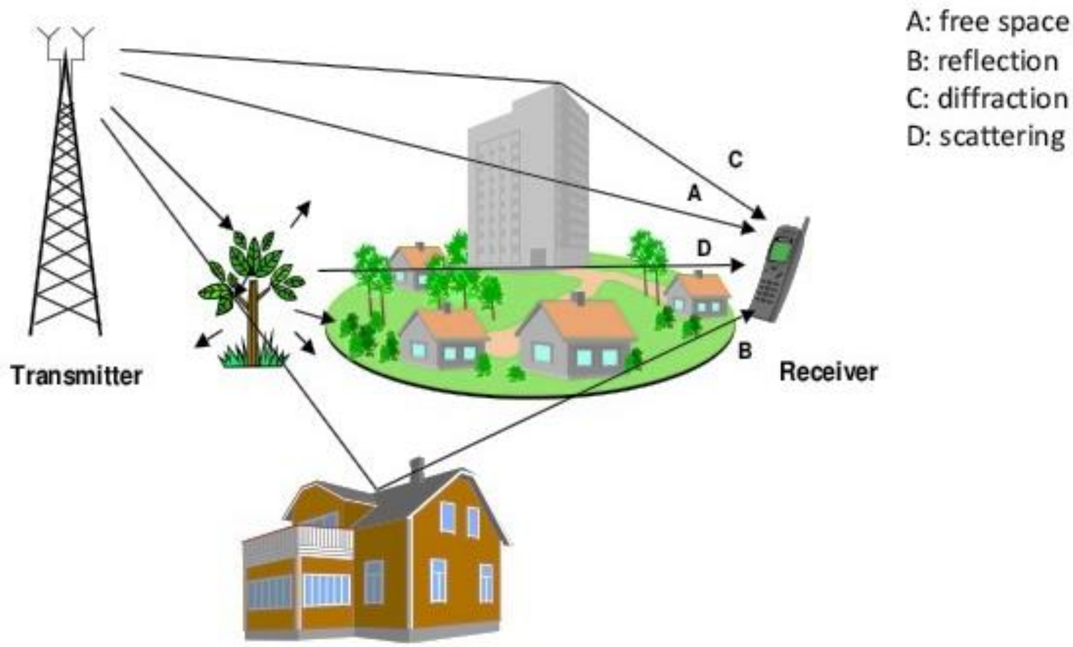

Fig 1.2: Multipath Channels

1.1.2 Multipath Fading

Components may have different channel gain and time delay. This combined effect causes what we known as multipath fading.

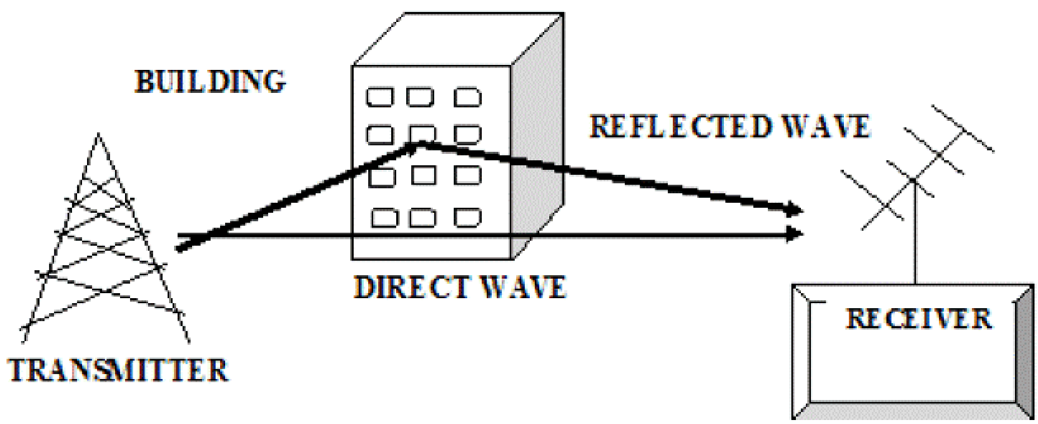

Fig 1.3: Occurrence of Multipath Fading

1.2 Interference

Wireless Communication systems use open space as the medium for transmitting signals. As a result, there is a huge chance that radio signals from one wireless communication system or network might interfere with other signals.

The best example is Bluetooth and Wi-Fi (WLAN). Both these technologies use the 2.4GHz frequency for communication and when both of these devices are active at the same time, there is a chance of interference.

1.2.1 Inter Channel Interference (ICI)

Often signal bandwidth of adjacent carrier frequencies overlap with each other giving rise to inter channel interference. Presence of Doppler shifts and frequency and phase offsets in an OFDM system causes loss in orthogonality of the sub-carriers. As a result, interference is observed between sub-carriers.

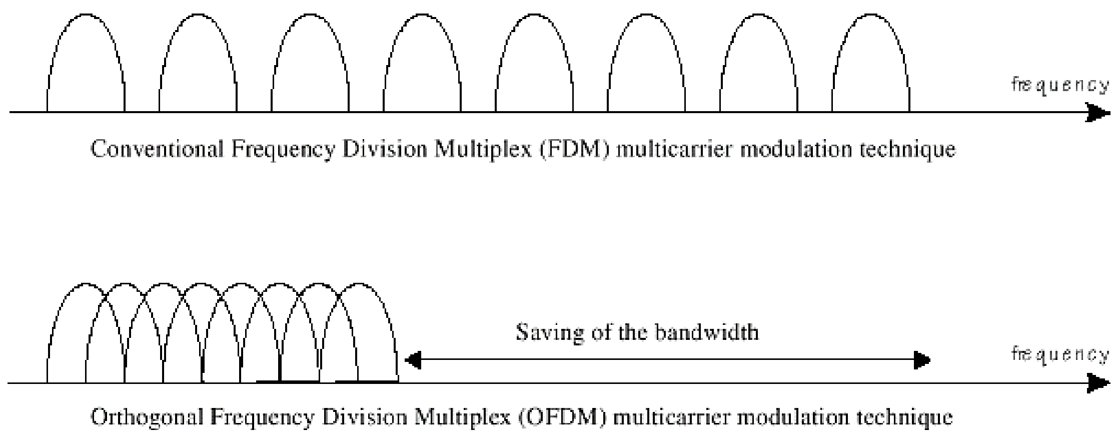

Fig 1.4: Occurrence of ICI

Guard bands are used to separate them in a frequency domain. This concept is used in FDMA. By the insertion of guard band interval, the carrier frequencies are prevented from getting overlapped with each other as shown in Fig 1.5.

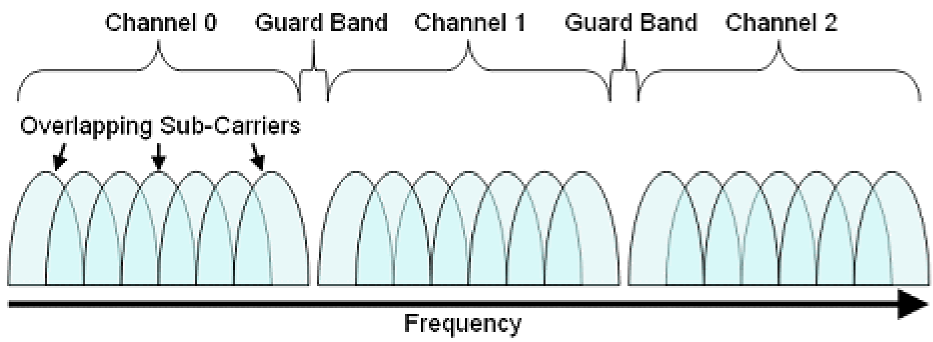

Fig 1.5: Guard Band Insertion

1.2.2 Inter Symbol Interference (ISI)

As a consequence of multipath propagation the duration of a symbol gets extended. This may interfere with the next symbol. Inter-Symbol Interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect a noise, thus making the communication less reliable.

SI usually caused by multipath propagation or the inherent non - linear frequency response of a channel causing successive symbols to blur together. The presence of ISI in the system introduces error in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI and thereby the digital to its destination with the smallest error rate possible.

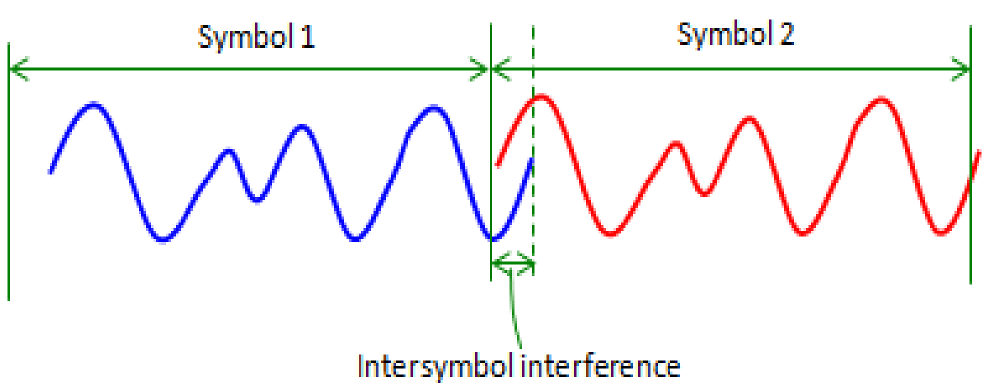

Fig 1.6: Occurrence of ISI

1.2.3 Cyclic Prefix (CP)

The Cyclic Prefix or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is removed at the receiver before demodulation.

The cyclic prefix has two important benefits –

- The cyclic prefix acts as a guard interval. It eliminates the inter symbol interference from the previous symbol.
- It acts as a repetition of the end of the symbol thus allowing the linear convolution of a frequency – selective multipath channel to the modelled as circular convolution which is in turn maybe transformed to the frequency domain using a Discrete Fourier Transform. This approach allows for simple frequency – domain processing such as channel estimation and equalization.

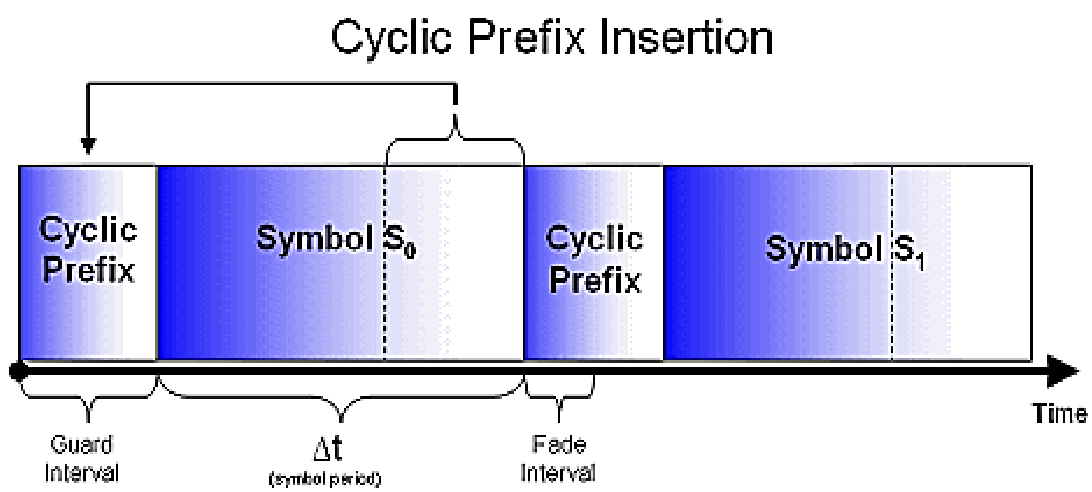

Fig 1.7: Cyclic Prefix (CP) Insertion

1.3 Need for Multicarrier Modulation

Multi- Carrier Modulation (MCM) is the principle of transmitting data by dividing the stream into several bit streams, each of which has a much lower bit rate, and by using these sub streams to modulate several carriers. It is a method of transmitting data by splitting it into several components, and sending each of these components, and sending each of these components over separate carrier signals. The individual carriers have narrow bandwidth, but the composite signal can have broad bandwidth.

The advantages of MCM include relative immunity to multipath fading, less susceptibility to interference, and enhanced immunity to inter-symbol interference. Recently, MCM has attracted attention as a means of enhancing the bandwidth of digital communications. The scheme is used in some audio broadcast services.

A special form of MCM, Orthogonal Frequency Division Multiplexing (OFDM), with densely spaced subcarriers with overlapping spectra of the modulating signal, was patented. OFDM abandoned the use of step band pass filters that completely separated the spectrum of individual subcarriers, as it was common practice in older Frequency Division Multiplexing systems. Instead, OFDM time-domain waveforms are chosen such that mutual orthogonality is ensured even though spectra may overlap.

It appeared that such waveform can be generated using a Fast Fourier Transform at the transmitter and receiver. Implementation aspects such as the complexity of a Fast Fourier Transform, appeared prohibitive, such as the stability of oscillators in transmitter and receiver, the linearity required in RF power amplifiers, and the power back-off associated with this.

1.4 Orthogonality

Two periodic signals are orthogonal when the integral of their product over one period is equal to zero.

For the case of continuous time:

$$\int_0^T \boldsymbol{cos(2\,\pi nft)cos(2\pi mft)dt = 0}, \qquad \ldots\ldots\ldots\ldots..(1.1)$$

For the case of discrete time:

$$\sum_0^{N-1} \mathbf{cos}\left(\frac{2\pi kn}{N}\right) \mathbf{cos}\left(\frac{2\pi km}{N}\right) \boldsymbol{dt = 0} \qquad \ldots\ldots\ldots\ldots..(1.2)$$

Where m ≠ n in both cases.

1.5 Orthogonal Frequency Division Multiplexing

OFDM is a most attractive fast growing multi-carrier modulation technology enabling high capacity of data transmission over a single path. Wireless communication system is developing and evolving at furious pace.

In today's era of mobile and high-speed wireless communications, OFDM technology is having special Multi-Carriers Modulation transmission scheme which is considered as either a modulation technology or multiplexing technique to enable transmission of multiple signals together at same time, over a single transmission path.

After more than thirty years of research and developments carried out in different places, orthogonal frequency division multiplexing (OFDM) has been widely implemented in high speed digital communications.

In telecommunications, Orthogonal Frequency Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, used in applications such as digital television and audio broadcasting, DSL internet access, wireless networks, power line networks, and 4G mobile communications.

Orthogonal Frequency Division Multiplexing (OFDM) transmission scheme is another type of a multichannel system, which is similar to the FMT transmission scheme in the sense that it employs multiple subcarriers. The multiple orthogonal subcarrier signals, which are overlapped in spectrum, can be produced by generalizing the single-carrier Nyquist criterion into the multi-carrier criterion.

In practice, Discrete Fourier Transform (DFT) and inverse DFT (IDFT) processes are useful for implementing these orthogonal signals. Note that DFT and IDFT can be implemented efficiently by using Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT), respectively.

The principle condition of OFDM is dividing a single high-data-rate stream into a multiple number of lower rate streams being transmitted simultaneously at same pace over same narrower sub channels. Hence it not only uses frequency modulation technique. Term “Orthogonality” defines mathematical relationship between frequencies of the individual subcarriers in the system. It has many advantages, such as senior band efficiency and less impact of inter symbol interference.

In recent years OFDM has gained a lot of interest in diverse digital communication applications. This has been due to its favourable properties like high spectral efficiency and robustness to channel fading.

Today, OFDM is mainly used in digital audio broadcasting system (DAB) initiated by CCETT in France, and digital video broadcasting (DVB) enabling an end-to-end digital transmission system, which is spectrally efficient and rugged against channel distortions.

This can be used for services such as HDTV, offering increased capacity for program broadcasting. In the conventional serial data transmission system, the information symbols are transmitted sequentially where each symbol occupies the entire available spectrum bandwidth.

- **Development of OFDM Systems**

The development of OFDM systems can be divided into three parts. This comprises of Frequency Division Multiplexing, Multicarrier Communication and Orthogonal Frequency Division Multiplexing.

- **Frequency Division Multiplexing**

Frequency Division Multiplexing is a form of a signal multiplexing which involves assigning non-overlapping frequency ranges or channels to different signals or to each user of a medium. A gap or guard band is left between each of these channels to ensure that the signal of one channel does not overlap with the signal from an adjacent one. Due to lack of digital filters it was difficult to filter closely packed adjacent channels.

- **Multicarrier Communication**

As it is ineffective to transfer a high rate date stream through a channel, the signal is split to give a number of signals over that frequency range. Each of these signals are individually modulated and transmitted over the channel. At the receiver end, these signals are fed to a de-multiplexer where it is demodulated and recombined to obtain the original signal.

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. Here the different carriers are orthogonal to each other, that is, they are totally independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other.

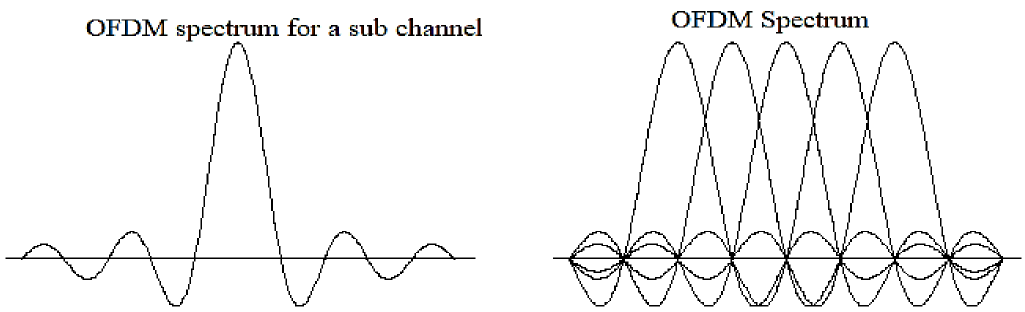

Fig 1.8: OFDM Spectrum

1.6 Block Diagram of OFDM System

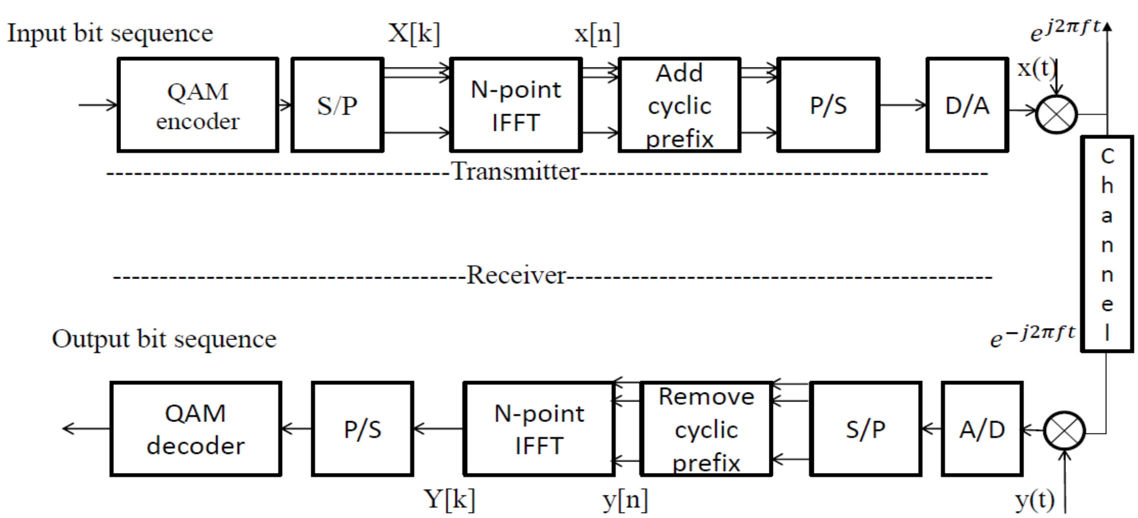

Fig 1.9: OFDM System Block Diagram

- **Modulation**

Modulation is the technique by which the signal wave is transformed in order to send it over the communication channel in order to minimize the effect of noise. This is done in order to ensure that the received data can be demodulated to give back the original dat. In an OFDM System, the high data rate information is divided into small packets of data which are placed orthogonal to each other. This is achieved by modulating the data by a desirable modulation technique (QPSK).

- **QPSK:**

Quadrature Phase Shift Keying (QPSK) is another modulation technique which actually transmits two bits per symbol. In other words, a QPSK symbol represents 00, 01, 10, or 11 instead of 0 or 1. In QPSK, the carrier varies in terms of phase, not frequency, and there are four possible phase shifts.

We have 360° of phase to work with and four phase states, so our four QPSK phase shifts are 45°, 135°, 225°, and 315°. Compared to modulation schemes that transmit one bit per symbol, QPSK is advantageous in terms bandwidth efficiency. BPSK uses two possible phase shifts instead of four, and thus it can transmit only one bit per symbol.

The base band signal has a certain frequency, and during each symbol period, one bit can be transmitted. A QPSK system can use a baseband signal of the same frequency, yet it transmits two bits during each symbol period. Thus, its bandwidth efficiency is (ideally) higher by a factor of two.

After modulation, IFFT is performed on the modulated signal which is further processed by passing a cyclic prefix to the signal. OFDM can be generated using multiple modulated carriers transmitted in parallel.

- **Inverse Fast Fourier Transform (IFFT)**

By working with OFDM in frequency domain the modulated QPSK data symbols are fed into the orthogonal sub-carriers. But transfer of signal over a channel is only possible in the time-domain. For which we implement IFFT which converts the OFDM signal in from frequency domain to time domain. IFFT being a linear transformation can be easily applied to the system.

IFFT expression is given in equation (1.3)

$$X_n = \frac{1}{N}\sum_{k=0}^{N-1} X_k\, e^{2\pi ikn/N} \ldots \ldots \ldots \ldots.. (1.3)$$

- **Communication Channel**

This is the channel through which the data is transferred. Presence of noise in this medium effects the signal and causes distortion in its data content. The performance of a communication system is quantified by the probability of bit detection errors in the presence of thermal noise (Additive White Gaussian Noise).

- **AWGN :**

- In the context of wireless communications, the main source of thermal noise is addition of random signals arising from the vibration of atoms in the receiver electronics.
- Just like the white color which is composed of all frequencies in the visible spectrum, white noise refers to the idea that it has uniform power across the whole frequency band.
- As a consequence, the spectral density of white noise is ideally flat for all frequencies. The probability distribution of the noise samples is Gaussian, i.e., in time domain, the samples can acquire both positive and negative values and in addition, the values close to zero have a higher chance of occurrence while the values far away from zero are less likely to appear.

An AWGN channel is the most basic model of a communication system. Even simple practical systems suffer from various kinds of imperfections in addition to AWGN. Examples of systems operating largely in AWGN conditions are space communications with highly directional antennas and some point-to-point microwave links.

- **Fast Fourier Transform (FFT)**

FFT can be applied at the receive end to regain the original data in frequency domain at the receiver end. Since the basis of Fourier transform is orthogonal in nature we can implement to get the time domain equivalent of the OFDM signal from its frequency components. Usually, in practice we implement Fast Fourier Transformation for an N-input signal system because of the lower hardware complexity of the system.

FFT expression is given in equation (1.4)

$$X_k = \sum_{n=0}^{N-1} X_n \, e^{2\pi ikn/N} \qquad \dots \dots \dots \dots .(1.4)$$

- **Demodulation**

Demodulation is the technique by which the original data (or a part of it) is recovered from the modulated signal which is received at the receiver end. In this case, the received data is first made to pass through a low pass filter and the cyclic prefix is removed.

FFT of the signal is done after it is made to pass through a serial-to-parallel converter. A demodulator is used, to get back the original signal. The bit error rate and the signal-to-noise ratio is calculated by taking into consideration the unmodulated signal data and the data at the receiving end.

1.7 Advantages & Disadvantages OFDM System

- **Advantages**

- Due to increase in symbol duration, there is reduction in delay spread.
- Addition of guard band almost removes ISI and ICI in the system.
- Conversion of the channel into many narrowly spaced orthogonal sub-carriers render it remains it immune to frequency selective fading.
- Can be efficiently implemented using IFFT.
- As it is evident from the spectral pattern of an OFDM system, orthogonally placing the sub-carriers lead to high spectral efficiency.

- **Disadvantages**

- These systems are highly sensitive to Doppler shifts which affect the carrier frequency offsets, resulting in ICI.
- Presence of a large number of sub-carriers with varying amplitude results in a high Peak-to-Average Power Ratio (PAPR) of the system, which in turn hampers the efficiency of the RF amplifier.

UNIT 2

PEAK TO AVERAGE POWER RATIO

OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non-linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem one faces while implementing this system is the high peak-to-average power ratio of this system.

Presence of large number of independently modulates sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of same phase produces a peak which is N times the average signal.

The major disadvantages of a high PAPR are-

1. Increased complexity in the analog to digital and digital to analog converter.

2. Reduction is efficiency of RF amplifiers.

Regularity and application constrains can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate. This has a harmful effect on the battery lifetime. Thus in communication system, it is observed that all the potential benefits of multi carrier transmission can be out-weighed by a high PAPR value.

The signal with a complex envelope can be represented by using the equation (2.1):

$$x(t) = \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} X(n)e^{j2\pi fnt}, 0 \leq t \leq Nt \qquad \ldots\ldots\ldots(2.1)$$

Here N denotes number of subcarriers used.

The PAPR of the transmitted signal is defined as

$$\text{PAPR} = \frac{max(|x(t)|)}{E|x(t)|2} \quad \text{……….. (2.2)}$$

Where E [.] denotes the expected value.

The mathematical equation of PAPR is given in equation (2.3)

$$\text{PAPR} = 10 \log_{10} \frac{\max |x(t)|^2}{\frac{1}{\sqrt{Nt}} \int_0^{NT} |x(t)|^2 dt} \quad \text{………. (2.3)}$$

Reducing the max |x (t)| is the principle goal of PAPR reduction techniques. Since, discrete-time signals are dealt with in most systems, many PAPR techniques are implemented to deal with amplitudes of various samples of x (t). Due to symbol spaced output in the first equation we find some of the peaks missing which can be compensated by oversampling the equation by some factor the true PAPR value.

The performance of a PAPR reduction scheme is usually demonstrated by three main factors:

- Complementary Cumulative Distributive Function(CCDF),
- Bit Error Rate(BER),
- Spectral Spreading.

2.1 Complementary Cumulative Distribution Function (CCDF)

In practice, the empirical CCDF is the most informative metric used for evaluating the PAPR. PAPR reduction capability is measured by the amount of CCDF reduction achieved achieved. CCDF provides an indication of the probability of the OFDM symbol and is given by the equation below equation 2.4

$$\text{CCDF} = P_r\,(\text{PAPR} > P_0) \quad \text{………(2.4)}$$

Where P_r is the probability distribution function.

By implementing the central limit theorem for a multicarrier signal with a large number of sub-carriers, the real and imaginary part of the time domain signals have a mean of zero and a variance of 0.5 and follow a Gaussian distribution. So Rayleigh distribution is followed for the amplitude of the multicarrier signal, where as a central chi-square distribution with two degrees of freedom is followed for the power distribution of the system.

2.2 Bit Error Rate (BER)

The performance of a modulation technique can be quantified in terms of the required signal-to-noise ratio (SNR) to achieve a specific bit error rate (BER). Although the main focus of PAPR reduction techniques is to reduce the CCDF, this is usually achieved at the expense of increasing the BER.

Clipping the high peaks of the OFDM signal by the PA causes a substantial in-band distortion that leads to higher BER. Other techniques may require that side information be transmitted as well. If the side information is received incorrectly at the receiver, the whole OFDM symbol is recovered in error and the BER performance degrades.

2.3 Spectral Spreading

Due to the limit imposed on the maximum peak of the OFDM signal by the PA, an increase is encountered in both the in-band and out-of-band distortions. The second causes undesirable increase in the power of the side lobes of the power spectral density (PSD) of the OFDM signal. This effect is referred to as spectral spreading or spectral regrowth. When the nonlinearity of the PA is higher, and the spectral spreading is higher.

Spectral spreading leads to higher interference between the sub bands of the OFDM signal, unless the frequency separation between adjacent subcarriers is also increased to maintain orthogonality. However, this solution has the disadvantage of lowering the spectral efficiency.

2.4 PAPR Reduction Techniques

A large PAPR would drive power amplifiers at the transmitter into saturation, producing interference among the subcarriers that degrades the BER performance and corrupts the spectrum of the signal. To avoid driving the power amplifier into saturation, the average power of the signal may be reduced.

However, this solution reduces the signal-to noise ratio and, consequently, the BER performance. Therefore, it is preferable to solve the problem of high PAPR by reducing the peak power of the signal. Many PAPR reduction techniques have been proposed in the literature.

2.4.2 Companding Transforms

Companding transforms are typically applied to speech signals to optimize the required number of bits per sample. Since OFDM and speech signals behave similarly in the sense that high peaks occur infrequently, same companding transforms can also be used to reduce the OFDM signals PAPR. Besides having relatively low computational complexity compared to other PAPR reduction techniques, companding complexity is not affected by the number of subcarriers.

Also, companding does not require side information and hence does not reduce bit rate. Their simplicity of implementation and the advantages they offer make companding transforms an attractive PAPR reduction technique. The PAPR reduction obtained by companding transforms comes though with the price of increasing the BER.

2.4.3 Linear Block Coding

Instead of dedicating some bits of the code word to enhance BER performance, these bits are now dedicating to reduce PAPR. The goal is to choose the code words with low PAPR for transmission.

A simple linear block (LBC) scheme was proposed in where 3 bits are mapped into 4 bits by adding a parity bit. In a simple rate ¾ cyclic code is used for any number of subcarriers that is a multiple of 4 to reduce PAPR by more than 3dB. Similar performance with less complexity was obtained in using proposed sub-block coding (SBC) scheme, where long information sequences are divided into sub-block, and an odd parity bit is added to each sub-block.

2.4.4 Selective Mapping

Selective mapping (SLM) is a relatively simple approach to reduce PAPR. The main objective of this technique is to generate a set of data blocks at the transmitter end which represent the original information and then to choose the most favorable block among them for transmission.

The basic idea in SLM technique is to generate a set of sufficiently different candidate data blocks by the transmitter where all the data blocks represents the same information as the original data block and select the favorable having the least PAPR for transmission.

The main objective of this technique is to generate a set of data blocks at the transmitter end which represent the original information and then to choose the most favorable block among them for transmission. Among the modified data blocks, the one with the lowest PAPR is selected for transmission.

The amount of PAPR reduction for SLM depends on the number of phase sequences and the design of the phase sequences. Computational complexity, PAPR reduction capability are the major issues associated with SLM.

2.4.5 Partial Transmit Sequence

PTS technique is proposed by Miller and Hubber in 1997. It is implemented by dividing the initial data block into subsequent sub blocks with independent rotation factor. It is simply a modified form of selective mapping method unlike there is no necessary of sending any side information to the receiver.

This scheme avoids using the multiple IFFT modules that incur a heavy computational burden at the transmitter, thereby reducing the computational complexity. The reduction in complexity is however achieved at the cost of a slight degradation in PAPR reduction performance using PTS technique. This is implemented using MATLAB software.

UNIT 3

PARTIAL TRANSMIT SEQUENCE

Orthogonal frequency division multiplexing (OFDM) is one of the brilliant solutions to fasten wireless communication that is required for digital signal processing technology advance. It has been inserted in several application and standards as digital audio broadcasting (DAB), digital video broadcasting (DVB),

Although all advantages of OFDM, there are some obstacles such as high Peak to Average Power Ratio (PAPR) and Bit Error Rate (BER). The issue of PAPR that weaken system performance is related to the sensitivity of OFDM transmitter devices such as DAC (Digital to Analogue Convertor) and HPA (High Power Amplifier)

Several techniques have been suggested to decrease PAPR basically including four categories signal distortion, probabilistic (scrambling) techniques, coding methods, pre distortion methods. The concepts of PAPR reduction will be broaden for distortion less transmission and identifying better alternatives for performance increase, low data rate loss, efficient use of channel and overcoming complexity issues. Genetic algorithm is commonly applied for global optimum in combination problems; method of variable to variable crossover operation will enhance results to obtain best PAPR reduction with less BER.

3.1 Proposed Method

PTS Technique is proposed by Miller and Hubber in 1997. It is implemented by dividing the initial data block into subsequent sub blocks with independent rotation factor. It is simply a modified form of selective mapping method unlike there is no necessity of sending any side information to the receiver. Transmitting only part of data of varying sub-carrier which covers all the information to be sent in the signal as a whole is called Partial transmit sequence Technique.

Partial transmit sequence (PTS) is one of the attractive techniques to reduce the peak-to-average power ratio (PAPR) in orthogonal frequency division multiplexing (OFDM) system. The principle of PTS is to divide the input data block into several disjoint sub blocks and transform these sub blocks into partial transmit sequence by inverse fast Fourier transform these sub-blocks into partial transmit sequence by inverse fast Fourier transform (IIFT). Then, the transmitted sequence with minimum PAPR is selected from a set of candidate sequences formed by multiplying partial transmit sequence with a set of phase factors.

Partial transmit sequence (PTS) algorithm is a technique for improving the statistics of a multicarrier signal the basic idea of partial transmit sequence algorithm is to divide the original OFDM sequence into several sub-sequences and for each sub-sequences multiplied by different phases factors until an optimum value is chosen.

3.2 BLOCK DIAGRAM OF PTS

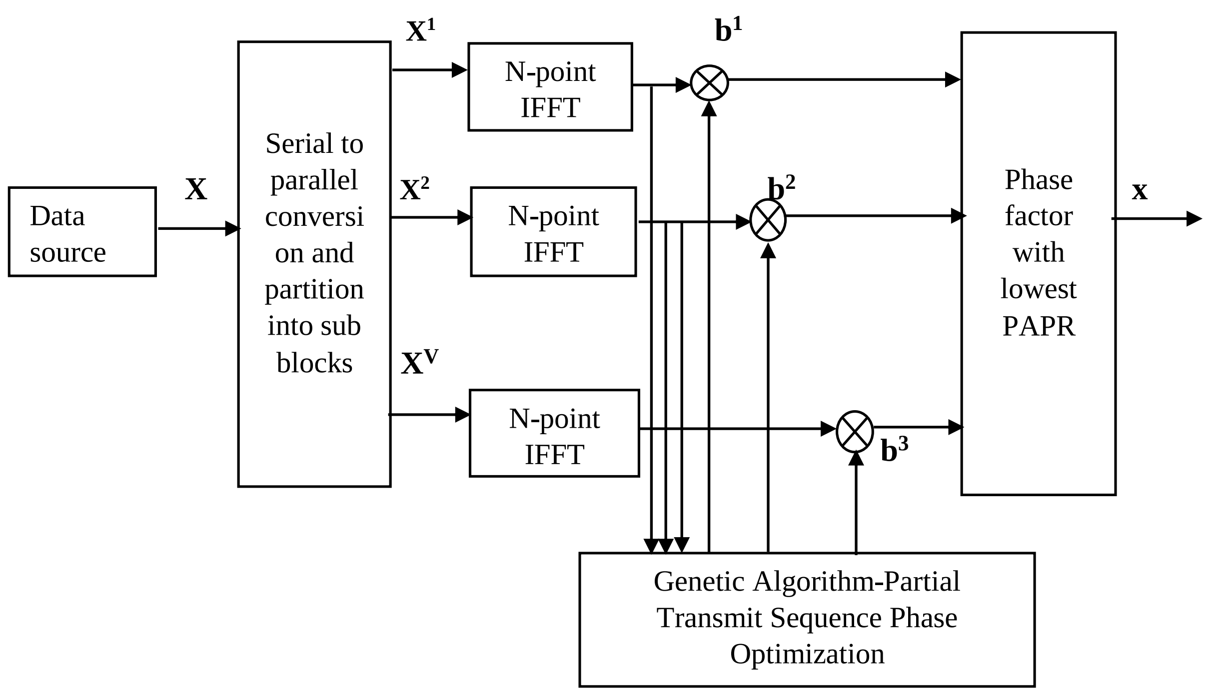

Fig 3.1: Block Diagaram of Partial Transmit Sequence

3.3.1 Working

In PTS, an input data block of length N is partitioned into a number of disjoint sub-blocks. Then each of these sub-blocks are padded with zeros and weighted by a phase factor. The commonly used phase sequence are the {+1, -1, +j and –j}. The sub-carrier in each sub-block are weighted by phase rotation. The phase rotations are selected such that the PAPR is minimized.

Then the sub-blocks are passed on to IFFT and multiplied by a corresponding phase value and then added up to get the output signal Whose PAPR will be comparatively less. Binary phase shift keying (BPSK) or Quadrature Phase Shift Keying (QPSK) or Quadrature Amplitude Modulation (QAM) is used to modulate the input and the modulated signal as input for the proposed block diagram of PTS

Consider the data block as vectors, X=[X1, X2………XN-1].Then, data vectors X are portioned into disjoint sets, represented by the vector {Xm, m=1, 2……..M}.

$$X' = \sum_{m-1}^{M} X_m b_m$$

This equation is to combine the M number of clusters and to obtain a optimal solution where {m=1, 2....M} are weighted phase factor Here X_m is the partially transmitted sequence the increase in the number of phase factors here X_m is the partially transmitted sequence.

3.3.2 Quadrature amplitude modulation (QAM)

QAM is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift Keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves of the same frequency, usually sinusoids, are out of phase with each other by 900 and they are called quadrature carriers or quadrature components – hence the names of the scheme.

The modulated waves are summed, and the final waveform is a combination of both phase shift keying (ASK), or, in the analog case, of phase modulation (PM) and amplitude modulation. In the analog case, of phase modulation (PM) and amplitude modulation. In the digital QAM case, a finite number of at least two phases and at least two amplitudes are used. PSK modulators are often designed using the QAM principle, but are not considered as QAM since the amplitude of the modulated carrier signal is constant.

QAM is used extensively as modulation scheme for digital telecommunication systems suitable constellation size, limited only by the noise level and linearity.

S (t) = d_1 (t) cos (2*pi*fc*t) + d_2 (t) sin (2*pi*fc*t)

Where, fc is carrier frequency,

t is time period.

In 64-QAM, each symbol is represented by 6 bits and in 256-QAM, each symbol is represented by 8 bits. As the level increases, QAM technique becomes more bandwidth efficient but it requires very robust algorithms in order to decode complex symbols to bits at receiver

3.3.3 Convolutional code

It is a type of error-correcting code that generates parity symbols via the sliding application of a Boolean polynomial function to a data stream. The sliding application represents the ‘convolution’ of the encoder over the data, which gives rise to the term ‘convolutional coding’. Convolutional codes are often described as continuous. However, it may also be said that convolutional codes have arbitrary block length. Convolutional encoded block codes typically employ termination. The arbitrary block length of convolutional codes can also be contrasted to classic block codes, which generally have fixed block lengths that are determined by algebraic properties. Serial-to-parallel conversion is nothing bit stream of data elements received in time sequence, i.e., one at a time, into a data stream consisting of multiple data elements transmitted simultaneously.

3.4 Sub block partition schemes for PTS

Sub block partition for PTS OFDM is method of division of sub bands into multiple disjoint sub blocks. In general, it can classified into three categories:

- Interleaved
- Adjacent
- Pseudorandom

As an example, allocation of sub band signals with above partition scheme are represented in fig 3.2, 3.3,3.4respectively, where weighted pulses represent the location of active sub bands in each sub block

$$X^{(i)} \text{ for } 0<i<L-1$$

➢ **Interleaved**

For the interleaved SPS, every sub bands signals spaced L a part is located at the same sub block.

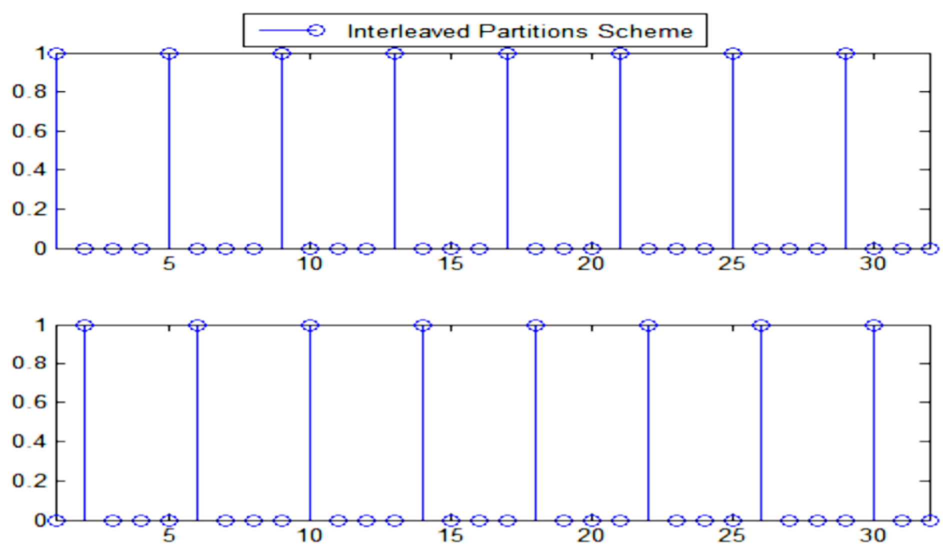

Fig 3.2: Interleaved Partition

- **Adjacent**

  In adjacent scheme, N/L successive sub bands are assigned into the same sub block sequentially.

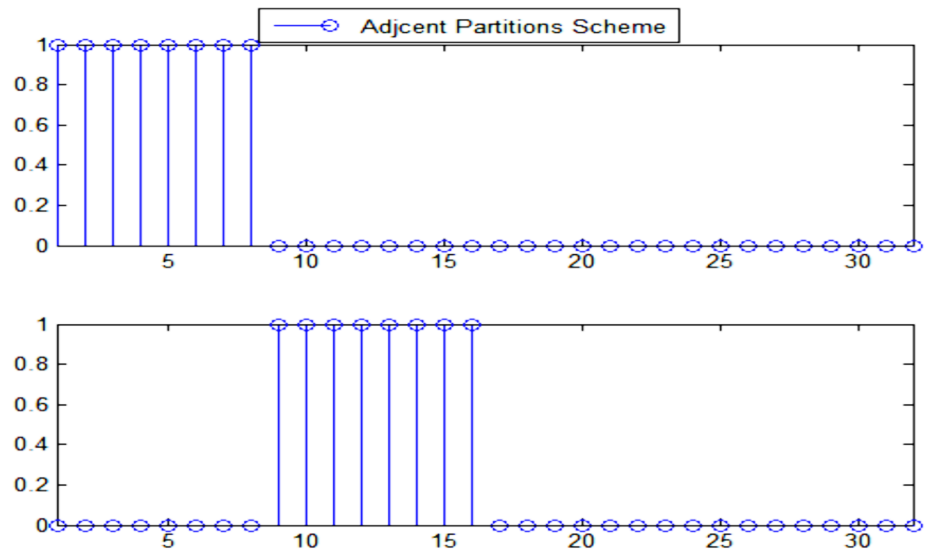

Fig 3.3: Adjacent Partition

- **Pseudo random SPS:**

  Each sub band signal is assigned into any one of the sub block randomly in pseudo random sequence.

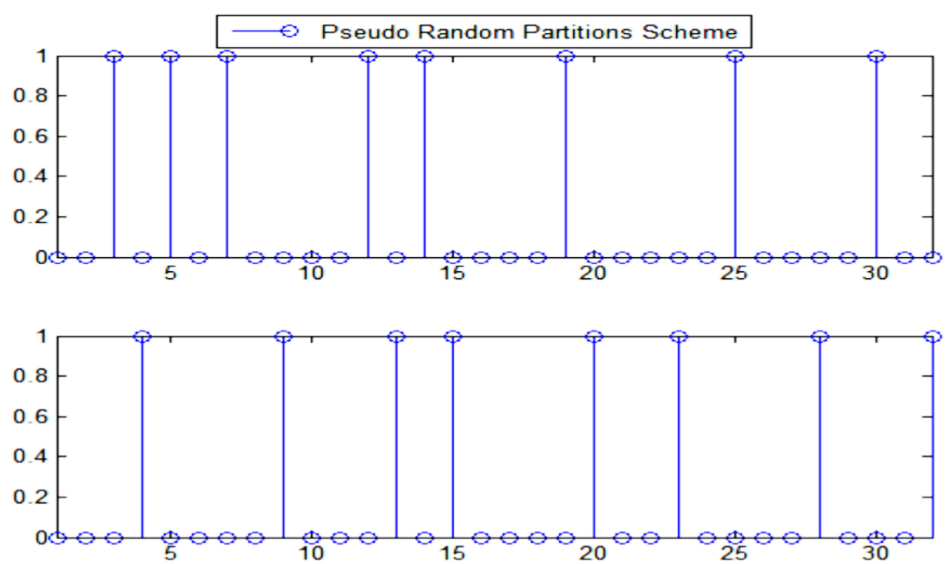

Fig 3.4: Pseudo random partition

In PTS OFDM each sub-block has to be modulated by IIFT independently the number of complex multiplications and additions required to modulate a sub block can be given as

$$n_{mul=} N/2 \log_2 N \quad ; n_{add} = N \log_2 N$$

Hence the computational complexity to transmit an OFDM symbol can be found in by multiplication and the number of sub blocks, L. It, therefore, can be verified that the complexity for PTS OFDM has been increased significantly as compared to the OFDM system without PTS algorithm.

3.5 Apply variable to variable crossover in genetic algorithm for OFDM systems

First ascending the values of the original OFDM signal in 8 elements then calculating PAPR for every 8 elements it is also ascending values for PAPR for every 8 elements called genes, selecting set of parents are half of the above genes then we have two set of parents.

3.5.1 Variable to variable crossover in genetic algorithm

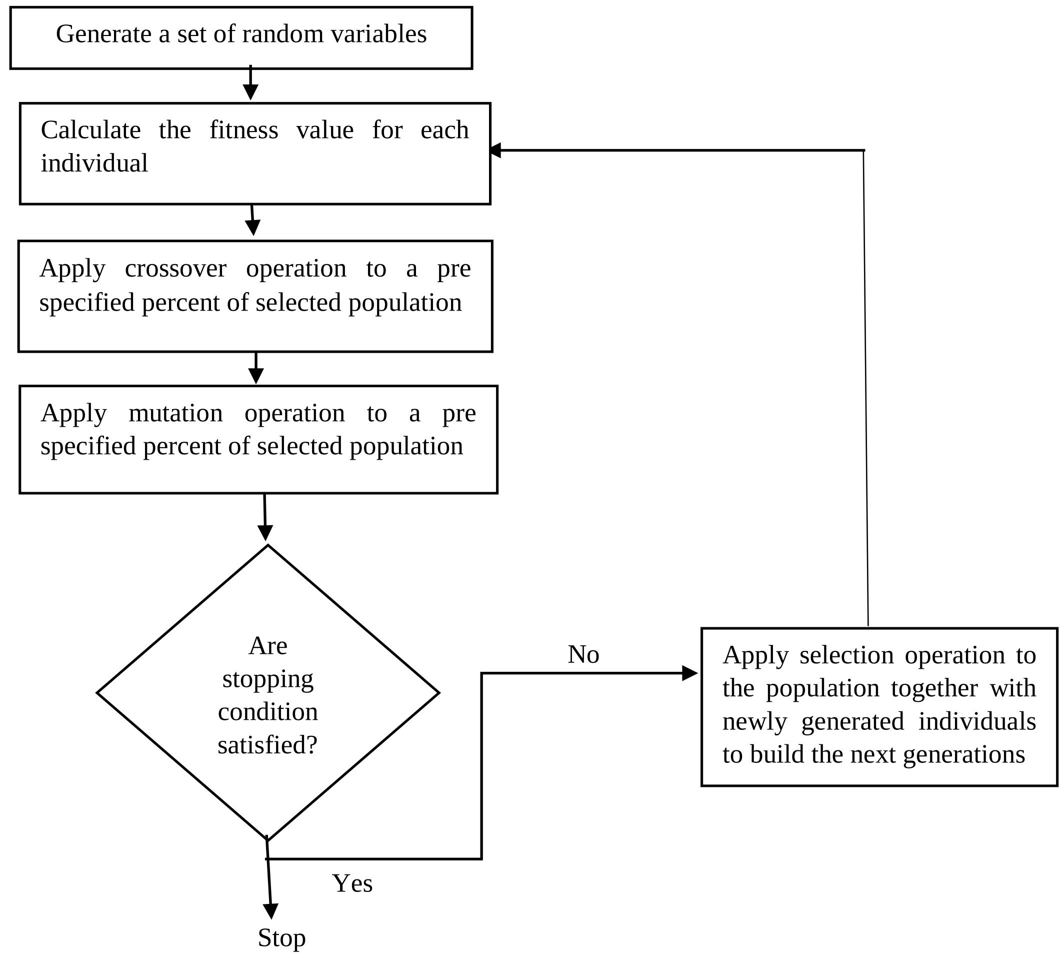

Fig 3.5: Flow chart of Genetic Algorithm

Now begin the loop firstly pick a cross-over point randomly and export number of row and column from this point this is a cross-over point. Secondly transferred from parent 1 to child 2, and parent 2 to child 1, Put child 1, child 2 in new functions this compose a matrix.

3.5.2 Mutation process

Randomly flip all the elements in this matrix then put it in one row. Repeated the two above operation until the number of iteration finish. Work on optimization for the candidate vectors of phase rotation to PTS technique using variable to variable crossover in genetic algorithm study optimum solution searching for trade off PAPR reduction in OFDM systems and cost of calculation with increasing the number of sub-blocks, my work in genetic algorithm make tournament selection with single-point crossover and boundary mutation but with less sub-blocks than other papers and work directly on the OFDM signal with increasing one condition when plotting if there is consecutive

3.6 PAPR & BER performance

We found that the PAPR for genetic algorithm less than 2dB after 20 Iteration. When original signal gives 19dB and the conventional PTS gives near 15dB also the code gives 43.5% good result when rerun with more iteration after 2000 we get PAPR less than 1dB at the 32 return with 38% good result. The PAPR for genetic algorithm give better BER performance than OFDM signals, Conventional PTS.

UNIT 4

SOFTWARE DESCRIPTION

4.1 Introduction

MATLAB stands for matrix laboratory.as the name itself indicates, we deal with matrices when we work with MATLAB. It is a simple and useful high-level language for matrix manipulation. Since images are matrices of numbers, many vision algorithms are naturally implemented in MATLAB. It is often convenient to use MATLAB even for programs for which this language is not the ideal choices in terms of data structures and constructs. In fact, MATLAB is an interrupted language which makes program development very easy, and includes extensive tools for displaying matrices and functions, printing them into several different formats like postscript, debugging, and creating graphical user interfaces. In addition, the MATLAB package provides a huge amount of predefined functions, from linear algebra to PDE solvers to image processing and much more.

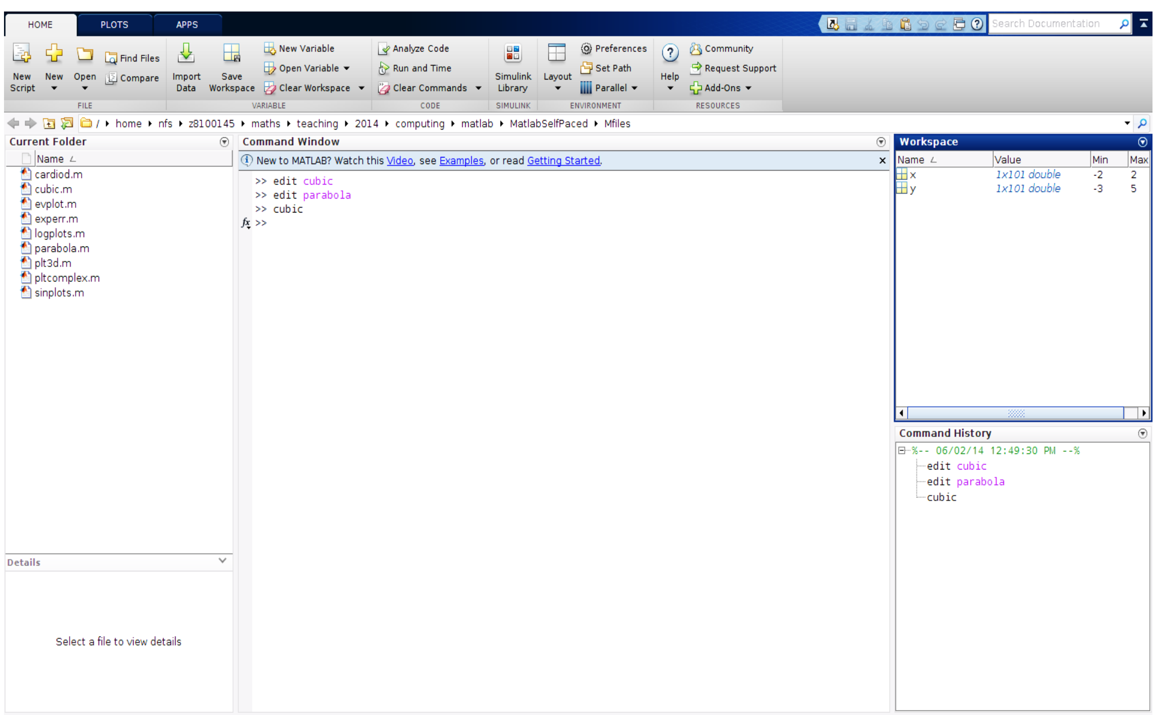

Fig 4.1: MATLAB Window

The major tools within or accessible from the desktop are:

1. Command window

2. Work space

3. Command History

4. Current folder

- **Command Window**

Command window, it shows output of some particular programmer other than graphs. This is the place where we type our program/code.

- **Work Space**

The MATLAB workspace consists of the variables you create and stores in memory during a MATLAB session. We can add variables to the workspace by using functions.

- **Command History**

This is similar to the history option of a web browser. This window shows a list of recently used commands and functions for easy access in the future.

- **Current folder**

Image processing involves changing the nature of an image in order to either

1. Improve its pictorial information for human interpretation,

2. Render it more suitable for autonomous machine perception.

4.2 Typical uses of MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or Fortran.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

4.3 MATLAB Functions used

randint

It is used to generate matrix of uniformly distributed random integers.

Syntax

Out= randint (m, n)

Description

Out=randint (m, n) generates an m-by-n binary matrix. Each of whose entries independently takes the value 0 with probability ½.

awgn

It is used to add white Gaussian noise to signal.

Syntax

Y= awgn (x,snr)

Description

Y=awgn(x,snr) adds white Gaussian noise to the vector signal x. the scalar snr specifies the signal-to-noise ratio per sample, in dB, if x is complex, awgn adds complex noise. This syntax assumes that the power of x is 0 dBW.

Erfc

It is used as complementary error function.

Syntax

Y=erfc(X)

Definitions

The complementary error function erfc(x) is defined as

Description

Y=erfc(x) computes the values of the complementary error function.

semilogy

It is a semi logarithmic plot

Syntax

semilogy (……,’propertyName’, PropertyValue,…..)

Description

semilogy plots data with logarithmic scale for the y-axis.

semilogy (X1, Y1,……) plots all Xn versus the rows or columns of the matrix, along the dimension of the matrix whose length matches the length of the vector. If the matrix is square, its columns plot against the vector if their lengths match.

switch

It is used to switch among several cases based on expression.

Syntax

Switch switch _ expression

Case case_ expression

Statement

Case case_ expression

Statement

Otherwise

Statement

End

ifft

It performs inverse fast Fourier transform.

Syntax

Y= ifft(X)

Y= ifft(X, n)

Description

Y= ifft(X) returns the inverse discrete fourier transform (DFT) of vector X. computed with a fast fourier transform (FFT) algorithm. If X is a matrix, ifft returns the inverse DFT of each column of the matrix.

Ifft tests X to see whether vectors in X along the active dimensions are conjugate symmetric.

If so, the computations is faster and the output is real. An N-element vector x is conjugate symmetric if x (i) = conj(x (mod (N-i+1, N) +1)) for each element of x.

If X is a multidimensional array, ifft operates on the first non-singleton dimensions.

Y=ifft (X, n) returns the n-point inverse DFT of vector X.

max

It gives largest element in array

Syntax

C= max (A)

C= max (A, B)

Description

C= max (A) returns the largest element along different dimensions of an array.

If A is a vector, max (A) returns the largest element in A.

If A is a matrix, max (A) treats the column of A as vectors, returning o row vector containing the maximum element from each column.

mean

It gives average or mean value of array.

Syntax

M= mean (A)

M= mean (A, dim)

Description

M= mean (A) returns the mean values of the elements along different dimension of an array.

If A is a vector, mean (A) returns the mean value of A.

If A is a matrix, mean (A) treats the columns of A as vectors, returning a row vector of mean values.

zeros

Create array of all zeros.

Syntax

B= zeros (n)

B=zeros (m, n)

Description

B=zeros (n) returns an n-by-n matrix of zeros. An error message appears if n is not a scalar.

B=zeros (m, n) or B= zeros ([m n]) returns an m-by-n matrix of zeros.

B=zeros (m,n,p,……) or B = zeros([m n p….]) returns an m-by-n-by-p-by……array of zeros.

Table 4.1: Special Mathematical functions

Pi	3.141592265
sI	Imaginary unit, $\sqrt{-1}$
I	Same as i
Eps	Floating-point relative precision, 2^{-52}
Realmin	Smallest floating-point number, 2^{-1022}
Realmax	Largest floating-point number, $(2_{-\varepsilon})\ 2^{1023}$
Inf	Infinity
NaN	Not-a-Number

4.3.1 Matrix Generators

MATLAB provides functions that generates elementary matrices. The matrix of zeros, of ones and the identity matrix are returned by the functions zeros, ones, and eye, respectively.

Table 4.2: Elementary matrices

Eye(m,n)	Returns an m-by-n matrix with 1 on the main diagonal
Eye(n)	Returns an n-by-n square identity matrix
Zeros(m,n)	Returns an m-by-n matrix of ones
Ones (m,n)	Returns an m-by-n matrix of ones
Diag(A)	Extracts the diagonal of matrix
Rand(m,n)	Returns an m-by-n matrix of random numbers

4.4 MATLAB System

The MATLAB system consists of five main parts:

4.4.1 Development Environment

This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and command window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files, and the search path.

4.4.2 MATLAB Mathematical Function

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix Eigen values, Bessel functions, and fast Fourier transform.

4.4.3 MATLAB Language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-array programs, and three –dimensional data visualization, image processing, animation and presentation graphics it also includes low-level functions that allows you to fully customize the appearance of graphics as well as to build complete graphical user interface on your MATLAB applications.

4.4.4 MATLAB Application Program Interface (API)

This is a library that allows you to write C and FORTRAN program that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-Files.

4.5 Some basic commands

pwd prints working directory

Demo demonstrates what is possible in MATLAB

Who list all of the variables in your mat lab workspace?

Whose list the variables and describes their matrix size

clear erases variables and functions from memory

clear x erases the matrix 'x' from your workspace

close by itself, closes the current figure window

figure creates an empty figure window

hold on holds the current plot and all axis properties so that subsequent graphing. Commands add to the existing graph

hold off sets the next plot property of the current axes to “replace”

find find indices of nonzero elements e. g,;

d=find(x>100) return the includes of the vectors x that are greater than 100

break terminate execution of m-file or WHILE or FOR loop.

for repeat statements a specific number of times, the general form of a FOR statement is:

FOR variable = expr, statement…………statement END

For n=1:cc/c;

magn (n,1)=NaNmean (a((n-1)*c+1:n*c, 1));

end

diff difference and approximate derivative e.g.;

DIFF(X) for a vector X, is [X(2)-X(1) X(3)-X(2)…….X(n)-X(n-1)].

NaN the arithmetic representation for Not-a-Number, a NaN is obtained as a result of Mathematically undefined operations like 0.0/0.0

INF the arithmetic representation for positive infinity, a infinity is also produced by operations Like dividing by zero, e.g, 1.0/0.0, or from overflow, e.g. exp (1000).

Save save all the matrices defined in the current session into the file,

matlab. mat, located in the current working directory

load loads contents of matlab. mat into current workspace

4.6 Some basic plot commands

Kinds of plots:

Plot (x,y) create a Cartesian plot of the vectors x & y

Plot (y) create a plot of y vs the numerical values of the elements in the y-vector

Semilogyx (x, y) plots log(x) vs y

Semilogyy (x,y) plots x vs log(y)

Loglog(x, y) plots log (x) vs log (y)

Polar (theta,r) creates a polar plot of the vectors r & theta where theta is in radians

bar (x) creates a bar graph of the vector x. (note also command stairs(x))

bar (x, y) creates a bar-graph of the elements of the vector y, locating the bar

according to the vector elements of ‘x’

4.6.1 Plot description

grid creates a grid on the graphics plot

title (‘text’) places a title at top of graphics plot

x label (‘text’) writes ‘text’ beneath the x-axis of a plot

y label (‘text’) writes ‘text’ beside the y-axis of a plot

text (x, y, ’text’) writes ‘text’ at the location (x, y)

text (x, y, ‘text’,’sec’) writes ‘text’ at point x, y assuming lower left corner is (0, 0) and upper right corner (1,1)

axis ([xmin xmax ymin ymax]) sets scaling for the x- and y-axis on the current plot.

4.7 Algebraic Operations in MATLAB

Scalar calculations

+ Addition

- Subtraction

* Multiplication

/ Right division (a/b means a ÷ b)

\ left division (a\b means b ÷ a)

^ Exponentiation

For example 3*4 executed in ‘MATLAB’ gives answer = 12

4/5 gives answer = 0.8

Array products: Recall that addition and subtraction of matrix involved addition or subtraction of the individual elements of the matrix. Sometimes it is desired to simply multiply or divide each element of a matrix by the corresponding element of another matrix ‘array operations’.

4.8 MATLAB working environment

MATLAB DESKTOP

MATLAB desktop is the main MATLAB application window. The desktop contains five sub windows, the command window, the workspace browser, the current directory window, the command history window, and one or more figures windows, which are shown only when the users displays a graphic.

The command window is where the user types MATLAB commands and expression at the prompt (>>) and where the output of those commands is displayed. MATLAB defines the workspace as the set of variables that the user creates in a work session.

The workspace browser shows these variables and some information about them. Double clicking on a variable in the workspace browser launches the array editor, which can be used to obtain information and income instances edit certain properties of the variables.

MATLAB uses a search path to find M-Files and other MATLAB related files, which are organized in directories in the computer file system. Any file run in MATLAB must reside in the current directory or in a directory that is on search path. By default, the files supplied with MATLAB and math works toolboxes are included in the search path. The easiest way to see which directories are soon the search path, or to add or modify a search path, is to select set path from the file menu the desktop, and then use the set path dialog box. It is good practice to add any commonly used directories to the search path to avoid repeatedly having the change the current directory.

The command history window contains a record of the commands a user has entered in the command window, including both current and previous MATLAB sessions. Previously entered MATLAB commands can be selected and re-executed from the command history window by right clicking on a command or sequence of commands.

This is a useful feature when experimenting with various commands in a work session.

UNIT 5

SIMULATION RESULTS

Simulations results show that GA-based PTS method is an effective method to compromise a better tradeoff between PAPR reduction and computation complexity. By appropriate selection of phase weighting factors according to the required performance and tolerable complexity, the proposed partition scheme can be adaptive. Additionally, optimum method, PTS. However, the complexity of the proposed method was remarkably lower than that of optimum method. Figure 6.1 shows an example of 324 carriers spreading out on IFFT.

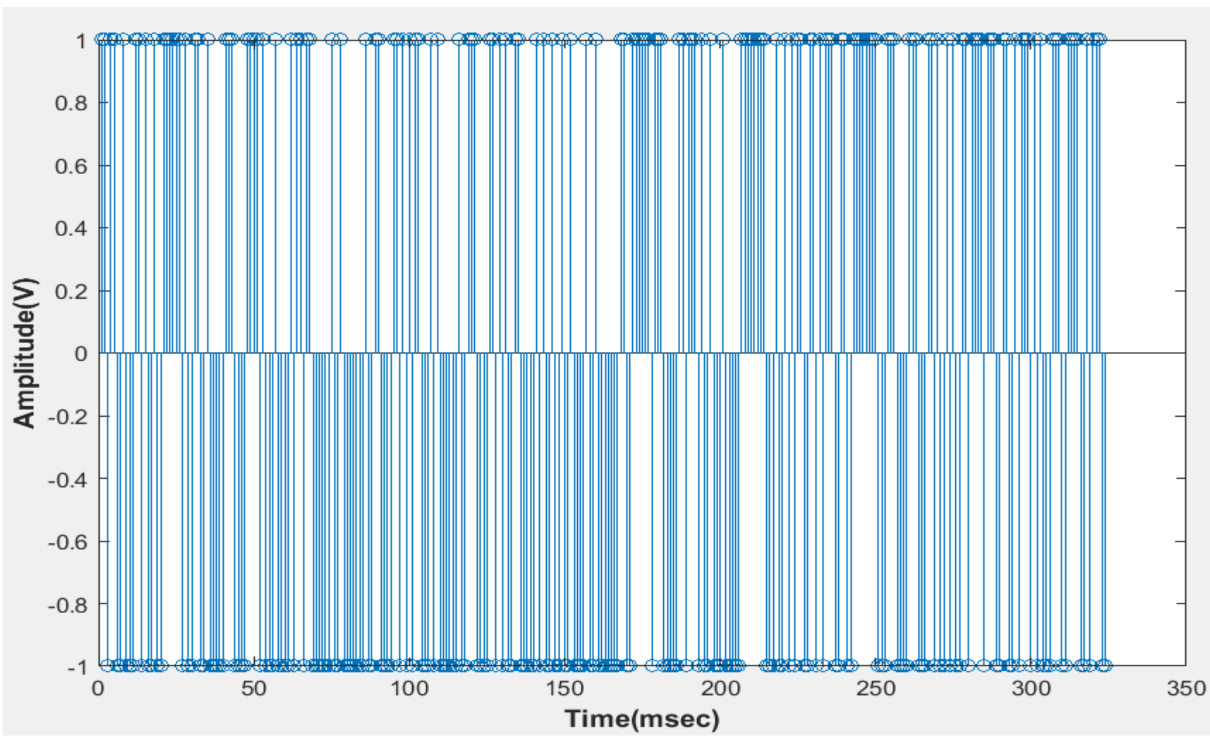

Fig 5.1: OFDM subcarriers

OFDM communications systems are able to more effectively utilize the frequency spectrum through overlapping sub-carriers. These sub-carriers are able to partially overlap without interfering with adjacent sub-carriers because the maximum power of each sub-carrier corresponds directly with the minimum power of each adjacent channel. Below, we illustrate the frequency domain of an OFDM system graphically. As you can see from the figure, each sub-carrier is represented by a different peak. In addition, the peak of each sub-carrier corresponds directly with the zero crossing of all channels. Below figure represents the sub-carriers formed in Orthogonal Division Multiplexing.

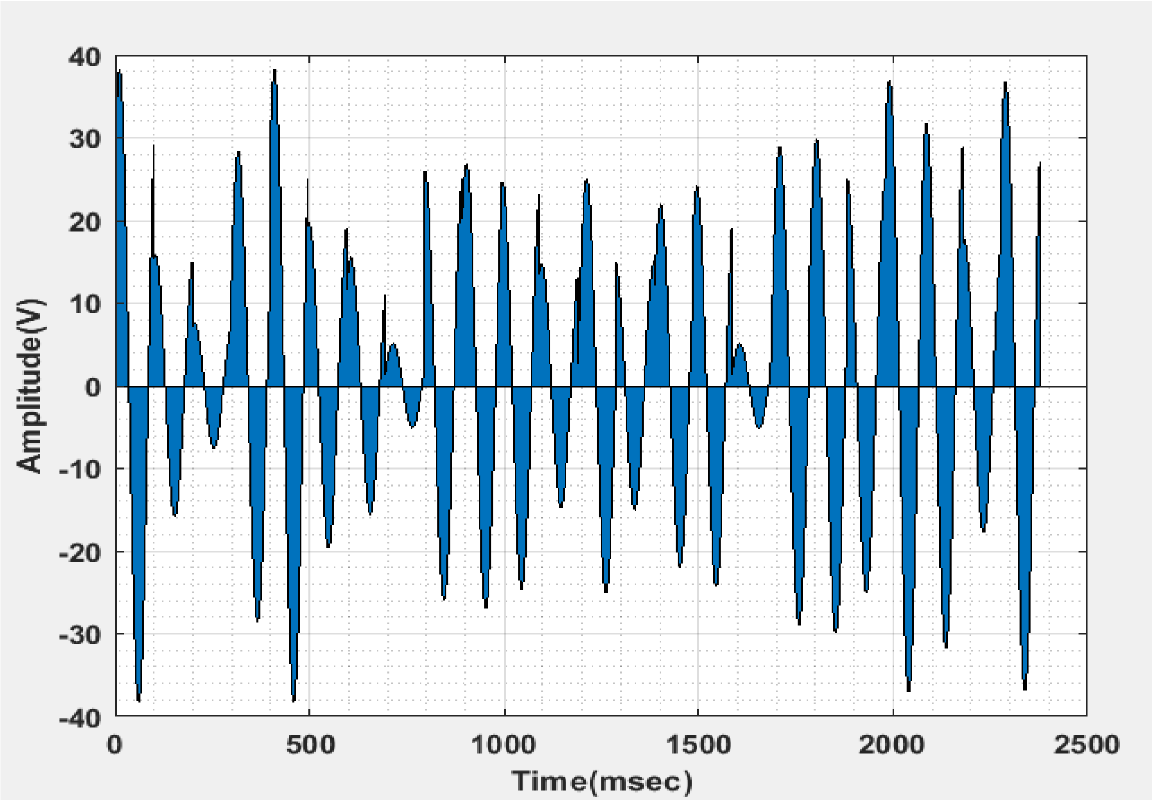

Fig 5.2: OFDM Simulation

Demodulated data is compared to the original baseband data to find the total number of errors. Dividing the total number of errors by total number of demodulated symbols, the bit error-rate (BER) is found. Moreover, it can be observed that probability of very high peak power has been increased significantly if PTS techniques are not used. As the number of sub-blocks and the set of phase weighting factor are increased, the performance of the PAPR reduction becomes better. However, the processing time gets longer because of much iteration.

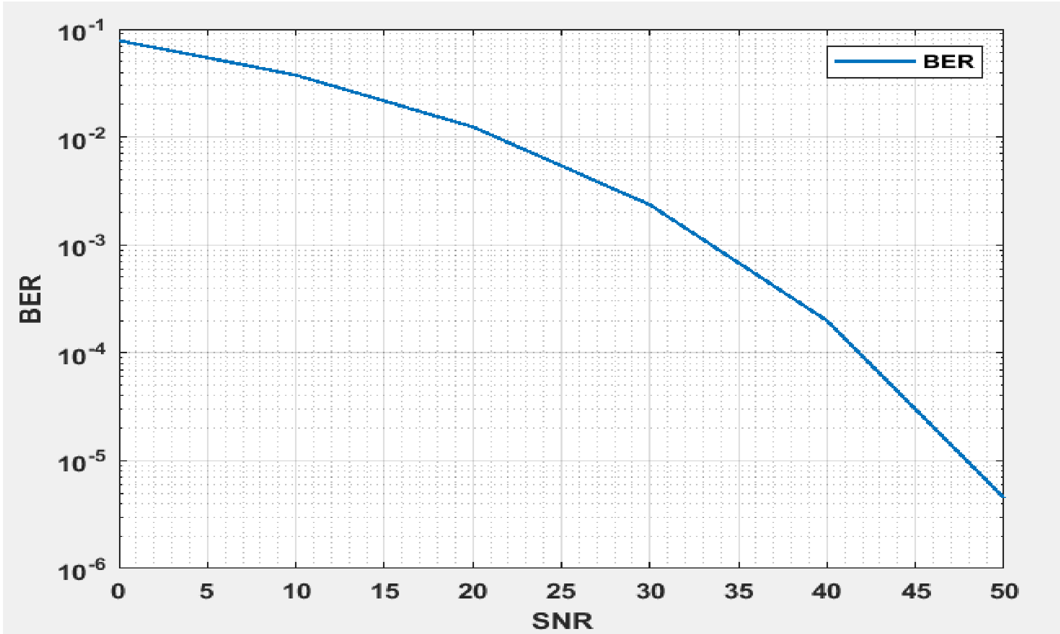

Fig 5.3: Bit Error Rate Vs Signal to Noise Ratio

In Figure 5.4, some results of the CCDF of the PAPR are simulated for the OFDM system with 128 sub-carriers, in which M=8 sub-block employing random partition and the phase weight factor W = {±M} m uniformly distributed random variable are used for PTS. As we can see that the CCDF of the PAPR is gradually promoted upon increasing the numbers of generations due to the limited phase weighting factor.

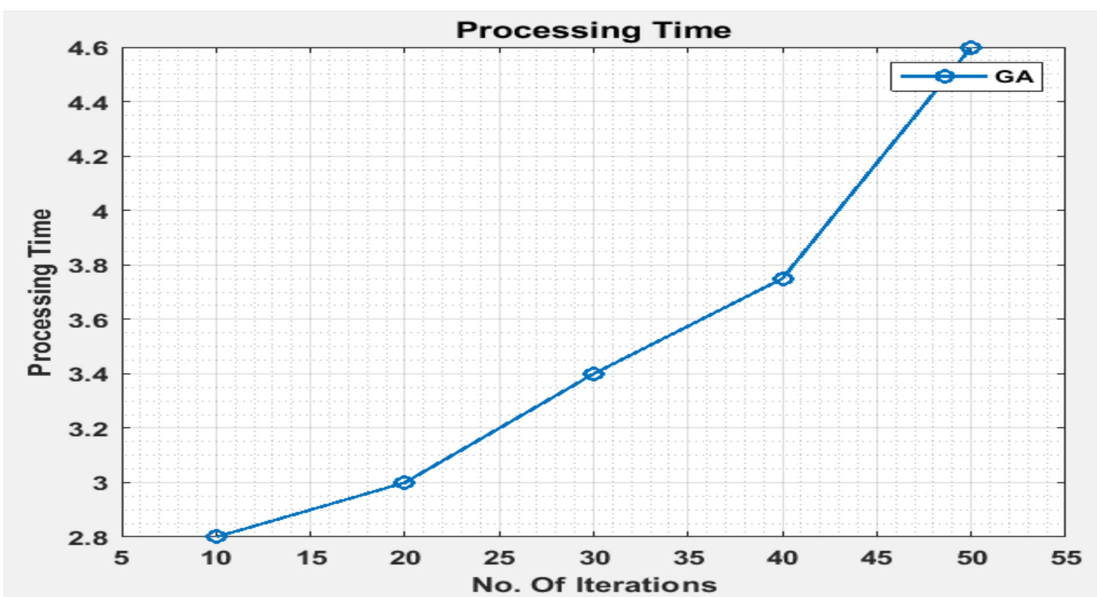

Fig 5.4: Number of Iterations in Genetic Algorithm

As the numbers of generation are increased, the CCDF of the PAPR has been improved. For a generation, we can see that the PSO-based PTS technique is capable of attaining a near PTS technique performance, with requirements of Pr (PAPR > PAPR0) = 10^{-3}.

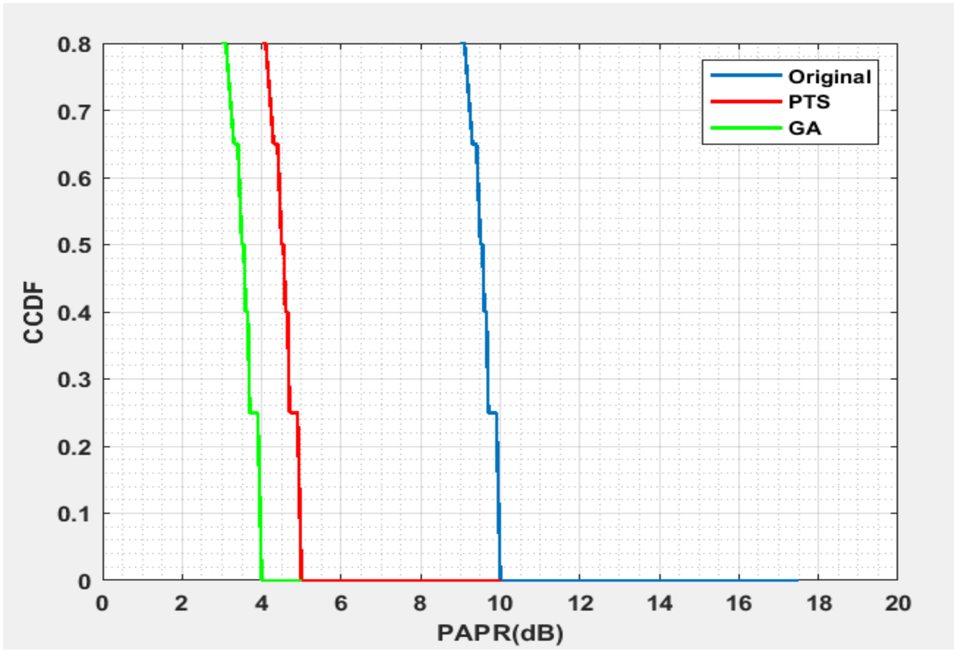

Fig 5.5: Comparison of PAPR

Table 5.1: Comparison of PAPR

CCDF	PAPR		
	ORIGINAL	PTS	GA
0.65	9.4	4.4	3.4
0.5	9.5	4.5	3.55
0.4	9.6	4.6	3.6
0.25	9.9	4.9	3.9

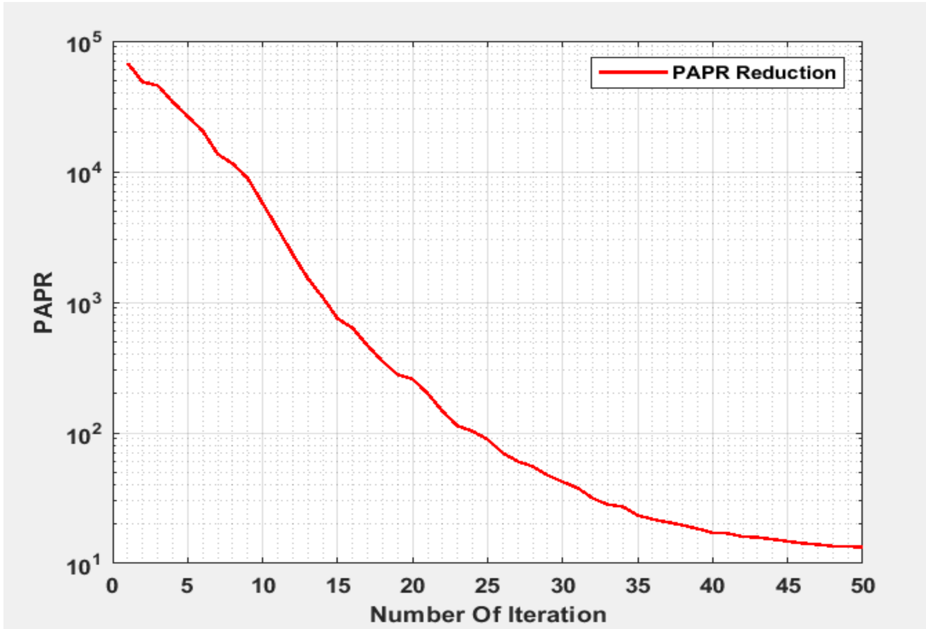

Fig 5.6: PAPR Reduction

The proposed method has better PAPR performance with adjacent partition and with pseudo-random partition. Future investigations could focus on the transmitted signal of PTS without the side information and extending our proposed method into the high-order modulation OFDM systems.

Table 5.2: No. of iterations vs PAPR

No. of iterations	**PAPR**
5	$2.568^{*}10^{4}$
10	8655
15	2173
20	521.4
25	128.8
30	53.44
35	21.65
40	10.76
45	6.675
50	4.264
52	3.694

UNIT 6

CONCLUSION

The major difficulty in the practical implementation of the Orthogonal Frequency Division Multiplexing is its high PAPR. To transmit signals with large PAPR, expensive wide range power amplifiers are required. High PAPR results in reduction of efficiency of the Power Amplifier. In this paper partial transmit sequence (PTS) PAPR reduction technique are described. One of the effective methods of PAPR reduction is Partial Transmit Sequence scheme. So, we can improve the performance of PAPR reduction using Genetic Algorithm (GA).

The PAPR reduction performance which is derived by using adjacent, interleaved and random sub-block partitioning methods. Random sub-block partitioning method has derived the most effective performance, and interleaved sub-block partition method has derived the worst. As the number of sub-blocks is increased, PAPR can be further reduced. Moreover, we formulate the phase weighting factors searching of PTS as a particular combination optimization problem.

Simulations results show that GA-based PTS method is an effective method to compromise a better tradeoff between PAPR reduction and computation complexity. The proposed algorithm considers a more practical environment where noise is characterized by a non-constant spectral content over the OFDM sub-carriers. This is often the case when the noise is dominated by a strong interference. The proposed solution can be very useful for adaptive modulation as well as for other adaptive transmitter and receiver algorithms, like optimal soft information calculation, improved channel estimation.

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