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An Overview of OFDM Technology being used for Wireless Communication

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***Abstract*— Orthogonal Frequency Division Multiple Access (OFDM), this is the new innovation that is being utilized as a part of the 4G wireless broadcast communications. As we realize that the computerized world is developing step by step in each perspective because of the enormous development happened in the advanced world, the desires from a customer side is likewise expanding as far as having a smart, advanced technology which should have a faster speed and less latency too. As we know that the 4G wireless technology is the recent and the current trend that is being utilized everywhere throughout the world today. The main reason to adopt the OFDM technology in 4G telecommunication services is to accomplish a higher transfer speed, and to avoid the inter carrier interference (ICI) and inter symbol interference (ISI).In this paper we will present the overview of an OFDM technology, its advantages and challenges and also discussing the available solutions to those challenges.**

***Index Terms*— OFDM, ICI, ISI, Synchronization, BER.**

I. INTRODUCTION

As we realize that in the 2G wireless telecommunication there was first time electromagnetic waves were used in the digital form by using various modulation techniques. Since from that point the electromagnetic waves were used for the communication purpose to transmit the information are mainly in terms of digital, i.e. precisely from 1991 onwards the digital modulation techniques were adopted in the wireless communication technology.

In 2G wireless telecommunication there are mainly two types of technologies were used they are TDMA and CDMA. In case of Time Division Multiple Access (TDMA) the carrier frequency is divided into many sub frequency bands, which are further allocated among the users. The advantage of this is it has the great adaptability for sending the information in terms of bits and also voice. Where as in Code Division Multiple Access (CDMA) the Spread Spectrum technology was used. In which each band at the transmitter end is allotted with some unique codes. Using spread code technology it has the capacity to allocate more number of users per bandwidth this is mainly achieved in terms of MHz's. The main challenges of 2G wireless technology will be intermittence while receiving the information [1].

The next will be the 3G wireless communication i.e. the third era of wireless communication. This was presented in the year 2000. And it will gives access to the users for accessing various digital communication

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services such as international roaming and providing high data rates etc[2]. Here also the technologies adopted were similar to the previous technologies i.e. TDMA and CDMA yet these are utilized with some advancement like WCDMA. But in any case this era provides many new services to the users like TV, Navigation for maps and video calling facility. But even though it wasn't possible to achieve a high bandwidth. The next generation is the 4th generation i.e. 4G .which will be discussed in the below section II.

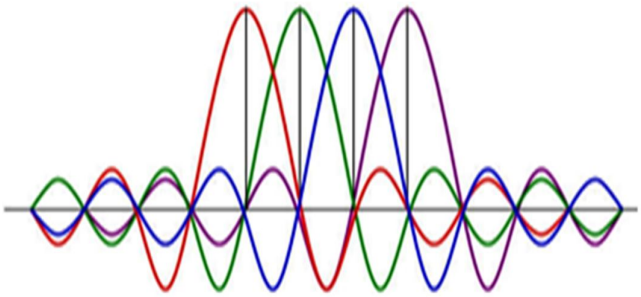

Figure 1. Orthogonality of Signals

Initially one should know that what exactly happens in the OFDM system and why it is so prevalent. In past technologies a single carrier wave was used to pass through from some amount of bandwidth. Through that single carrier wave only the information was going to transmit ,which will ultimately causes delay's .Suppose we increased the speed means at that time the data will be corrupted due to the interference of the symbols. To avoid all these things we use the OFDM technology. In 1985 for the first time digital mobiles were used the Discrete Fourier transform for the orthogonal frequency multiplexing to access the narrow sub channels [4].

In 1986 orthogonally multiplexed quadrature amplitude multiplexing (OQAM) methodology has been introduced to use the data modem. Here the data was transmitted successfully from transmitter to receiver. The entire process they proved both in mathematically and experimentally [5].

In the same year i.e. in 1996 Casas showened that we can improve the bit error rate (BER) performance. By using the normal fading channels only, such as Rayleigh Fading Channels which were mainly used for the wireless communication. Here he predicted that we can improve the performance in the bit error rate greatly by adopting the Orthogonal Frequency Division Multiplexing, for the transmission of data. But the simulation results were indicating that there was a very small amount of improvements occurred in the BER [6].

We can avoid the narrow band interference by measuring the different measures like filtering in time domain and in transfer domain i.e. in FFT. Here one more interesting approach can be advised multi carrier transmission that is achieved through orthogonal frequency division multiplexing. By using this technology we can avoid the frequency selective fading and interference [7].

In OFDM technology we will mainly use the multi carrier frequency waves. Which are sent through a channel at the same time to achieve a high data rate. This technology will be used as a multicarrier digital modulation technique. We can use the guard intervals to avoid the interferences and phase noise effects [8].

Advatages of OFDM Technology:

- It is having many advantages like we can see there is an increase in the spectral efficiency by obeying the principle of orthogonality, because of this we can see that the channel bandwidth is utilized at the maximum extent.
- Channel equalization becomes easy by adopting the different channel equalization techniques for each carrier wave of the system. Here the each channel will be divided into number of sub channels which will helps to avoid the flat fading of these sub channels. This will indicates that the OFDM is more powerful technology.
- By using this there is a great improvement occurred in the synchronization of frequency, amplitude and phase compare to the other technologies that were used in before communication generations

- We can also avoid the inter symbol interference and inter carrier interference by using the cyclic prefixes.
- By using OFDM we can avoid the multi path fading
- It is having great compatibility with FFT so that computations will become easier. Specifically in modulation and demodulation process.
- For the channel estimation we can use the Maximum likelihood (ML) decoding.
- The OFDM signal is less sensitive to timing offsets compare to the single carrier wave.
- It provides an excellent protection against co-channel interference and impulsive parasitic noise [10].

II. OFDM SYSTEM

The OFDM system consists of mainly two parts. They are Transmitter and the Receiver end. In transmitter side we can see the Modulation mapping block, IFFT block, guard period insertion block, baseband to RF converter block and at the Receiver side we can see that the RF to base band conversion block, guard period removal block, frame detection block, FFT computation block, Modulation slicer block, and finally we have a parallel to serial conversion block which is shown in the Figure 2 i.e. Block Diagram of an OFDM System.

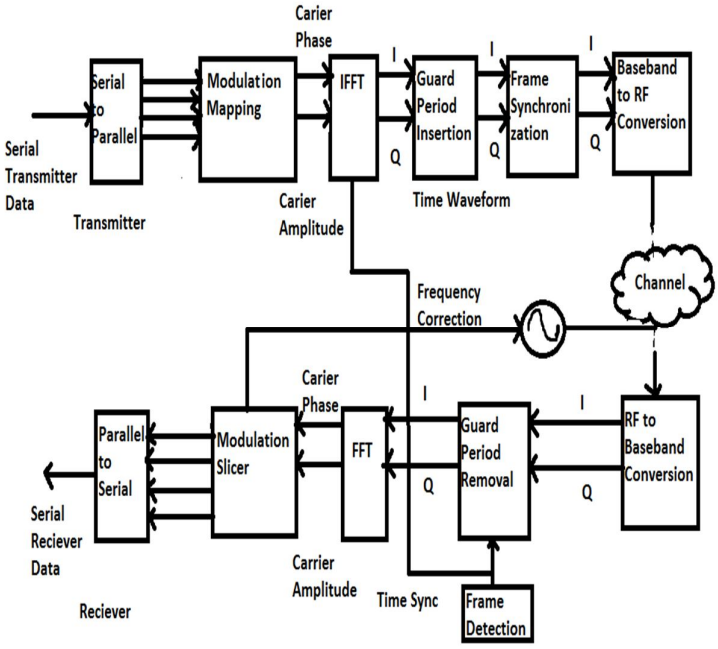

Figure 2. Block Diagram of an OFDM System

Here first the data is sent to the serial to parallel converter where the data before sending into the serial to parallel converter it will a number of serial bits which are passed into the block where in serial to parallel converter the data which are in the form of bits they are converted in terms of words and then transmitted parallel to the next block.

Next the data which has to be transmitted that is sent through different carriers which are encoded differently from each other then phase mapping will be done .We know that every carrier has to be encoded with differently for this we need to add one extra bit as a starting reference point. The purpose of doing phase shift keying is to get steady amplitude response and to avoid the fading of signals. For example the phase angles that are being used for QPSK will be 0, 90,180 and 270 degrees. Here we can also adopt the QAM modulation scheme.

After the modulation of signals we will get the band of frequencies, for these we should apply the Inverse Discrete Fourier Transformer (IDFT).To perform these computations we will use the linear transformation

i.e. Inverse Fourier Transform (IFFT) because using this we can achieve the fastest computations on IDFT . The IFFT will helps to find out the time domain for a corresponding waveform, After the guard period is added to the starting of each bit.
Insertion of the guard period to the signal has to be done. The starting of the signal is added with the 0 bit this will cover the half of the signal then next half of the signal should consists of the cyclic prefix of the symbol to be transmitted. By adding the cyclic prefix we can easily identify the symbol timings.
After this the frames will be formed each one will be consisting of the guard band and the cyclic prefix .these frames are then transmitted into parallel to serial converter where the frame will be synchronized and then these are transmitted to baseband. Where as next these baseband waveforms are converted into radio frequency (RF) waves. Which are further sent to the channel. While simulating through software there are various channels are available with the almost same probability function.
At the receiver side radio frequency waves are converted back into the base band signals. After that the guard period will be removed. Next the DFT of the signal has to be calculated with the help of FFT (Fast Fourier Transforms).the FFT is also a linear transformation which is used to perform the DFT operations in a fastest way.
After this demodulation process will begins the signal which has to be sent will be decoded and it will be transmitted parallel after this in the parallel to serial converter the data is converted back into the serial bits which are finally received at the receiver side.

A. Challenges of OFDM

- The transmitted OFDM signal possesses a high peak to average power ratio this is due to the variations in the amplitude of the different signals which are sent orthogonal to each other at the transmitter side of the system. Further these variations in the amplitude will causes in the increase of dynamic range. This change will reduce the efficiency of the RF amplifier.
- The OFDM signal becomes more sensitive at the receiver side such as it produces carrier frequency offset (CFO) this is caused mainly due to the Doppler Shift this offset will be resulting in the inter carrier interference(ICI), which will affect the overall performance of the system. Here it is necessary to have exact time synchronization between the IFFT and FFT. Symbol timing offset (STO).

B. Available Solutions for Challenges

There are many solutions for these challenges are available:
First one should know that why the Peak to Average Power Ratio (PAPR) will becomes high and what makes it to become so high? For these questions the answer will be very simple that is due to the increase in the subcarrier waves, which will allow achieving a high data rates. Due to the increase in the subcarriers there is a huge variation in the amplitude which will causes the very high Peak to Average Power Ratio (PAPR).Further which is going to affect the performance of the system so we have to minimize this.
We can improve the PAPR reduction efficiency by adopting various methodologies. Like by manipulating the signals, by probabilistic methods for many signals, and by coding [9].
The manipulating of signals can be achieved by clipping of the extra signals. After this we have to do the filtering for this clipped signal by this we can see there is an improvement in the bit error rate (BER).to prove this BER improving due to the clipping one must adopt the software simulation methodologies to obtain the simulation results, we have to perform the computer simulations.
There is one more methodology is available to manipulate the signals and this is achieved by clipping off the peak of a signal this can be generated, added ,subtracted and scaled to eliminate the high peak .This can be done at the transmitter side of the system. We can observe these results with the help of simulation waveforms [9].
There are various methodologies are there for probabilistic methods when many signals were used. The first way can be achieved by mapping of the same information carrying OFDM signals but which will be having various lengths. Here the selected or the mapped waveforms only sent at the receiver side. So that we can avoid the unwanted signals to be processed.
We can also achieve this by transmitting the half of the sequence first. And we can also achieve this by lowering the Signal to Noise (SNR) ratios which are being transmitted to the receiver side.
By transmitting the sorted OFDM signals of same lengths which are carrying the same information. This is similar to that of the mapping of the signals but there phases are going to differ [9].

The PAPR reduction is possible by adopting various error coding techniques which will mainly helpful in the reduction of bit error rates (BER).Here first the errors will be detected and then they were corrected by using the various error coding techniques. This can be achieved with the help of bits which are going to be transmitted at the receiver side [9].

Due to the Doppler Effect there will be an existence of frequency offset that means there will be deviation in the signal will take place from transmitter to the receiver end. This will cause the distortions in the system. To avoid the Doppler shift one must know how much shift was occurred at the receiver side. To calculate the Doppler shift one must use the long waves i.e. using wider bandwidth. It's been easy to find out the Doppler shift by using wider waves with accuracy. The Doppler shift can also be calculated by performing mathematical computations [10].

The inter carrier interference is one more challenge that is going to exist in an OFDM system .Which is going to degrade the performance of the system. The inter carrier interference will occurs due to the frequency offset and the Doppler shift. This can be avoided by various mathematical modeling and analysis for the transmission of the system [11].

C. Applications of an OFDM

OFDM is the most widely used technology that is being used in most of the today's wireless systems. Some of the major examples of OFDM system are listed below.

DAB (Digital Audio Broadcasting): The OFDM will be used as the basic technology in digital audio broadcasting process. It is going to be the future of FM radio broadcasting which is currently used all over the world. But in the Europe it has already standardized that the OFDM for DAB. The advantages of this DAB will be the error free transmission, it will also helps in providing the various other channels that were not available on FM and also it will helps to give the great sound quality [12].

HDTV (High-Definition Television): Using HDTV we can achieve the high quality i.e. in terms of quality of the picture. This is being currently used today. Here we can see the tremendous improvement in the technology compare to the standard definition TV which was used in the previous systems. This is due to the adopting the new technology in the system i.e. OFDM. It is also the current standard video format that is being used worldwide today we can achieve the resolution of the video in various mega pixels like 720p to 1080p.

Wireless LAN's: The Local Area Networks (LAN's) which were used to connect the two or more devices within a limited range of area. This wireless LAN's are used in small buildings, schools, offices, home etc. At the beginning it was accessed by using technology called CDMA this was achieved by expanding the spread codes but today this was replaced by a new technology that is OFDMA. But currently it was practiced using this new technology only in Europe and American countries.

IEEE 802.11g: The OFDM technique is also used in this to achieve a wireless transmission. Here we can achieve a high throughput and it will operate at 2.4GHz.

IEEE 802.16: This is mainly used to access the wireless mobile broadband and it operates at the 2 to 11 GHz. And the latest one will be 802.16.1a which was initially released in the year2013.This was also adopted the OFDM technology because of its larger spectral efficiency [11].

Wireless Money Transmission Systems: In the wireless money transmission systems also the OFDM technology is being used widely that is nothing but Plastic Currency.

LTE: The LTE stands for Long Term Evolution which is mainly used in Universal Mobile Telecommunication System (UMTS) that is being used in the wireless cellular technology. Which will allows mainly high bandwidth hence improving the spectral efficiency. It gives better quality of services and also low cost. This all possible due to adoption of the OFDM technology to the system.

III. CONCLUSION

The OFDM was proved as the great modulation scheme that is being used today to access the various wireless communication systems as stated in the section III i.e. in the applications of an OFDM. The reason behind the popularity of this technology was the great utilization of spectral efficiency, using multicarrier frequencies to send the data. Here researchers have well addressed about the OFDM technology, advantages of the OFDM and the challenges of OFDM technologies and also the solutions for them. There are many new changes that are invented to overcome the challenges so that we can try to make the technology better. The OFDM is one of the most active research areas in today's wireless communication field.

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