# Enhancement of Channel Carrying Capacity in 4G Wireless Communication Using OFDM

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**Abstract—**

*Since time immortal humans were and are always in search of simplest and the most effective mode of communication systems. Whether it is speech or gadgets used to process in the form of information or data.Similarly in telecommunication there is always need of fast data transfer thereby increasing the need of larger bandwidth and the technologies used to achieve the desired goal .Hence OFDM has been introduced for many existing and future communications systems throughout the world. It is well suited for systems in which the channel characteristics make it difficult to maintain ample amount of communications link performanc . In addition to high speed wireless applications, wired communication systems such as asynchronous digital subscriber line (ADSL) and cable modem uses OFDM as its underlying technology to provide a technique for delivering high-speed data communication. In this research , Our main aim is to implement a MIMO OFDM baseband transceiver on an FPGA by proper selection of one of the sixteen configurations to fulfill the need of faster data transmission on a wireless communication system with comparatively low prices of hardware implementation Moreover the implementation on FPGA is better than on a general purpose MPU in terms of speed and on ASIC in terms on cost.FPGAis having the flexibility of reconfiguring by the base station to meet future requirements. This section deals with discussions and analysis on the simulation results that are obtained till date with the standard results in the future research area in order to achieve high throughput.*

*This investigation focus on the design of project and its model development using matlab Simulink, Xilinx and then implementing it on FPGA. This includes understanding of OFDM, its spectrum, symbol structure, and its applications.*

**Keywords**: *MIMO, OFDM matlab Simulink, Xilinx and FPGA.*

**1.Introduction-**

The need for high-speed data transmission has been increased in recent years. The mobile teleco mmunications industry faces the problem of providing the technology that will be able to support a variety of services ranging from voice communication with a data transfer rate of a few kbps to wireless multimedia in which the rate is up to 2 Mbps. Many systems have been proposed and OFDM system has gained much interest for different reasons. Although OFDM was first developed in the 1960s, only in recent years, it has been recognized as an outstanding method for high-speed wireless data communication where its implementation relies on very high-speed digital signal processing. This method has only recently become available with reasonable prices versus performance of hardware implementation.

Since OFDM is carried out in the digital domain, there are several methods to implement the system. One of the methods to implement the system is using ASIC (Application Specific Integrated Circuit). ASICs are the fastest, smallest, and lowest power way to implement OFDM into hardware. The main obstacle using this technique is inflexibility of design process associated and the comparatively longer time to market period for the designed chip.

Another method that can be utilized to implement OFDM is general purpose Microprocessor or Micro Controller. The processors are highly programmable and flexible in case of changing the OFDM design into the system. The shortcoming of using this hardware is that, it needs memory and other peripheral chips to support the operation. Moreover, it uses the most power usage and memory space, and would be the slowest in term of time to produce the output compared to other hardware.

Field-Programmable Gate Array (FPGA) is an example of VLSI circuit. This hardware is reprogrammable and the designer has full control over the actual design implementation without the need (and delay) for any physical IC fabrication facility. An FPGA combines the speed, power, and density properties of an ASIC with the programmability of a general purpose processor will give advantages to the OFDM system. An FPGA could be reprogrammed for new functions by a base station transceiver system to meet upcoming needs particularly when new design is going to fabricate into chip. This will be the best choice for OFDM implementation since it gives flexibility to the program design besides the low cost hardware component comparatively.

## 2. Research details-

Orthogonal Frequency Division Multiplexing (OFDM) is a combination of modulation and multiplexing. In this method, the given bandwidth is shared among individual modulated data sources. Normal modulation techniques like AM, PM, FM, BPSK, QPSK, etc... are single carrier modulation techniques, in which the incoming information is modulated over a single carrier frequencies.

OFDM is a multicarrier modulation technique, which employs several carriers, within the allocated bandwidth, to convey the information from source to destination. Each carrier may utilize one of the several available digital modulation techniques like BPSK, QPSK, and QAM.

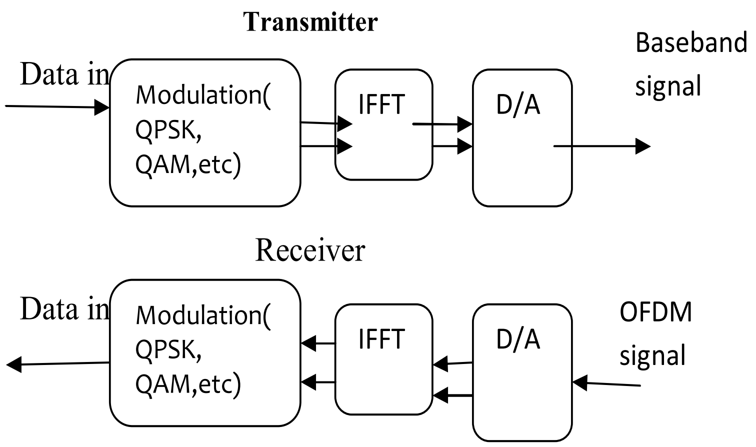


Fig.2.1: OFDM Transmitter and Receiver.

A communications data stream is effectively devided into N parallel low bandwidth modulated data streams. Each sub-carrier overlaps, but they are all orthogonal to each other, such that they do not interfere with one another. Each of the sub-carriers has a low symbol rate. But the combination of sub-carriers carrying information in parallel allows for high data rates. The other advantage of a low symbol rate is that inter-symbol interference (ISI) can be reduced dramatically since the symbol time represents a very small proportion of the typical multipath delay

The transmitter stage of an OFDM transceiver takes data, converts, and encodes it into a serial stream before modulation. The OFDM signal is generated using an Inverse Fast Fourier Transform (IFFT). The receiver stage of the transceiver simply reverses the process.

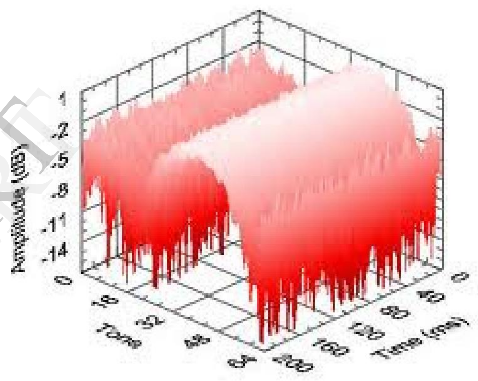

Fig.2.2: OFDM spectrum.

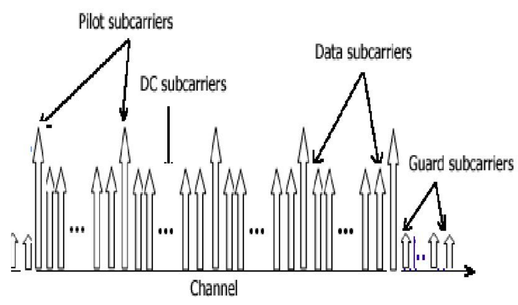


Fig.2.3: OFDM Symbol Structure

In OFDM each symbol consists of data sub-carriers frequencies that carry data, pilot sub-carriers as reference frequencies and for various estimation and analysis purposes, DC sub-carrier as the center frequency, and guard sub-carriers or guard bands for keeping the space between OFDM signals.

## 3. LITERATURE SURVEY

### 3.1 Orthogonal Frequency Division Multiplexing (OFDM):

OFDM is one of the most promising physical layer technologies for high data rate wireless communications due to its robustness to frequency selective fading, high spectral efficiency, and low computational complexity. OFDM can be used in conjunction with a Multiple-Input Multiple-Output (MIMO) transceiver to increase the diversity gain and/or the system capacity by exploiting spatial domain. Because the OFDM system effectively provides numerous parallel narrowband channels, MIMO-OFDM is considered a key technology in emerging high-data rate systems such as 4G, IEEE 802.16, and IEEE 802.11n.

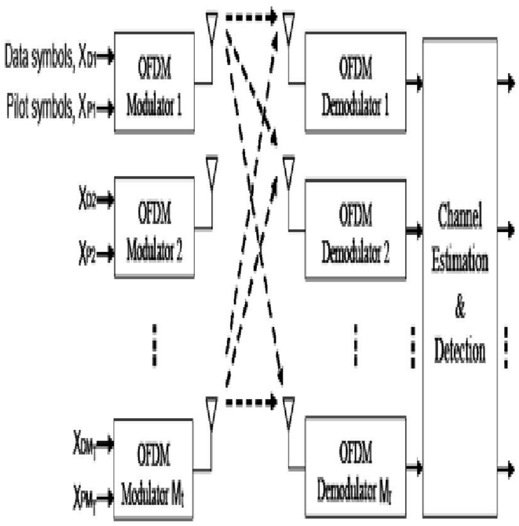


Fig. 3.1 OFDM communication subsystem.



### 3.2 Applications of OFDM.

OFDM has been chosen for several current and future communications systems all over
the world. It is well suited for systems in which the channel characteristics make it difficult to maintain adequate communications link performance. In addition to high speed wireless applications, wired systems such as asynchronous digital subscriber line (ADSL) and cable modem utilize OFDM as its underlying technology to provide a method of delivering high-speed data. Recently, OFDM has also been adopted into several European wireless communications applications such as the digital audio broadcast (DAB) and terrestrial digital video broadcast (DVB-T) systems.

#### 3.2.1 Digital Broadcasting of information.

Digital Audio Broadcasting (DAB) was the first standard to use OFDM. DAB uses a single frequency network, but the efficient handling of multi path delay spread results in improved CD quality sound, new data services, and higher spectrum efficiency. Digital broad casting had brought avalanche of data communication in the field of broadcasting A broadcasting industry group also created digital Video Broadcasting (DVB) in 1993. DVB produced a set of specifications for the delivery of digital television over cable, DSL and satellite.

#### 3.2.2 Terrestrial Digital Video Broadcasting for Television industry.

A pan-broadcasting-industry group created Digital Video Broadcasting VB in 1993. DVB produced a set of specifications for the delivery of digital Television over cable, DSL and satellite. In 1997 the terrestrial network, Digital Terrestrial Television Broadcasting (DTTB), was standardized. Now a days terrestrial video broadcasting became the most common and efficient tools for the communication.

### 3.2.3 Mobile Wireless Communication.

OFDM's capability to work around interfering signals gives it potential to threaten the existing CDMA (2.5G and 3G) wireless technology. This is what is allowing the technology to push forward in Europe. In densely populated areas where buildings, vehicles and people can scatter the path of a signal, broadcasters as well as high-speed data providers are anxious to eliminate multi-path fading effects. According to industry analysts, telecom providers may also be persuaded to OFDM technology because it could end up causing only a fraction of what it costs to implement 3G wireless technologies.

### 3.3 MIMO:- Multiple Input Multiple Output

In MIMO technique, the system exploits the fact that the received signal from one transmit antenna can be quite different than the received signal from a second antenna. This is most common in indoor or densely populated metropolitan areas where there are many reflections and multipath between transmitter and receiver . In this case, a different signal can be transmitted from each antenna at the same frequency and still be recovered at the receiver by signal processing unit.

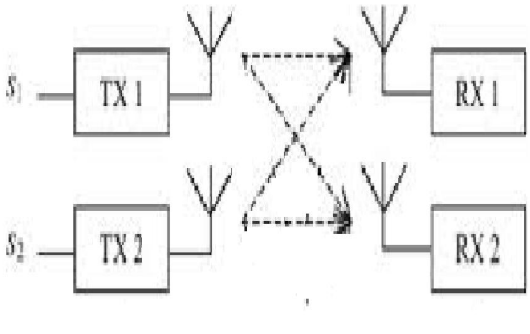


Fig.3.2 Transmit 2 Receive (2x2) MIMO channel.



### 3.3.1 Space Time Block Code

Alamouti discovered a remarkable space time block coding scheme for transmission with two antennas. This scheme supports maximum-likelihood (ML) detection based only on linear processing at the receiver [9]. The very simple structure and linear processing of the alamouti construction makes it very attractive scheme. There may be applications where a higher order of diversity is needed and multiple receive antennas at the remote units are feasible. In such cases, it is possible to provide a diversity order of 2M with two transmit and M receive antennas.

Using two transmit and M receive antennas, we can use the combiner for each receive antenna and then simply add the combined signals from all the receive antennas to obtain the same diversity order as 2M–branch MRRC(Maximum ratio receiver combining). In other words, using two antennas at the transmitter, the scheme doubles the diversity order of systems with one transmit and multiple receive antennas.

A space time block code is defined by a p x n transmission matrix G. The entries of the matrix G are linear combinations of the variables $x_1, x_2 \ldots x_k$ and their conjugates [10]. The number of transmission antennas is n, and we usually use it to separate different codes from each other. For example $G_2$ represents a code which uses two transmit antennas and is defined by

$$\mathcal{G}_2 = \begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix} \quad \text{-------------(3.1)}$$

$G_3$ represents a code which utilizes three transmit antennas and is defined by

$$\mathcal{G}_3 = \begin{pmatrix} x_1 & x_2 & x_3 \\ -x_2 & x_1 & -x_4 \\ -x_3 & x_4 & x_1 \\ -x_4 & -x_3 & x_2 \\ x_1^* & x_2^* & x_3^* \\ -x_2^* & x_1^* & -x_4^* \\ -x_3^* & x_4^* & x_1^* \\ -x_4^* & -x_3^* & x_2^* \end{pmatrix} \quad \text{----(3.2)}$$

$G_4$ represents a code which utilizes four transmit antennas and is defined by

$$\mathcal{G}_4 = \begin{pmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2 & x_1 & -x_4 & x_3 \\ -x_3 & x_4 & x_1 & -x_2 \\ -x_4 & -x_3 & x_2 & x_1 \\ x_1^* & x_2^* & x_3^* & x_4^* \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & x_4^* & x_1^* & -x_2^* \\ -x_4^* & -x_3^* & x_2^* & x_1^* \end{pmatrix} \quad \text{----(3.3)}$$



## 4. Methodology for Design and Implementation:

The first stage will be verification of each block using matlab. The Matlab is multi-purpose software which is usually used for mathematical computation in the Electronics and Telecommunication Engineering field. After the algorithm is verified, the hardware implementation will be obtained by constructing block diagram in Simulink [5]. Then a VHDL code will be imported into Simulink via Xilinx system generator block set which will create bit true and cycle accurate hardware model

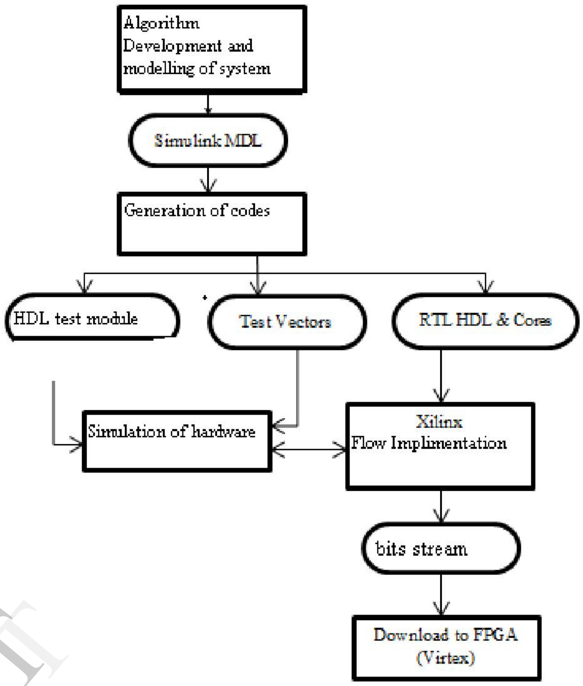


Fig.4.1 Methodology and flow diagram

The problem starts where one needs to select convolution encoder rate, constellation type and MIMO usage to ensure that the system works effectively [2]. For example in figure 5.2 we have selected convolution rate 1/2, 2/3 mapper and QAM constellation as it provides higher data rates. All block set function is implemented in the FPGA development board

## 4.1 Arrangement of subcarriers:

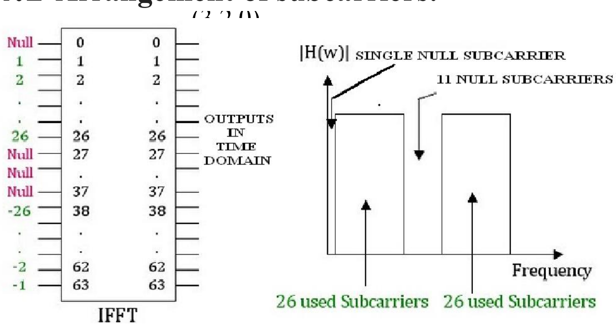


Fig.4.2 OFDM Subcarriers status

The IEEE 802.11 specification guides how to arrange the given subcarriers. The 52 used subcarriers (data + pilot) are assigned numbers from -26,-25...-2,-1 and 1, 2... 25, 26. The following figure illustrates the scheme of assigning these subcarriers to the IFFT inputs [1].

Table 4.1: OFDM Specifications

| **Given parameters in the condition:** | **Explanation** |
|---|---|
| N = 64 | Size of FAST FOURIER TRANSFORM(FFT) or total number of subcarriers (used + unused) are 64 |
| Nsd = 48 | Number of information subcarriers are 48 |
| Nsp = 4 | Number of pilot subcarriers are 4 |
| **Derived Parameters** | |
| Ofdm BW = $20 * 10^6$ | Bandwidth of OFDM |
| ΔF = ofdm BW/N | Each subcarriers Bandwidth Which - includes all used and unused subcarriers |
| $T_{fft}$ = 1/ΔF | IFFT or FFT Time period = 3.2µs |
| $T_{gi}$ = $T_{fft}/4$ | Guard band interval duration - duration of cyclic prefix - 1/4th portion of OFDM symbols |
| $T_{signal}$ = $T_{gi}+T_{fft}$ | Total Time duration of OFDM symbol = Guard time + FFT period |
| Ncp = $N*T_{gi}/T_{fft}$ | Number of symbols allotted to cyclic prefix |
| Nst = Nsd + Nsp | Total number of used subcarriers |
| nBitsPerSym = Nst | For QPSK the number of Bits per Symbol is twice as number of subcarriers |

## 5. Reported Results and discussion:

FPGA is superior method for implementation of OFDM compared to ASIC and Microprocessors. FPGA hardware is programmable and the designer has full control over the actual design implementation without the need (and delay) for any physical IC fabrication facility.

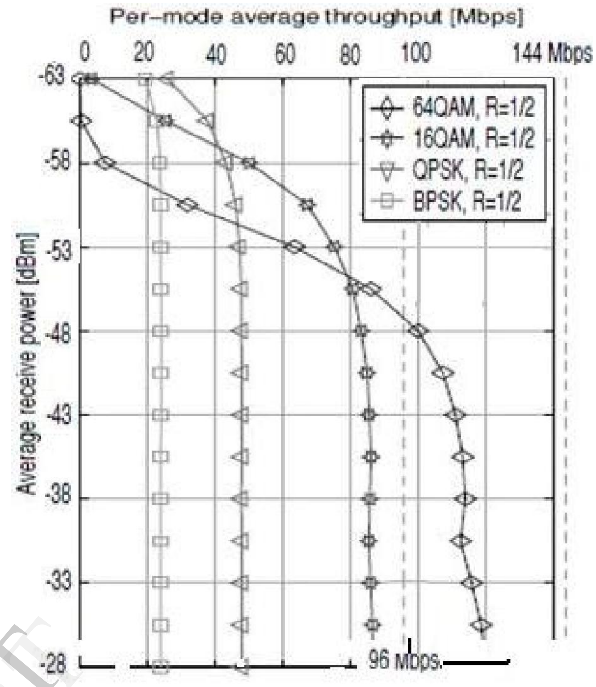


Fig 5.1. Actual Constellation Performance

Table 5.1 Constellation Performance

| **Constellation Of digital communication techniques** | **Code Rate** | **Data Rate in Mbps** |
|---|---|---|
| 64-QAM | 1/2 | 120 |
| 16-QAM | 1/2 | 88 |
| QPSK | 1/2 | 49 |
| BPSK | 1/2 | 25 |

The greater the number of symbols transmitted the higher data rates are achieved thus higher order QAM is used, however this scheme becomes more susceptible to ISI. The result shown above is for four transmit and four receive antennas. Thus proper selection of one of the sixteen configurations is important.

Our main aim is to implement a MIMO OFDM baseband transceiver on an FPGA by proper selection of one of the sixteen configurations to fulfill the need for high-speed data transmission for a wireless communication system with reasonable prices of hardware implementation.

In figure 4.1 we have different data rates which are achieved till date by using different constellation types.

## 6. Conclusion.

OFDM systems are the answer to our ever increasing data rate needs by both the subscriber and as well as the telecom operator. By implementing a MIMO OFDM baseband transceiver on an FPGA by proper selection of one of the sixteen configurations we expect to fulfill the need for high-speed data transmission for a wireless communication system with reasonable prices of hardware implementation. We understand the challenges and opportunities available in the technology. Moreover implementation on FPGA rather than on a general purpose MPU yields in terms of speed and on ASIC in terms on cost. Based on the more flexible properties , FPGA can be easily reconfigured by the base station to ever changing future demands.
The successful implementation of the transceiver on a FPGA would pave a way towards developing 802.11n modem. The architecture is applied for realization of 802.16 (Wi-max) and LTE(Long term evolution) transceivers. It intends to study various alternatives for implementation of the OFDM which results in reduced chip size which by extension means cost reduction. Finally to develop a complete system of indigenously developed 802.11n modem which then results in robust, maximum throughput, highly scalable wireless LAN network.



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