ANALYSIS OF FBMC AS A CANDIDATE WAVEFORM FOR 5G NETWORKS

DISSERTATION-II

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Requirement for the award of the
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By

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CERTIFICATE

This is to certify that the Dissertation-II entitled "**Analysis of FBMC as a candidate waveform for 5G networks**" which is being submitted by **S*atwinder Kaur*** in partial fulfillment of the requirement for the award of degree Masters of Technology in Electronics and Communication Engineering to Lovely Professional University, Jalandhar, Punjab is a record of the candidates own work carried out by her under my supervision. The matter embodied in this report is original and has not been submitted for the award of any other degree.

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DECLARATION

I, Satwinder Kaur, student of M. Tech under the department of School of Electronics and Electrical Engineering of Lovely Professional University, Punjab, hereby declare that all the information furnished in this Dissertation-II report is based on my own intensive research and is genuine.

This Dissertation-II does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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ABSTRACT

Filter bank multicarrier is a multicarrier scheme. It is a modulation techniques to overcome the inter symbol interference and inter carrier interference. The inter symbol interference is a big challenges in network systems. FBMC is a modification of orthogonal frequency division multiplexing (OFDM). In OFDM cyclic prefix are used for robustness of signal, but by using cyclic prefix orthogonal frequency division multiplexing has some drawbacks. To overcome the drawback of OFDM, use the Filter Bank Multicarrier (FBMC). It provides the efficient bandwidth.

As we know about that the wireless devices connecting with internet burgeoning very fast day by day. To handle this situation modulation techniques are used and other new methods will be used in future. One of them is Filter Bank Multicarrier; it provides high efficiency rather than OFDM. By using filter bank to reduce the large bandwidth requirements. In which OFDM pre-processing and post processing are used. After this, the main topic of this report i.e. FBMC-OFDM is explained in detail by using different type of polyphase filters such as synthesis polyphase filter ad analysis polyphase filter.

The MIMO applicability to filter bank based multicarrier (FBMC) modulations for low coherence bandwidth channels. Under these conditions the channel frequency response cannot be modeled flat at a subcarrier level. This implies that the techniques originally devised for OFDM do not restore the orthogonality between subcarriers when they are directly applied to FBMC. Aiming at circumventing this problem we propose the design of different MIMO FBMC schemes, which are based on different channels such as AWGN and Rayleigh channel. The figures of merit that govern the design of the first and second channels are the Bit Error Rate (BER) and the signal to noise ratio (SNR), respectively. Simulation-based results have demonstrated that the addressed solutions clearly outperform conventional FBMC schemes in terms of BER. To appropriately respond to these requirements while ensuring an efficient usage of available spectrum and system resources, the Analysis of FBMC as a candidate waveform for 5G system is expected to provide much more flexibility compared to today's systems**.**

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LIST OF ABBREVIATIONS

AFB	Analysis filter bank
AMPS	Advance Mobile Phone Systems
BPSK	Binary Phase Shift Key
BER	Bit Error Rate
CC	Convolution Codes
CDMA	Code Division Multiple Access
CP	Cyclic Prefix
CSI	Channel State Information
EDGE	Enhanced Data Rates for GSM Evolution
FEC	Forward Error Control
FFT	Fast Fourier Transform
FDD	Frequency Domain Duplexing
FDMA	Frequency Division Multiple Access
GSM	Global Service for Mobile
GPRS	General Packet Radio Service
HSDPA	High Speed Downlink Packet Access
IEEE	Institute of Electrical and Electronics Engineering
IFFT	Inverse Fast Fourier Transform
IMPS	Improved Mobile Telephone Service
IMT-Advanced	International Mobile Telecommunications Advanced
IP	Internet Protocol
ISI	Inter symbol Interference
ICI	Inter Carrier Interference
ITU-R	International Telecommunications Union-Radio
MRC	Maximal Ratio Combining

ML	Maximum Likelihood
MC	Multi-Carrier
MIMO	Multiple Input Multiple Output
MMS	Multi Media Messaging Service
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PPP	Point to Point
PMP	Point to Multipoint
PTT	Push to Talk
SFB	Synthesis Filter Bank
STC	Space-Time Codes
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Key
QOSTBC	Quasi-orthogonal space time block coding
UMTS	Universal Mobile media transmission Systems

CHAPTER 1 INTRODUCTION

The wireless defined as “having no wires”. In network systems, wireless means any computer network where there is no physical wired link between the transmitter and receiver, but there is network connected with the help of radio waves and microwaves. Wireless networks used specific equipment such as routers and NICs instead of wires. The wires used in wireless networks such as copper wire and optical wires. Different type of wire used as per requirement of network. Each wireless network backbone is wired network.

1.1 Evolution of wireless

Technology is burgeoning day by day. Due to change in technology people demand automatically changed. To fulfill the customer demands companies provides good services. With change of time systems change simple to advanced and correspondence change wired to remote. It has different generations are 1G, 2G, 2.5G, 3G, 4G and upcoming 5G. These all generations are different role in network systems.

- **1G:** It refers the first generation of mobile networks. It was introduced in 1980s by Japan. In which radio signals are analog used. It cover only 10-25 km, cells are very small and frequency reuse concepts are not used in it. 1G contained the accompanying Mobile advancements: Cell phone Systems (MTS), Advance Mobile Phone Systems (AMTS), Push to Talk (PTT) also Improved Mobile Telephone Service (IMTS). It has certain issues then we switch 1G to 2G. These issues are: security of data because in this network analog cellular phones are used, analog is very less secure. It is easy to hack or code. Example: paging system.

- **2G:** 2G is second generation of cellular networks. It was launched in Finland by Radiolinja in 1991 with GSM (global service for mobile). It changed analog to digital. In which digital services were used. Its speed is higher than 1G. In which speed up to 64kbps and it provide SMS (short services message) facilities and bandwidth range used 30-200KHZ. In which different technologies are used from 1G are General Packet Radio Service (GPRS), Code Division Multiple Access (CDMA) and Global System for Mobile Communication (GSM) and Enhanced Data Rates for GSM Evolution (EDGE).

In 2G some problems for instances in less populated places, the weaker computerized flag sent on higher frequencies may not be adequate to achieve a cell tower. Simple Signals have a smooth rot bend while advanced has a steeply one. This was viewed as both favorable position and in addition an inconvenience. Under great conditions, advanced sounded better. Under marginally awful conditions, simple experienced static, while advanced has periodic dropouts. As conditions compounded, advanced signs began to totally fall flat, while simple deteriorated progressively, for the most part holding a call longer and permitting no less than a couple words to get past.

- **3G:** 3G is modification of 2G. To overcome the problems of 2G, 3G is introduced. It is a generation of guidelines for cell phones and portable media communications administrations satisfying the International Telecommunication Union. It was introduced in 2001 in Japan. Its data rate speeds up to 2MBPS for stationary and 348KBPS for moving users. For instances of 3G is universal Mobile telecommunication service. In 2G and 3G circuit switching is used. Technologies are used in 3G are 3G Technology contains Wideband CDMA, WLAN, Bluetooth, Universal Mobile media transmission Systems (UMTS), High Speed Downlink Packet Access (HSDPA). Information is sent through bundle exchanging. Voice calls are deciphered utilizing circuit exchanging. It additionally gives offices, for example, Global Roaming Clarity in voice calls, Fast Communication, Internet, Mobile T.V, Video Conferencing, Video Calls, Multi Media Messaging Service (MMS), 3D gaming and Multiplayer-Gaming. A few issues in 3G 7Because of high information exchange limit transmission of 3G progressions; control use staggeringly extends which realizes decreased device battery life. The data usage of 3G now and again ends up being so overpowering a direct result of the high transmission rates that it puts a noteworthy load on the framework; to relieve which, various cell overseers realized data utilize tops which were disadvantageous to customers.

- **4G:** In March 2008, the International Telecommunications Union-Radio correspondences division (ITU-R) determined an arrangement of necessities for 4G principles, named the International Mobile Telecommunications Advanced (IMT-Advanced) determination, setting top speed prerequisites for 4G benefit at 100 megabits for every second (Mbit/s) for high versatility correspondence, (for example, from trains and autos) and 1 gigabit for every second

(Gbit/s) for low portability correspondence, (for example, people on foot and stationary clients). One of the underlying gadgets to get to 4G system was USB remote modem which was later trailed by PDAs with Wi-Max and LTE innovation. Long term Evolution Standard in view of the GSM/EDGE and UMTS/HSPA, third Generation Partnership Project, Multiple In Multiple Output brilliant radio wire innovation, Orthogonal Frequency Digital Multiplexing, 802.16e - Worldwide Interoperability for Microwave Access, 802.20 - Mobile Broadband Wireless Access. 3G and 4G segments made for one mainland isn't generally good with another landmass sue to conveying recurrence groups. Another noticeable issue in 4G frameworks is to make higher piece rates accessible in bigger bit of the cell, particularly to clients in an uncovered position in the middle of a few base stations.

- **5G:** The development of Long term evolution does not end with LTE propelled (Release 10) rather keeps on advancing into further discharges. Each new discharge additionally improves framework execution and includes new capacities with new application ranges. A portion of the extra applications, profiting from versatile availability, are home mechanization, brilliant transportation, security, etc. Some advantages of using 5G for saving battery power, improved scope run and higher information rate accessibility at cell edge. Multiple simultaneous ways for information transmission and hand over. 5G offers help for intuitive sight and sound, voice, video, Internet, and other broadband administrations which are more viable and more alluring and have Bidirectional precise movement insights improved security highlights; better subjective radio/Software Development Radio. Higher framework level ghostly productivity.

Table 1.1 Comparison of 1G to 5G technologies

Parameters	**1G**	**2G/2.5G**	**3G**	**4G**	**5G**
Development	1970/1980	1980/1999	1990/2002	2000/2010	2010/2015
Technology	Analog	Digital	Digital broadband Packet data	Digital broadband packet data	Not yet
Data Bandwidth	2 KBPS	14.4/64 KBPS	2 MBPS	2000 MBPS	1GBPS and higher
Multiplexing	FDMA	TDMA/CDMA	CDMA	CDMA	CDMA

Core Network	PSTN	PSTN	Packet network	Internet	Internet
Service	Mobile telephony (voice)	Digital voice, short messages/ Higher capacity packetized data	Integrated higher quality audio, video and data	Dynamic information access, wearable	Dynamic information access, wearable device with IA capabilities
Handoff	Horizontal	Horizontal	Horizontal	Horizontal and vertical	Horizontal and vertical
Switching	Circuit	Circuit	Packet except circuit for air interface	All packet	All packet

- **Threats in 5G:** Some threats are explained as

1. Since all the framework executives and master associations would share a commonplace focus framework establishment, exchange off of a singular chairman will provoke the fold of the entire framework system, if not purposely coordinate against.

2. Outsiders can take on the appearance of honest to goodness clients bringing about burglary of administration and charging fakes can without much of a stretch emerge.

3. In 5G is a secure Internet Protocol based arrangement it will be defenseless against all the security dangers as the present Internet world.

4. On the lines of email spam, the Spam over Internet correspondence, the new spam over VoIP may wind up discernibly veritable and twist up observably authentic risks.

5. Spooling ambushes can incite deceived correspondence and web keeping cash related fakes.

6. Roof dropping and capture attempt of private interchanges.

7. Phishing assaults, taking ledger points of interest and other secured data, are more probable.

1.2. Basic of multicarrier system

Multicarrier modulation works by isolating the information stream to be transmitted into various lower information rate information streams. Each of the lower information rate streams is then

used to adjust an individual transporter. At the point when the general transmission is gotten, the collector needs to then re-gather the general information stream from those got on the individual transporters. It is conceivable to utilize a wide range of strategies for multicarrier transmissions. Each type of MCM has its own particular points of interest and can be sued in various applications.

1.2.1 History of multicarrier system

Multicarrier is firstly used by military users. In the late 1950s and early 1960s the first Multicarrier modulations were used military high frequency radio links. By this effects of fading were overcome from several channels. In Multicarrier carrier required the utilization of a few channels that were separated into sub channels by utilizing steep sided channels since they were close dispersed. Along these lines, impedance from the diverse channels could be expelled. It has a few applications, for example, multicarrier regulation frameworks initially turned out to be generally utilized with the presentation of broadcasting frameworks, for example, DAM computerized radio and DVB, Digital Video Broadcasting which utilized OFDM, orthogonal recurrence division multiplexing. OFDM utilized handling power inside the collector and orthogonality between the bearers to guarantee no impedance was available.

1.2.2 Need of multicarrier modulations

Different types of multiple access techniques are used for different generations of wireless communication systems. For instance, in 1G Frequency division multiple access (FDMA), 2G Time division multiple access and Code division multiple access (CDMA), 3G Wavelength Code division multiple access (WCDMA), 4G and 5G Code division multiple access (CDMA) is used. These are used for achieving high data rate, to increase the capacity of system and for combining the different services for mobile communication in wireless communication system. The guideline obstruction of FDMA and TDMA are the point of confinement (the amount of customers, which these can suit). The CDMA frameworks have been delivered for the most part for restrain reasons. CDMA methods can possibly oblige a bigger number of customers than either TDMA or FDMA. WCDMA is a 3G remote standard, created from CDMA to help the blended media remote organizations at data rate as high as 2 Mbps.

In 2G systems and 3G systems frequency selective multipath fading is a common problem. Frequency selective multipath fading is common in big areas and small areas such as urban and indoor environment respectively. By this source performance is degradation. On the off chance that the quantity of clients increments quickly then the execution corrupts more. The fast variance of the adequacy of a radio banner over a concise time period or travel isolate is known as obscuring which rises on account of mix of multipath waves at the beneficiary gathering device to give a resultant banner, which can vary extensively in plentifulness and stage, dependent upon the apportionment of the power and relative inducing time of the waves and the information exchange limit of the transmitted signal. Also other cell frameworks have utilized multicarrier procedures to accomplish high information rates by utilizing at least two bearers from a standard cell framework. Double Carrier HSPA is one case. With new systems administration and cell frameworks not too far off, other multicarrier methods have been examined and their utilization appears to be likely sooner rather than later.

1.3 Orthogonal frequency division multiplexing

In remote correspondences, the signal transmitted from the source normally encounters constriction, diffusing, reflection and refraction before it achieves the goal. These impacts are normally displayed as one or a few qualities known as the channel reaction [3-6] which is convolved with the transmitted signal. The reaction of the channel between the transmitter and the recipient is not settled but rather shifts with time and recurrence. The data transfer capacity whereupon the channel reaction can be expected settled (level) is known as the intelligence transfer speed of the channel. In the event that the information is transmitted at high image rates, the data transfer capacity of the flag turns out to be wide and may surpass the cognizance transmission capacity of the channel [3, 5]. This contorts the flag and prompts entomb image impedance (ISI). ISI corrupts the flag in two ways. To start with, beforehand transmitted images meddle with the current symbol second, some portion of the present image vitality is lost as it will bring about ISI for resulting images. To dispense with ISI equalization is generally utilized. The equalizer is a versatile computerized channel with a specific number of taps. The weights of the taps in the equalizer are planned to such an extent that the joined reaction of the channel and equalizer is a consistent incentive inside the flag transmission capacity. The equalizer is a versatile computerized channel with a specific number of taps. The weights of the taps in the equalizer are composed to

such an extent that the joined reaction of the channel and equalizer is a steady esteem (level) inside the flag data transfer capacity. Equalizers experience the ill effects of various confinements. Finding the ideal weight of each tap is a muddled procedure which increments exponentially as the length (number of taps) of the channel increments. In addition, these weights are figured from a boisterous gauge of the channel reaction and consequently the estimation blunder will be higher contrasted with the single tap channel required for level channels. Another constraint is equalizers are outlined with a greatest length (number of taps). Such equalizers will perform ineffectively if the channel reaction is longer than the equalizer's length. To take out the requirement for multi-tap equalizers, it was proposed in the 1960s that the information be part into parallel streams, in this way decreasing the image rate and data transmission of each stream. On the off chance that the quantity of streams is sufficiently expansive, the data transfer capacity of each stream can turn out to be not as much as the channel lucidness transmission capacity and subsequently each stream encounters a level channel reaction. These streams are then tweaked utilizing separate orthogonal bearers known as subcarriers. The subcarriers must fit inside the data transfer capacity assigned for transmission yet should be sufficiently far so they don't meddle with each other. The base separating between the subcarriers was observed to be 1/T where T is the image term in the wake of part the information into parallel streams.

Orthogonal frequency division multiplexing is a mix of adjustment and multiplexing. In balances information or data is mapped on to changes in adequacy or stage, recurrence of a bearer flag. Multiplexing manages distribution/convenience of clients in a given data transfer capacity and that is manages portion of accessible data. In this procedure, the given transfer speed is shared among individual tweaked information sources. Basic modulation techniques are like Amplitude modulation ,Phase modulation, Frequency modulation, Binary phase shift keying, Quadrature phase shift keying and so on. These are single transporter regulation procedures, in which the approaching data is adjusted over a solitary bearer. OFDM is a multicarrier balance procedure, which utilizes a few transporters, inside the designated data transmission, to pass on the data from source to goal. Every transporter may utilize one of the few accessible advanced regulation systems are BPSK, QPSK and QAM.OFDM is a special case of frequency division multiplexing. On the off chance that the transporters are sounds are b=2a, c=3a, d=4a, d=5a, vital several of basic part and afterward they wind up noticeably orthogonal. This is an extraordinary instance of FDM, which is called OFDM. In which IFFT and FFT are used. IFFT is act as modulator at the

transmitter side and FFT is act as demodulator at the receiver side. It gives high data rates, high spectral efficiency and dynamic allocation of bandwidth to users using low complexity hardware.

1.3.1 History of OFDM

The essential OFDM contrive backpedals to 1966 when Robert W. Chang appropriated his leading tackle the mix of band-limited orthogonal signs for multi-channel data transmission. He was then issued a patent in 1970 for his work. He showed another arrangement of transmitting signs at the same time over a band-confined channel without bury bearer obstruction (ICI) and entomb image impedance (ISI). The major considered OFDM is to segment the repeat particular channel into different parallel, repeat level sub channels. By making the sub-channels narrowband, the individual channels encounter level darkening, this influences beneficiary to chart clear. Chang made orthogonality between the sub-channels by Fourier changes, utilizing the summation of sine and cosine. Safe guarding of orthogonality inside each channel licenses setting up singular channel information transmission rates similar to the channel trade speed. This is a substantial bit of the ideal Nyquist rate. Regardless, in view of the way that adjacent channels are synchronized, they can be secured by 50 percent, as is showed up. In 1967, Saltzberg dissected and showed the execution of the useful parallel information transmission frameworks, where he accepted that the method of orchestrating a competent parallel structure should focus on diminishing crosstalk between bordering channels than on satisfying the individual channels themselves. His decision has been displayed far-discovered today in the advanced baseband hail managing to fight Inter transporter entomb image. Each sub-diverts orthogonality in the OFDM structure can be ensured through the staggered QAM framework.

1.3.2 Single carriers versus multicarrier transmitted

The single carrier transmission implies one Radio Frequency bearer is utilized to convey the data. Consequently data as bits is conveyed by one single RF bearer. OFDM, otherwise called multicarrier transmission or tweak, utilizes various bearer signals at various frequencies, sending a portion of the bits on each channel. This is like FDM (Frequency Division Multiplexing) however on account of OFDM; the majority of the sub channels are devoted to a solitary information source. For OFDM case IFFT is utilized at the transmitter to achieve this, which does not exist in Single bearer case. Subsequent to passing the multipath diverts in the recipient a channel

coordinated to the channel is utilized to augment flag to clamor proportion the gadget used to remove the information.

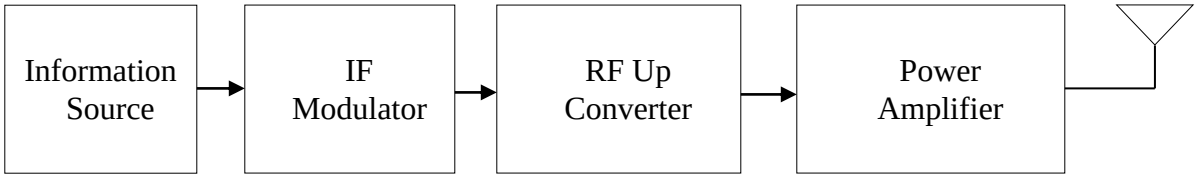

Fig. 1.1: Simple diagram of single carrier

In which information source or data is binary form. An IF Modulator is intermediate frequency θh $\pm \theta l$. Power amplifiers used for amplifies the signals or weaker signals.

Fig. 1.2: Single carrier system

The circumstance we are overseeing in DVB-T is portrayed by the going with conditions:

Transmission Rate:

$$Tr = \frac{1}{T} = 7.4 \frac{\text{M sym}}{s} \tag{1.1}$$

Maximum channel delay:

$$Tm = 224\mu s \tag{1.2}$$

For the single carrier system this results in an ISI of:

$$\frac{Tm}{T} \approx 1600 \tag{1.3}$$

The general structure of a multicarrier framework:

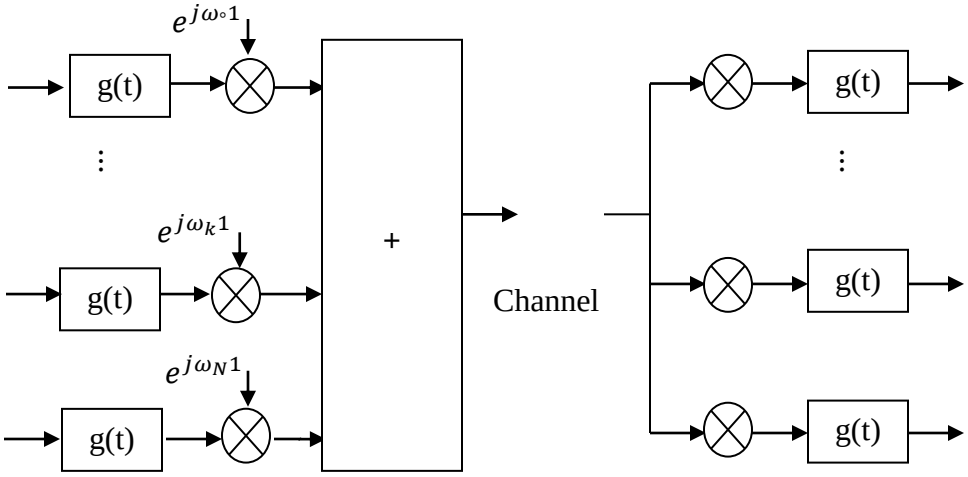

Fig. 1.3: Simple structure of a multicarrier system

The first information stream of rate Rmc is multiplexed into N parallel information data rate

$$Rmc = \frac{1}{Tmc} = R/N \tag{1.4}$$

Each of the information streams is regulated with an alternate recurrence and the subsequent signs are transmitted together in a similar band. Correspondingly the collector comprises of N parallel beneficiary ways. Because of the drawn out separation in the middle of transmitted images the ISI for each sub framework lessens to

$$\frac{Tmax}{Tmc} = \frac{Tmax}{N.T} \tag{1.5}$$

On account of DVB-T we have N=8192 prompting an ISI of

$$\frac{Tmax}{Tmc} = 0.2 \tag{1.6}$$

Such little ISI can frequently be endured and no additional counter measure, for example, an equalizer is required. Oh dear to the extent the unpredictability of a beneficiary is concerned a framework with 8192 parallel ways still isn't plausible. This requests a slight adjustment of the approach which drives us to the idea of OFDM.

1.3.3 Orthogonality of OFDM system

In OFDM the subcarrier beat utilized for transmission is been rectangular. This has the perfect position that the undertaking of heartbeat encompassing and change can be performed by a basic Inverse Discrete Fourier Transform (IDFT) which can be finished beneficially as an Inverse Fast Fourier Transform (IFFT). Fittingly in the beneficiary we basically require a FFT to turn this operation. As showed by the theories of the Fourier Transform the rectangular heartbeat shape will incite a sin(x)/x kind of extent of the subcarriers. The scopes of the subcarriers are not disconnected yet rather cover. The inspiration driving why the information transmitted over the bearers can even now be segregated is the indicated orthogonality association giving the system its name.

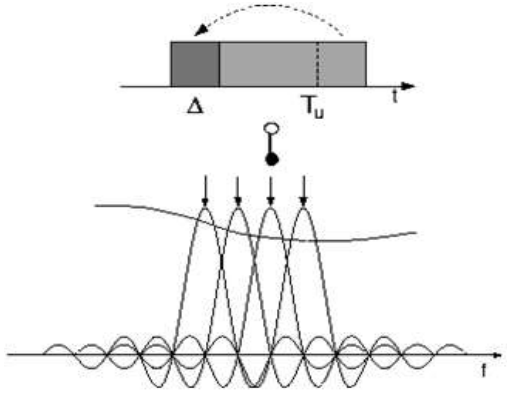

Fig. 1.4: Orthogonality principle

By using an IFFT for alteration we surely picked the scattering of the subcarriers with the end goal that at the repeat where we survey got hail (showed as jolts) each other banner are zero. All together for this orthogonality to be spared the going with must be substantial:

a) The beneficiary and the transmitter must be immaculately synchronized. This suggests they both must acknowledge the exceptionally same direction repeat and a comparable time-scale for transmission (which usually will be not the circumstance).

b) The basic fragments, some bit of transmitter and recipient, must be of high bore.

c) There should be no multipath channel.

1.3.4 OFDM system description

It is orthogonal recurrence division multiplexing. The fundamental OFDM standards will be presented utilizing a straightforward simple OFDM execution and afterward those ideas will be stretched out to the advanced area with a basic computerized OFDM usage which uses the quick Fourier change and computerized flag handling innovation. It is a strategy for encoding advanced information on multicarrier frequencies. It has brought into a mainstream technique for wideband advanced correspondence, utilized as a part of utilization, for example, computerized television& sound telecom, DSL web get to, remote systems, control line systems and 4G versatile correspondences. In which 100Mbps information rate is abundance.

Cyclic prefix are used, the cyclic prefix is made so that each OFDM image is gone before by a duplicate of the end some portion of a similar channel. For various OFDM cyclic prefix lengths are accessible in different frameworks. A staggered modulated multitone and in old schemes cosine modulated multitone were used.

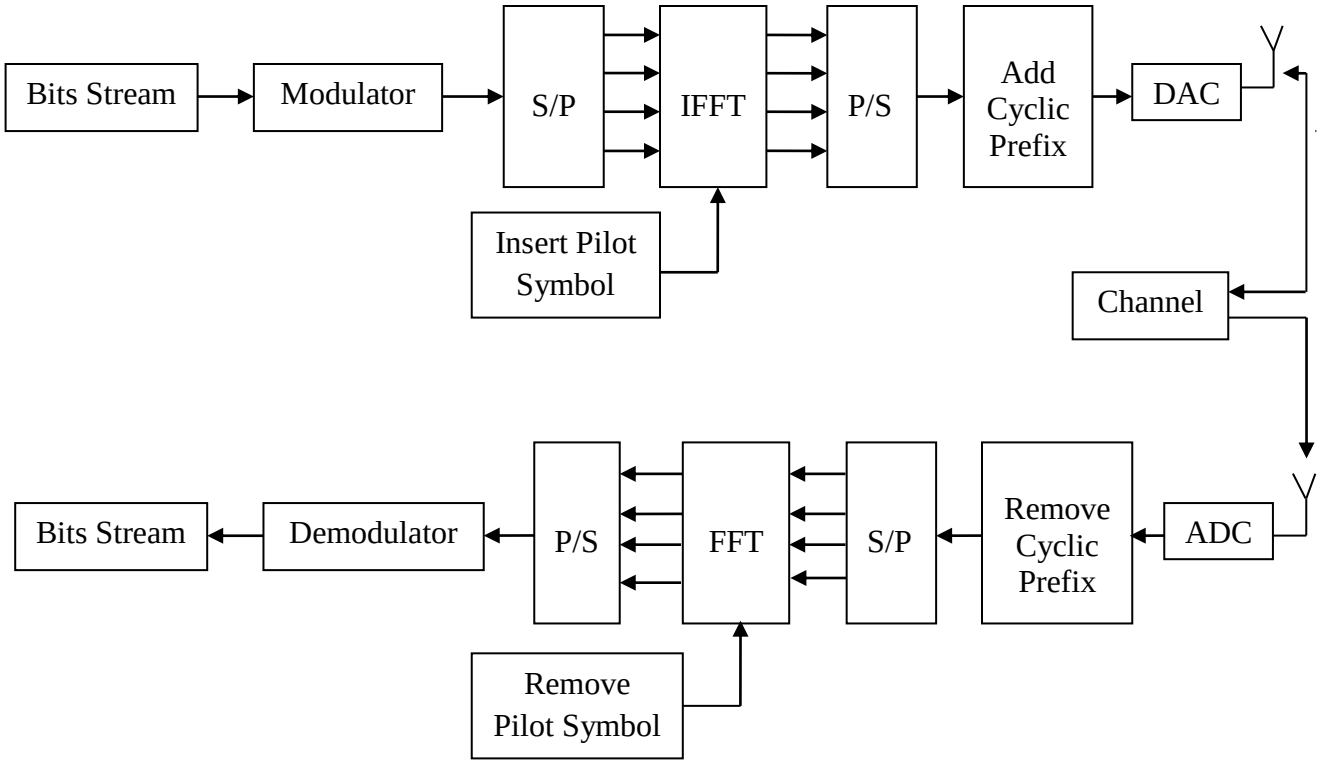

Fig. 1.5: Architecture of OFDM TX and RX

It gives the idea about different type of modulations like multi pulse modulation isolation in time etc. In FBMC physical layer we use different type of filters such as synthesis filter bank (SFB) in OQAM preprocessing or modulator part and analysis filter bank (AFB) in OQAM post processing or demodulator part.

1.3.5 Merits and demerits of OFDM

a) Merits

1. Reduce Inter symbol Interference and ICI by using cyclic prefix.
2. Provide robustness.
3. Makes efficient use of the spectrum by allowing overlap.
4. Channel equalization becomes simpler than by using adaptive equalization techniques with single carrier systems.
5. Provides good protection against co-channel interference and impulsive parasitic noise.

b) Demerits

1. Reduce data capacity by retransmit the data that is already send by transmitter.
2. In which OFDM flag has a clamor like abundance with a substantial element run, in this way it requires RF control enhancers with a high crest to normal power proportion.
3. It is touchier to bearer recurrence balance and float than single transporter frameworks are because of spillage of the DFT.

1.3.6 Applications of OFDM

1. **DAB:** DAB is an advanced innovation offering extensive focal points over the present FM radio, both to audience members and broadcasting.DAB adaptability will likewise give a more extensive selection of projects, including many not accessible on FM.

2. **HDTV:** HDTV refers high definition television. It is first published by England. There are three mechanisms for broadcasting system in European (COFDM), North America (8-VSB), and Japan (BST-OFDM).

3. **Wireless LAN:** HIPERLAN2 (European) introduced by ETSI. It has High and scalable capacity. Data rate is 54 Mbps provides through an OFDM technique.

4. **IEEE 802.16, IEEE 802.20:** IEEE 802.20 or bile broadband wireless access was a specification by the standard association of the institute of EEE for MBWA networks.

5. **LTE and LTE Advanced:** In Nov. 2004, 3GPP began a project. This project is to define the long-term evolution (LTE) of Universal Mobile Telecommunications System (UMTS) cellular technology. This application is used for different purpose. These purposes are explained below:

   i. Performance is higher.

   ii. Spectral efficiency is improving.

   iii. Cost is less.

   iv. Services are also improving.

   v. Use of new spectrum chances is there.

   vi. Quality of service (QOS) is also enhanced.

Table 1.2 OFDM practical systems

Parameters	DAB	DVB-T	IEEE802.11a	HIPERLAN
Carrier Frequency	VHF	VHF&UHF	5GHz	5GHz
Bandwidth	1.5MHz	8MHz	20MHz	20MHz

Max. Data Rate	1.7Mbps	31.7Mbps	54MHz	54Mbps
No. of Sub-Carriers or (FFT size)	192 up to 1536 (26 up to 2048)	1705 to 6817 (2048 &8196)	52 (64)	52 (64)

1.4 Filter Bank Multicarrier

Filter bank multicarrier is a multicarrier scheme. It is a modulation technique to overcome the Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI). The inter symbol interference is a big challenges in network systems. FBMC is a modification of orthogonal frequency division multiplexing (OFDM). In OFDM cyclic prefix are used for robustness of signal, but by using cyclic prefix orthogonal frequency division multiplexing has some drawbacks [7]. To overcome the drawback of OFDM, use the Filter Bank Multicarrier (FBMC). It provides the efficient bandwidth. To handle this situation modulation techniques are used and other new methods will be used in future. One of them is Filter Bank Multicarrier; it provides high efficiency rather than OFDM.

1.4.1 History of FBMC

The first multicarrier schemes that were based on filter bank developed in 1960 by chang. A channel bank multicarrier plans to beat a segment of the inadequacies that were knowledgeable about OFDM, orthogonal repeat division multiplexing. One of the major lacks rises up out of the way that OFDM requires the use of what is named a cyclic prefix [7]. The cyclic prefix is fundamentally a copy of part of a transmitted picture in OFDM that is joined toward begin. This repetition decreases the throughput of the transmission and furthermore squanders away control. In FBMC at the input IFFT is used as a modulator and at the receiver side FFT used and it act as a demodulator. A further burden of OFDM is that spooky confinement of the subcarriers is weak and this results in extraordinary spillage and impedance issues with unsynchronized signs. Channel bank multicarrier is a change of OFDM. A utilizing bank of channels, that are executed ordinarily devouring propelled standard getting ready methodologies, FBMC. When transporters were balanced in an OFDM structure, side flaps spread out either side. With a channel bank system, the channels are used to empty these and thusly a much cleaner conveyor happens.

1.4.2 Merits and demerits of FBMC

The Merits of filter bank multicarrier are:

- In which cyclic prefix are not utilized.
- A similar kind of channels can be utilized for recipient information flag preparing (DSP) and adaptable high determination range utilized.
- Elite range detecting and transmission.
- Heartiness to tight band jammers and drive commotion.
- Other worldly insurance of neighboring client.

Demerits of filter bank multicarrier are:

- High computational multifaceted nature.
- Analog radio recurrence execution is basic for usage non- specific range detecting with wide data transfer capacity and high element go.
- The advancement of numerous information various yield channel bank multicarrier framework is nontrivial and might be exceptionally constrained.

1.4.3 Applications of FBMC

- **Subjective radio correspondence:** As examination of OFDM, FBMC offers higher otherworldly productivity and more material for the psychological radio system with little size of gaps.
- **Different get to networks:** In multiuser setting, the uplink of an OFDM arranges utilizes a strategy called various get to impedance cancelation with a specific end goal to meet its essential operational necessities.

- **Access to TV white space (TVWS):** It has adaptability, low contiguous spillage control proportion; recurrence spryness and sharp range move off are essential elements.

- **Control line correspondence:** It is one the most imperative use of channel bank multicarrier.

- **MIMO correspondence:** In Multiple info various yield FBMC frameworks for direct and exceedingly recurrence specific channels, got signs are adulterated by bury image obstruction and entomb radio wire impedance.

1.5 MIMO

The wireless communication is a technique there is no physical connection through wires such as cables and optical fiber between transmitter and receiver. It is connectionless services or we can say that it is wireless communication and transmit information through air. So air is the medium for transmission data from source to destination. It is useful for long distance communication because communication with wires is difficult process. In the current scenario we use wireless communication because it provides large advantages in terms of productivity and cost. MIMO will make a development in the field of remote correspondence [25]. The correspondence framework has been created a considerable measure in the decade ago and this advancement is becoming quickly. To get the high information rate radio wire (antenna) is one of the prime components since to send information at high rate, more extensive channel width is required and it is just conceivable when radio wire can be included a cluster. Numerous information different yield ((MIMO) has been making this framework more successful and nowadays large MIMO will be presented for 5G to achieve high data rate. Main Component of wireless communication such as transmitter, receiver and channel. The source is the starting purpose of the data that will be passed on. This data could be voice, content, picture, bundle information and so forth. More often than not, this message is encoded upon a bearer or a medium called the Baseband flag. The baseband flag conveys no data all alone, however before achieving the transmitter, the data to be sent is added to it. The transmitter then conveys the message into the correspondence channel. The channel is a medium through which the transmitter yield is sent to the receiver. This in the wired framework could be a wire, a coaxial link, or an optical fiber. In remote frameworks these are by and large waves like IR or radio. At the flip side of the channel would be the collector. It would separate the data from the approaching sign got, by subtracting the baseband motion from it. The

collector yield is the data that had originated from the source, and this can be coordinated to the beneficiary.

MIMO is characterizes as multiple-input multiple-output. It is a strategy for increasing the limit of a radio connection utilizing various transmit and get reception apparatuses. In remote correspondence, MIMO has turned into a basic component of norms including IEEE 802.11n and IEEE 802.11ac (Wi-Fi), HSPA+ (3G), Wi-MAX and Long Term Evolution (4G) [21].This is likely due to some extent to the way that OFDM (orthogonal recurrence division multiplexing), which encourages the usage of MIMO, is presently normally utilized as a part of today's remote measures. MIMO methods are utilized today in advances like Wi-Fi and LTE, and new strategies are under review for future benchmarks like LTE Advanced. The primary element of MIMO frameworks is space-time preparing. Space-Time Codes (STCs) are the codes intended for the utilization in MIMO frameworks. In STCs, signs are coded in both transient and spatial areas. Here we use encoder at the transmitter side and decoder at the receiver side [22].

At one time, in remote the articulation "MIMO" alludes to the usage of various getting wires at the transmitter and the beneficiary. In current usage, "MIMO" especially alludes to a valuable technique for sending and getting more than one data signal at the same time finished a comparable radio channel by abusing multipath multiplication. MIMO is on an exceptionally fundamental level not exactly the same as clever radio wire systems made to enhance the execution of a lone data hail, for instance, beamforming and diversity.

1.5.1 History of MIMO

MIMO innovation has been created over numerous years. Not exclusively did the fundamental MIMO ideas should be defined, yet moreover, new innovations should have been created to empower MIMO to be completely actualized. New levels of preparing were expected to permit a portion of the highlights of spatial multiplexing and also to use a portion of the additions of spatial assorted variety [21]. Up until the 1990s, spatial not too bad assortment was routinely limited to systems that traded between two gathering contraptions or merged the signs to give the best banner. Also extraordinary sorts of shaft trading were executed, however in context of the levels of getting ready included and the degrees of dealing with available, the systems were generally respectably obliged. However with the additional levels of taking care of energy that started to

twist up recognizably available, it was possible to utilize both spatial grouped assortment and full spatial multiplexing. The hidden work on MIMO systems focused on basic spatial tolerable assortment - here the MIMO structure was used to compel the defilement caused by multipath spread. However this was recently the underlying advance as structure by then utilized the multipath multiplication to advantage; changing the additional banner courses into what may enough be considered as additional channels to pass on additional data. Two researchers: Arogyaswami Paulraj and Thomas Kailath were first to propose the use of spatial multiplexing using MIMO in 1993 and in the following year their US patent was yielded [21]. Nevertheless it tumbled to Bell Labs to be the first to show an examination office model of spatial multiplexing in 1998.

1.5.2 Functions used in MIMO

In MIMO different types of functions are used. The three main functions are given below:

- Precoding
- Spatial multiplexing (SM)
- Diversity coding

1.5.3 MIMO –Multiple input multiple output basics

A channel may be impacted by obscuring and this will influence the banner to confusion extent. Subsequently this will influence the mix-up rate; tolerating mechanized data is being transmitted. Administer of arranged assortment is to outfit the beneficiary with various variations of a comparative banner. If these can be made to be affected in different courses by the banner way, the probability that they will all be impacted meanwhile is altogether diminished. In like way, tolerable assortment offsets an association and improves execution, diminishing goof rate. A few distinctive assorted variety modes are accessible and give various favorable circumstances:

- Time diversity
- Frequency diversity

- Space diversity

These are explained as:

- In Time diversity, at different times a message can be transmitted. For instance: using different coding and timeslots.

- In frequency diversity, different frequencies are used. For instance, in which different channels are used, or technologies such as spread spectrum or OFDM.

- In space decent variety, the assortment used as a piece of the broadest sentiment the definition is used as the purpose behind MIMO. It uses gathering devices arranged in different positions to abuse the assorted radio ways that exist in an average terrestrial condition.

By utilizing MIMO, these extra ways can be utilized to merits. They can be utilized to give extra strength to the radio connection by upgrading the flag to commotion proportion, or by enhanced the connection information limit.

The two main formats for MIMO are given below:

- **Spatial diversity:** Spatial diversity variety utilized as a part of this smaller sense regularly alludes to transmit and get decent variety. These two strategies are used to give updates in the banner to hullabaloo extent and they are portrayed by improving the resolute nature of the system concerning the diverse sorts of obscuring.

- **Spatial multiplexing:** This sort of MIMO is used to give additional data restrict by utilizing the differing approaches to pass on additional development, i.e. extending the data throughput limit.

At last utilization of numerous radio wires, MIMO remote innovation is utilized to enhance the limit of a given channel while as yet complying with Shannon's law. By expanding the quantity of goal and source reception apparatuses it is conceivable to straightly build the throughput of the channel with each combine of receiving wires added to the framework.

1.5.4 MIMO Formats

There are different types of MIMO formats are used. These are named as SISO, SIMO, MISO and MIMO. These different MIMO formats offer different merits and demerits - for any given application, these can be balanced to provide the optimum solution. The different MIMO formats - SISO, SIMO, MISO and MIMO. They require different numbers of antennas as well as having different levels of complexity. Also dependent upon the format, processing may be needed at one end of the link or the other - this can have an impact on any decisions made. The diverse types of reception apparatus innovation allude to single or different data sources and yields. These are identified with the radio connection. Along these lines the info is the transmitter as it transmits into the connection or flag way, and the yield is the collector. It is at the yield of the remote connection. The different forms of single / multiple antenna links are defined as below:

- SISO- Single Input Single Output
- SIMO- Single Input Multiple Output
- MISO- Multiple Input Single Output
- MIMO- Multiple Input Multiple Output

1.5.5 Applications of MIMO

- It is efficient for OFDM when multipath fading will occur.
- It gives reliable communication.
- It also improved capacity.

1.6 Objective of study

- **Performance improvement:** The performance of FBMC can be improved by using different diversity schemes and multipath fading will be reduced. The analysis cann be carried out over different multipath channels.

- **Integration of FBMC with MIMO system:** In integration of FBMC with MIMO, FBMC and MIMO can be combined for better performance of system. In MIMO multiple numbers of antennas will be used at transmitter and receiver side at same time for better results.

- **Analysis of FBMC using different MIMO schemes:** MIMO-FBMC using different diversity schemes can be analyzed by utilizing diverse MIMO methodologies such as MRC, SC, Alamouti, STBC3 and STBC4.

1.7 Chapter outline

- **Chapter 1:** It includes the basic information about Wireless communication and its generations. Moreover, an overview of OFDM, FBMC and MIMO is also presented in it.

- **Chapter 2:** It presents the literature survey about OFDM, FBMC, MIMO and integrated MIMO-FBMC.

- **Chapter 3:** The building blocks of FBMC and its applications are proposed in this chapter. Different types of FBMC filters are also explained.

- **Chapter 4:** It includes the MIMO and its types. Different types of diversity schemes are used. By using different diversity schemes performance of system is better.

- **Chapter 5:** It summarizes the main results, and provides several directions for future extension based on the frameworks. The simulation work AWGN and Rayleigh channels are used for analyzing the performance of FBMC system augmented with MIMO system. In MIMO-FBMC, different diversity combining techniques are used to analyze the performance of system.

- **Chapter 6:** It concludes the finding of the work carried out in this report.

CHAPTER 2 LITERATURE SURVEY

2.1 OFDM

OFDM is an orthogonal frequency division multiplexing. It overcomes the frequency division multiplexing problems by using cyclic prefix (CP). Taewon Hwang et al. [1] elaborate the OFDM and its modulation techniques as well as its applications. By using these techniques performance of OFDM system will increased. Some applications will required high data rate transmission over mobile or wireless channels. When the data rate increased then symbol duration decreased and dispersive fading of the wireless channels will cause of severe inter symbol interference (ISI). TDMA and GSM still used for single carrier modulation. If the delay spread is less than the symbol duration then ISI effect will be overcome. In OFDM whole channel is separated into small sub channels, by using parallel transmission high data rate is maintained at same time and symbol duration increased. At the transmitter side IFFT is used and at receiver side FFT is used for modulation and demodulation purposes. To utilize efficiently bandwidth in OFDM cyclic prefix (CP) is introduced in it. In this paper CP or without CP channels are used. To reduce peak to average ratio these techniques include such as clipping and filtering, selected mapping (SLM) partial transmit sequence (PTS), etc.

For high data rate we used frequency selectivity at the transmission channels. Brijesh Kumar et al. [2] proposed the information about structure and implementation of orthogonal frequency division multiplexing in wireless communication.MC-CDMA used to improve the capacity of Multi-user in OFDM. In this paper different modulations are used and by using these modulation techniques to achieve different data rates. We demonstrates that OFDM is vastly improved suited to a multipath channel than the standard single bearer transmission technique such as16-QAM. The want for high information rate remote correspondence have been expanding definitely all through the most recent decade. This paper has investigated the part of OFDM inside the remote correspondence and it is favorable circumstances over single supplier transmission. There are likewise a couple of impediments of this method which is frequently expelled with the guide of reasonable strategies.

Orthogonal frequency division multiplexing is a multi-carrier (MU) modulation. Manushree Bhardwaj et al. [3] state that orthogonal recurrence division multiplexing (OFDM) is an

extraordinary instance of multicarrier transmission where a solitary DataStream is transmitted over various lower rate subcarriers. In July 1998, the IEEE institutionalization assemble chose to choose OFDM as the reason for their new 5-GHz standard pointing a scope of information stream from 6 up to 54 Mbps. This new standard is the first to utilize OFDM in bundle based correspondences. By using parallel transmission high data rate and better transmission quality is achieved. Parallel transmission is done because entire channel is split into small sub channels so channel throughput is high. OFDM has some different applications in wireless areas used in Europe for example, Advanced Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB), and for Asymmetric Digital Subscriber Line (ADSL) high data rate wired associations. One way to deal with transmit this high data rate information is to use surely understood customary single-bearer frameworks. Since the transmission exchange speed is altogether greater than the discernment information exchange limit of the channel, exceedingly complex equalizers are required at the authority for definitely recovering the transmitted information. Multi-transporter techniques can handle this issue in a general sense.

When orthogonal frequency division multiplexing (OFDM) spectrum split into many sub-channels and at a lower data rate each sub-channel is modulated and noise and fading are less effect on each sub-channel, therefore each sub-channels can be easily separately. Job Chunkath et al. [4] demonstrate that due to the rectangular pulse used OFDM has large side lobes. This can be a major cause of the poor performance of orthogonal frequency division multiplexing. To conquer commotion issue, cyclic prefix (CP) is utilized. With utilization of cyclic prefix transmission capacity productivity is decreased on the grounds that cyclic prefix takes transfer speed without conveying any valuable data. Another factor is large peak to average power ratio (PAPR). Wavelet based systems provide flexibility and they have lower PARP as compared to OFDM system. The wavelet systems do not use cyclic prefix (CP) and increase the bandwidth efficiency. As basic functions complex exponentials are used to analyze in Fourier representation of periodic and non-periodic signals. The time is very important factor in some applications such as signal processing but Fourier transform lacks in. This downside of FT is overcome by Windowed Fourier change or Short Time Fourier Transform in which time confinement is presented. Wavelets are generally utilized as a part of multi determination of signs examination. Daubechies, Meyer and Battle-Lemarie are has a place with wavelet families.

At the transmitter, the client data bit arrangement is first subjected to channel encoding to decrease the likelihood of blunder at the beneficiary because of the channel impacts. As a rule, convolution encoding is favored. At that point the bits are mapped to images. For the most part, the bits are mapped into the images of either 16-QAM or QPSK. Sandeep Kaur et al. [5] elaborated about OFDM has high data rates in mobile communication. A compressed the audit of OFDM in remote correspondence framework. At that point author contrasted the utilization of OFDM and fundamental correspondence framework. OFDM takes care of the issue of ISI through utilization of a cyclic prefix because of high information rates. It additionally gives different points of interest like high unearthly effectiveness, Low execution unpredictability and so on. A portion of the real utilizations of OFDM incorporate advanced sound telecom computerized video broadcasting, neighborhood, Wi-Max and so on. Regardless of every one of these points of interest and applications the transporter recurrence balance (CFO) and high top to normal power proportion (PAPR) are real impediment of OFDM. This detriment should be tended to legitimately to permit promote across the board utilization of OFDM.

2.2 FBMC

The main motive of using a staggered modulated multitone and in old schemes cosine modulated multitone is for the modulation purpose. It gives the idea about different type of modulations like multi pulse modulation isolation in time etc. In FBMC physical layer we use different type of filters such as synthesis filter bank (SFB) in OQAM preprocessing or modulator part and analysis filter bank (AFB) in OQAM post processing or demodulator part. Saeed Afrasiabi Gorgani [6] depicts the about a basic idea of OFDM/OQAM with Synthesis and Analysis filter bank. Synthesis filter bank is used for modulation to subcarrier frequencies. An analysis filter bank is used for the process of demodulation purpose at the receiver end. The channel equalization is used by this the problem is that equalizing a severely frequency-selective channel, in case of modern applications, requires a high-order FIR filter. In Cosine Modulated Multitone (CMT) real value (0 or 1) are used and in Staggered Modulated Mulitone (SMT) used only imaginary or complex values.

Filter bank multicarrier uses the different filter banks and gives better results. On FBMC physical layer, and highlight those features which impact the most on the wireless network. Ari Viholainen et al. [7] proposed the different blocks are used for different operation for instance different blocks

in transmitter side and different on reception side. The IFFT (inverse fast Fourier transform) work as the modulator and FFT (fast Fourier transform) work as the demodulator in the FBMC transmitter or receiver side respectively, and the IFFT and FFT are cascaded. Due to the cascade structure of serial to parallel conversion and parallel to serial conversion the one symbol delay has been occurred at the FFT output with respect to the IFFT input symbol. The bank of filters is obtained, when all the FFT symbols are obtained. In the filter banks terminology, the first filter in the bank, which associated with the zero frequency carriers, is called the prototype filter, and the other filters are deduced from this first filter by frequency shifts. FBMC is multicarrier technique same as OFDM and it can handle the situations where users are not synchronized. A Filter bank approach is extension of the FFT approach and called as the extended FFT. To reduce the computations PPN (polyphase network)-FFT technique is required, which keeps the size of the FFT but adds a set of digital filters. In OFDM the orthogonality is required for each carrier, but in FBMC the orthogonality is required only for the neighboring sub-carriers. OFDM divide the given frequency bandwidth with the number of carriers, but FBMC divides the transmission channel into number of sub-channels associated with its given bandwidth. In order to utilize the bandwidth of channel, the modulation technique we are using should adapt the close of orthogonality constraint and OQAM (Offset Quadrature Amplitude Modulation) is used for this purpose. So that the combination of both, filter banks and OQAM provide the maximum bit rate without using guard time or cyclic prefix as in OFDM. In addition, as a multicarrier technique the FBMC can apply on multi antenna systems and MIMO techniques can be apply. In cognitive radio, FBMC offers the possibility of sensing the spectrum and transmission with the same device, jointly and simultaneously. Moreover, the users can have the guaranteed level of spectral protection.

Duplexing is a two way communication between transmitter and receiver. The forward direction is called uplink and in the reverse direction is called downlink. Yonghong Zeng et al. [8] demonstrate about FBMC duplexing. In FBMC uplink and downlink happen simultaneously and add some mechanism to separate the signals so the signals will never overlap with each other. In which two types of duplexing are used Time division duplexing and frequency division duplexing are used, in TDD used different time slots and in FDD different frequency (guard band) are used for to overcome interference problems. OFDM has also been introduced for two way communication, in which the base station to mobile station and mobile station to base station use same frequency band with different subcarriers for their transmission. In OFDM duplexing the signals are orthogonal

with each other, so that downlink and uplink signals do not mixed with each other. Orthogonality can destroy by the non-ideal radio or by non-perfect synchronization. OFDM duplexing uplink and downlink signal don't interfere with each other because they are orthogonal. It may be destroyed by asynchronization. OFDM as compared to FBMC, FBMC uses localized prototype filter. FBMC signals in both time domain and frequency domain make it more efficient to timing error and frequency offset, it can also reduce the empty subcarriers to control the out-of-band emission. In this paper discuss about the problems of FBMC like high PAPR (peak to average ratio), high dynamic range and requirement for high resolution analog to digital converter (A/D) and so on.

Multicarrier modulation is the transmission technique, which is used to divide the channel bandwidth into many small channels. In filter bank multicarrier modulation techniques are used. Two filter banks are used for modulation and demodulation purpose, a synthesis and analysis filter bank is named as TMUX (trans- multiplexer) and it is a basic of the system. Ari Viholainen et al. [9] suggest about the synthesis filter bank (SFB) consists of all parallel transmit filters and the analysis filter bank (AFB) consists of the matching receive filters. The main processing blocks of the TMUX are OQAM preprocessing, synthesis filter bank, analysis filter bank, and OQAM post-processing. The first operation in TMUX the first block is the preprocessing OQAM is used for complex input data symbols to real output symbols conversion, where the real and imaginary parts of symbols are separated to two new symbols forms. The second block of TMUX is the post processing which is used for real to complex conversion, real valued symbols multiplied by j and form a complex valued symbol. A filter bank based multicarrier transmission system consists of two filter banks, a synthesis filter bank at the transmitter side for a modulation purpose and an analysis filter bank at the receiver side for demodulation purpose. In these systems there is no need of the guard times to separate the symbols. With the perfect reconstruction property filter banks can be designed. If we are using OQAM preprocessing complex to real conversion is done by increasing by factor 2, then the complex number is input and the symbols are transmitted instead on the real part and the imaginary part. To controls the phase, amplitude distortions and interference between the small channels by using prototype filters. Phase is linear in prototype filter, phase distortion is eliminated. The performance of any system depends upon the delay and this can be monitor in the system by using many functions at the source and destination. The main calculation of delay comes from the modulation and error correction used in the system. For

instance, QAM and Carrier less Amplitude Phase, more delay is used for decode the data and correct the error by using error correction in single carrier transmission.

Markku Renfors et al. [10] provide some solution of OFDM, with the radio channels; it provides efficiency and multicarrier techniques can be used with multiple antenna source and destination. The previous transmission systems depend on the OFDM technique to achieve the goals. But the OFDM has a many negative points, the use of the cyclic prefix to maintain channel impulse response which is cause the loss the capacity and bandwidth. It required maintaining the orthogonality among all the subcarriers. The frequency sub bands have leakage and it has a serious effect on the performance of FFT-based spectrum sensing. Due to the limitations of OFDM, introduce filter bank multicarrier in the radio communications systems. Filter bank multicarrier can achieve higher channel capacity than OFDM because of the low spectral leakage of its prototype filter. In communications signal processing Digital filter banks used in very good applications and to separate different communications channels and used different frequency channels from each other and interference problem decrease. The spectral components are interfering to obtain very sharp frequency selectivity they can be used very effectively. This can be done in very flexible manner.

Nowadays wireless services are increased day by day. Due to increased demand of high data rate by users, 5G will be introduced to fulfill the customer demands in 2020. Mu Xu et al. [11] described that different generations. In this generation small cells, millimeter wave are used for power optimization and flexibility and spectral efficiency. Optical fiber is used to transfer the data. Orthogonal recurrence division multiplexing (OFDM) and channel bank multicarrier (FBMC) with and without recurrence area pre-balance are thought about in a 50-GHz radio over fiber test bed. For pre-equalization Minimum mean square error method is used. In examination, FBMC pre-evening out performs better on the grounds that non concurrent uplink CCs can be semi flawlessly accumulated without obstruction, which empowers baseband unit pool to exactly assess the channel quality and perform pre-leveling for various groups with high ghastly effectiveness. At the receiver side strong inter band interference adjacent correct channels and users due to this BBU fail to obtain the correct channel information. Contrasted and customary MFH systems in view of basic open radio interface, simple space transporter collection (CA) and radio-over-fiber plans

increment the data transfer capacity productivity and lessen the inertness. In the test bed one is BBU pool and two user equipment terminals are used.

MIMO is a multiple-input multiple-output. In which we use multiple antennas in transmitter and receiver side. According to Aliyu Buba Abdullahi [12] the MIMO-OFDM (multiple input multiple output-orthogonal frequency division multiplexing) is used in long term evolution downlink transmission. The multiple input multiple outputs transmit diversity and MIMO-SM (spatial multiplexing) is multiple independent channels. In LTE transmit diversity sends single code word but spatial multiplexing send multiple code words are transmitted at downlink. MIMO-TD sends a single code word while the MIMO-SM send number of code words and both schemes depends on the coding system. Each code word used Physical Downlink Shared Channel handle for transmission, it is the key of remote structure the purpose of this system to growing as far as possible MIMO system with spatial multiplexing is an important favored point of view of systems like (long-term evolution) LTE, the information transmission is use by the TD plot. It may not be of favorable position at low Signal to Noise Ratio however it gives higher information rate than the past MIMO frameworks with transmitting diversity. The primary focal points of spatial multiplexing frameworks are the enhanced flag transmission at the transmitter with the suitable flag discovery at the collector consequently, the MIMO pre-coding and location. In high flag to clamor proportion SM is more successful with rich disseminating conditions where divert have little scattering in mix with reasonable radio wire setups and relationship coefficient. In which BER is most important factors, SNR is depends on the BER. If BER is less then SNR is more and gets the efficient signal at the receiver end and the more number of antennas are used in the Base Station transmitting antennas. An eNodeB is utilized at the transmitter, the premise at which eNodeB choose to transmit the code words depends chiefly on the quality or connection between various multiple input multiple output reception apparatuses of connection.

A hybrid peak-to-average power ratio minimizing scheme was proposed by Han Wang et al. [13] for FBMC/OQAM signals by using multi data block partial transmit sequence and tone reservation. In the hybrid PTS-TR methods, the data blocks signal is separated into different segments and the number of data blocks has overlapping factor by this each segment is determined. In each segment, we select the optimal data block to transmit and combined assume the adjacent overlapped data block to achieve minimum signal power. Hybrid PTS-TR scheme could provide

better PAPR (peak-to-average power ratio) reduction than traditional PTS and TR schemes in FBMC/OQAM systems. The M-hybrid scheme can achieve about 0.2-db PAPR performance better than the hybrid PTS-TR scheme. In which we use hybrid algorithm for a better performance of peak-to- average power ratio. In which cyclic prefix (CP) insertion in OFDM transmission symbol sacrifices spectral efficiency, CP is used in OFDM but not in FBMC. The hybrid PAPR issue is emerged in all MCs (multicarrier communication systems) by this avoids the distortion from transmitter side.

OFDM/OQAM is the modulation techniques used for reduced the interference. Quentin Bodinier et al. [14] show the different modulation techniques. The For the most part sent Cyclic Prefix Orthogonal Frequency Division Multiplexing (CP-OFDM). A champion among the most proper arrangements is OFDM-Offset Quadrature Amplitude Modulation in light of the PHYDYAS channel beat. The Cyclic Prefix-Orthogonal Frequency Division Multiplexing utilized as a part of LTE-A is not adjusted for adaptable sharing and conjunction in divided range for heterogeneous systems. OFDM with Offset Quadrature Amplitude Modulation is one of the major new waveform orchestrates investigated by the examination accumulate. To be sure, it overcomes the referred to Cyclic Prefix-Orthogonal Frequency Division Multiplexing constraints and empowers both most adaptability and lessening of impedance spillage for multi-standard frameworks concurrence. The concurrence between OFDM/OQAM based D2D (gadget to gadget) sets. The impedance made by the particular sorts of customers onto each other is measured with the Power Spectral Density based model. In which Gaussian noise is not used.

FBMC techniques are used to inclined the data bit rate, by reducing the guard interval and no cyclic prefix but in OFDM cyclic prefix are used to reduce computations PPN (polyphase network)-FFT are used for which keeps the size of FFT but add a digital filters. Orthogonality is required for neighboring sub carriers. Lalit Chettri et al. [15] built that FBMC gives likewise permit to clients to distribute diverse subcarriers to various un-synchronized clients. The mobile phone user increased day by day and efficiency decreased. The efficiency will be increases in future by using filter bank multicarrier techniques and the bandwidth will perfect utilization. The design of filter will be complex; it is one of disadvantages of it. In the OQAM system Offset Quadrature amplitude Modulation preprocessing, post processing and PPN (Polyphase network) are not present but these all blocks are present in FBMC. OQAM post-handling has two

techniques: an) augmentation by θ design b) paired to complex change. In which two real valued symbols makes a complex valued. Sample rate decreases by converting the real to complex conversion. A Software System value 2013.01 is used. In this model input signal are using random bits then these random bits are converted into integer. To create computerized regulation flag on baseband Digital Modulation model can be utilized. The 16QAM modulation scheme is used. At the receiver side model three tap FIR filter, it works as a modulator. The carrier will overlap at some interval of time, so equalizers are used to overcome overlapping problems. In this system FIR (finite impulse response) or IIR (inverse impulse response) using the Least Mean Squares algorithm. The LMS calculation is utilized for limit the blunder between the information flag and the yield flag of the channel. The new fifth generation of wireless communication uses the FBMC technique as a wave shape. The cyclic prefix in OFDM is supplanted by exhaust images in FBMC purge images are included toward the finish of a gathering.

The multicarrier transmission is used in OFDM. In which Davide Mattera et al. [16] tells the same symbol rate is used for complex lapped transform operating. In which no cyclic prefix are used, instead of cyclic prefix null symbols are used. It gives a high level of spectral difference between different users. A key property of the channel bank gained is that the deterrent between closer sub-channels. This impedance is expelled by stage movements of π/2 and immaculate outcomes are gotten. The essential perspective is utilized as a part of this framework is recurrence equalizer. A powerless purpose of OQAM balance is that it needs a 2times the image rate and 2 times calculation stack in handsets. The obstruction is because of that the channel plays out a straight by utilizing direct convolution rather than a round convolution, it is wiped out by utilizing just the mid bit of each evened out piece. The benefit of FBMC-PAM and OFDM/OQAM as far as ghastly proficiency the nearness of the cyclic prefix in OFDM; since we have set it at 1/4 of the OFDM multicarrier picture period. To the extent structure complexity, the essential qualification is the traverse of the FFT, which is duplicated for the filter bank multicarrier pulse amplitude modulation scheme.

OFDM and FBMC suffer with high peak to average paper ratio. Liu Kaiming et al. [17] give the information about that in OFDM it is decreased by utilizing the P-PTS conspire yet it has downsides of constrained otherworldly proficiency, unearthly out-of-band radiation and strict recurrence synchronization. These issues make OFDM minor alluring. After that utilizing OQAM

in FBMC frameworks higher ghastly proficiency can be accomplished and there is no compelling reason to include any monitor band. Because of utilization of watch band effectiveness will be expanded and framework make more productive. FBMC is a multi-transporter method, FBMC have a one noteworthy issue of high top to normal power proportion (PAPR), and there are diverse sorts of procedures are utilized to take care of this issue, for example, cutting and sifting, particular mapping, incomplete transmit succession, companding changes, tone reservation etcetera. But these techniques are not useful for FBMC, because FBMC have the overlapping problems, so in this paper discussed the efficient way to minimize the PAPR, that P-PTS (pretreated partial transmit sequence) with lower computational complexity. Presently extraordinary sorts of PAPR diminishment strategies have been produced for FBMC-OQAM. One of them is an option motion (AS) technique. This strategy utilizes a consecutive streamlining system, it makes a joint enhancement among the covered OFDM/OQAM images and the another method is a sliding window tone reservation procedure and this procedure utilizes the pinnacle lessening tones of a few information squares to scratch off the pinnacles of the FBMC-OQAM motion inside a window for PAPR decrease. In which the entire lengths initially separate the FBMC-OQAM signals into (M/2+F) interims similarly with the time span T so the P-PTS is a valuable technique to expel the PAPR from the framework. The pinnacle energy of the signal information square is diminished when this plan is straightforwardly connected in FBMC-OQAM frameworks. In this plan the covered FBMC-OQAM signals partitioned into various little parts. Phase of the signal is changed at the transmitter P-PTS and at the receiver, recovery of the correct phases of the signals is required, and the side information must be transmitted.

Orthogonal frequency division multiplexing (OFDM) systems used for the analytical bit error probability (BEP) of filter bank based multicarrier (FBMC) transmission and conventional cyclic prefix (CP). Qinwei He et al. [18] firstly compare and evaluate these two schemes under the additive white Gaussian noise (AWGN) channel, and then extend the outcomes to the Rayleigh channel. Closed shape articulations of the bit mistake probabilities for both two techniques are inferred and approved in this examination. The outcomes uncover that the execution of these two techniques is a similar when the ideal recreation states of them are fulfilled. In any case, the FBMC procedure has less out of-band control spillage because of lower side projections. Then, the oversight of CP enhances the transfer speed productivity of the framework with an expansion in

the balance many-sided quality. Thus, the further research can focus on the new adjustment procedure for PPN-FBMC which diminishes the multifaceted nature for moderating the signals.

Robin Gerzaguet et al. [19] compare the OFDM, UFMC, FBMC and GFDM complexity and performance. 5G should adapt to a high level of heterogeneity as far as administrations and necessities. Among these last mentioned, the adaptable and productive utilization of non-bordering unused range for various system arrangement situations is viewed as a key test for 5G frameworks. To expand range effectiveness, the 5G air interface innovation will likewise should be adaptable and fit for mapping different administrations to the best appropriate blends of recurrence and radio assets. We survey spectral productivity, control otherworldly thickness, crest to-normal power proportion and heartiness to offbeat multi-client uplink transmission. In addition, we assess and look at the many-sided quality of the diverse waveforms. Notwithstanding the multifaceted nature investigation, in this work, we additionally show the appropriateness of FBMC for particular 5G utilize cases by means of two exploratory usages. The advantages of these new waveforms for the predicted 5G utilize cases are obviously featured on delegate criteria and analyses.

The prototype filters designed for QAM-based filter bank multicarrier (FBMC). Donghyun Jeon et al. [20] proposed two different types of prototype filters such s even or odd. The conditions comprise of a summed up Nyquist foundation (GNC) for almost idealize recreation (NPR) and meeting the stop band condition for a little side-projection. In a pragmatic situation, a little side-projection is a key part of accomplishing high ghostly productivity, which turns into an essential factor in diminishing the measure of the watch band among channels. Also, in light of the fact that the customary GNC is determined under the suspicion of a perfect channel, which can be effortlessly broken over a down to earth multipath channel, we propose a casual NPR that considers the multipath defer utilizing a 2L-oversampled discrete Fourier change (DFT) in the recurrence area. In light of the unwinding of the GNC relying upon a multipath channel, we define a streamlining issue for a QAM FBMC prototype channel plan and propose a model channel with a little side-flap and solid BER execution. Recreation comes about demonstrate that the proposed model channel surprisingly decreases the side-projection contrasted with traditional QAM-FBMC in view of two sorts of model channels and orthogonal recurrence division multiplexing (OFDM) by means of the exchange off amongst GNC and side-flap execution. The advantage of the side-

flap condition permits the proposed model channel, the Relaxed-NPR-F, to enhance otherworldly effectiveness by lessening the protect band in the recurrence space.

2.3 MIMO

The multiple- input multiple output- orthogonal frequency division multiplexing (MIMO-OFDM) used in wireless communication. Helmut Bolcskei et al. [21] talked about why we shift from OFDM to MIMO. In OFDM we used cyclic prefix (CP) for utilize the bandwidth spectrum and in MIMO we use multiple no. of antennas. In MIMO we used two different techniques such as spatial multiplexing and diversity. By using these two signaling methods ISI eliminates from the system. The additions achievable in (MIMO-OFDM) frameworks come at a (regularly huge) increment in equipment unpredictability. Equipment usage issues of critical current intrigue incorporate productive calculations for (delicate) circle unraveling and for divert preprocessing in MIMO-OFDM frameworks.

The performance of OSTBC-MIMO with different channels Paresh M. Dholakia et al. [22] proposed. Nowadays technology is burgeoning day by day, with increasing the usage of this new wireless technology some environment effects will occurs. One problem in wireless communication is data rate and range. So, one solution is there to overcome this kind of problem such as MIMO (multiple-input multiple-output). By this we can use multiple no. of antennas and solve this particular problem. These multiple antennas perform space time coding and spatial multiplexing. By using the beam forming techniques we can transmit same signal with different gain and phase on all transmit signals and through receiver antennas we can receive maximum signals. In spatial multiplexing, high data rate signals are divided into large no. of lower rate streams and these signals are transmitted through different antennas. MIMO is the best techniques to transmit multiple signals on same channels without using additional antennas, bandwidth and transmit power. Execution examination is completed and framework comes about are seen by transmitting mp3 sound clasp utilizing QPSK, 16-QAM, and 64-QAM balance plots in Rayleigh blurring appropriations. A fundamental introduction to Space-Time coding was given by showing Alamouti's plan. At that point examined piece codes plans with various code rates of ½ and ¾ for the instance of 3 and 4 transmitting receiving wires. The encoding and interpreting calculations for each were exhibited. Finish numerical model is demonstrated first and after that reproductions are

completed with Simulink. It was watched that higher OK assortment get recommend better execution in Audio cut [mp3] transmission at low SNR. 16-QAM with high code rate (3/4) has beated in each one of the three examples of sound catch [.mp3] transmission so it is attractive over use low star gathering with high code rate in OSTBC-MIMO with 4×4 setup.

An Alamouti's scheme used for Filter bank multicarrier (FBMC) to overcomes the problem of intersymbol interference (ISI). By using Alamouti's methods for FBMC modulation there are some application issues are discussed. Due to error propagation interference removes are not effectively with receiver methods. R. Zakaria et al. [23] shares own views regarding some arrangements such as space time block coding (STBC) and space frequency block coding (SFBC) are used to cancelling the effect of interference. After that Alamouti's decoding are used by interference canceller. In which we used basic 2x1 Alamouti's coding methods. The execution is surveyed regarding the bit-error-rate (BER) as a component of the signal-to-noise ratio (SNR). We will demonstrate that these proposed game plans permit us to reach practically the ideal execution. Filter-bank multicarrier gives the solution to overcome the problems of orthogonal frequency division multiplexing (OFDM). In FBMC filters are used so there is no need to insert guard intervals. FBMC gives the high spectral efficiency. It is better than OFDM. During the decoding process self- interference is not removed automatically.

To improve spectrum efficiency and cyclic prefix orthogonal frequency division multiplexing (CP-OFDM) replaced in 4G LTE frameworks for this new waveform configuration is one of the unmistakable 5G examine headings. Zuleita Ho et al. [24] discussed about QAM-FBMC. Specifically, channel bank multi-bearer framework (FBMC) is considered as a promising post-OFDM competitor. we demonstrate that a Quadrature amplitude modulation (QAM) based FBMC(QAM-FBMC) space-time piece code (STBC) framework can accomplish near CP-OFDM execution with a direct collector just, settling the customary view of the need of nonlinear equalizers in FBMC to help different information various yield. The commitment of this paper is two-overlay: the first is that as far as multifaceted nature and blunder rates execution our proposed QAMFBMC framework beats regular OQAM-FBMC conspire; second is that an execution bring down bound is indicated numerically that QAM-FBMC accomplishes near CP-OFDM error rates.

Orthogonal space time block codes are used because when we use Hundreds of antennas at the transmitter and then the signal undergo Rayleigh fading. Basically we use large number of antenna

at the transmission side and receiving side to achieve data rate, high Capacity and to improve the reliability. Arti M.K. et al. [25] indicate the information for Alamouti's code used to achieve overall rate orthogonal Space time block code (OSTBC). One advantage of OSTBC is that it has no requirement of channel state information at the transmitter for obtaining the diversity. OSTBC supports up to 32 transmitter and receiving antennas. For large dimension OSTBC not satisfied for complex functions, if it exist then the data rate may be reduced. One important thing is that in OSTBC the transmitter antenna should be less than the receiving antenna. Suppose we have Tx=8 and Rx=20, 16, 14, 12 and 10 then result that diversity is equal to Tx*Rx/2. In this we use BPSK, QPSK and analysis. When we use BPSK then it gives estimation about channel state information but analysis obtain the perfect channel state information through moment generating function.

2.4 MIMO-FBMC

In Filter bank multicarrier (FBMC) has two diverse model channels for QAM images at transmitter and beneficiary side. Hyungju Nam et al. [26] advise the signs are orthogonal to each other than orthogonality conditions for the FBMC-QAM framework with no covering is acquired. A few transmitters are proposed to play out the individual separating for the Even and odd numbered sub-transporter images, separately. The obtained orthogonality a condition is demonstrated, the little square savvy switch requesting system for the yields of the odd-numbered sub-transporter channel is performed. So we used MIMO with conventional orthogonal recurrence division multiplexing (OFDM). By this we analyzed bit error rate (BER) and Signal to interference power ratio (SIR) results. Practically results indicate that the new FBMC-QAM system has almost the same bit error rate outcomes compared to the FBMC-OQAM and OFDM systems.

Filter bank multicarrier modulation used different techniques MIMO precoding and decoding. Marius Caus et al. [27] talked about conventional system gives good performance with high coherence bandwidth channels. The principle thought process is increment the strength against the channel recurrence selectivity; we have reconsidered the issue, which brings about another sub-band preparing. Simulation-based outcomes described that the rethought solution can achieve similar bit error rates as the orthogonal frequency division multiplexing (OFDM) solution, during the spectral efficiency is increased. These results are theoretically proved but not practical. In the end, we conclude that in frequency selective channels FBMC becomes attractive. So they are not

just on the grounds that it unwinds the edge synchronization as for OFDM, however MIMO-FBMC gives better outcome for otherworldly effectiveness.

Quadrature amplitude modulation (QAM) per-tone minimum mean square error (MMSE) is used for transmit purpose. We assumed that an interference channel from other subcarriers and symbol durations for reduces the problem named as residuals interference. Simulation results depicts that the proposed Taehyun Lee et al. [28] elaborates that for FBMC frameworks in multipath blurring channels contrasted with the customary per-tone beneficiary with same size of collector network. A collector can enhance the bit blunder rate (BER) execution of FBMC frameworks. In MIMO OFDM systems, at the transmitter side we use the cyclic prefix (CP) in conjunction with the IFFT and FFT operation and at receiver respectively decouple the frequency selective channel into parallel flat fading channels.

In OFDM and FBMC comparison, FBMC has better results as analyzed as to orthogonal frequency division multiplexing. At the cost of imaginary interference makes MIMO more challenges. Ronald Nissel et al. [29] discussed about the spread symbols in time and frequency domain so that with the help of this we can remove the imaginary interference from the system. Spreading process has low complexity due to present of Hadamard matrices. In FBMC within one transmission blocks, spreading allows restoring complex orthogonality; by this we can observe interference into neighboring. Signal to Interference ratio can be removed by using guard slots. Moreover we can use the more ways to find the effects of time-variant channels on such spreading approach. In the end, test bed measurements depicts the applicability of our FBMC based MIMO transmission scheme in real world environments. When block wise transmission is needed, we have idea if we use guard slots then signal to interference will be increased.

FBMC modulation used filters and overcome the problem of interference and it becomes more useful not by this one reason there are other reasons. The one of them is that it unwinds the synchronization regarding OFDM, yet in addition since it accomplishes a similar execution comes about as OFDM for multiuser MIMO precoding even on account of defective CSI at the transmitter. Didier Le Ruyet et al. [30] elaborate the effect of defective channel state data (CSI) because of criticism interface on the execution of MU-MIMO framework utilizing Filter bank multicarrier (FBMC) balance. At the receiver, transmitter performing zero-forcing precoding and decoding techniques by a single antenna. It depicts that the number of users are less than no. of

transmit antennas then it gives better results. The bit error rate (BER) and capacity of MIMO and orthogonal frequency division multiplexing (OFDM) are similar to each other. Due to distribute of interference we can analyze the results in theoretically forms. OFDM is depends upon the number of interferes, for a given bit error rate target is set, the no. of feedback bits per channel vectors are high.

CHAPTER 3 FILTER BANK MULTICARRIER

3.1 Introduction

FBMC implies Filter Bank Multicarrier. A channel bank multicarrier means to beat a bit of the inadequacies that were knowledgeable about OFDM, orthogonal repeat division multiplexing. One of the major inadequacies rises up out of the way that OFDM requires the usage of what is named a cyclic prefix [7]. The cyclic prefix is essentially a copy of part of a transmitted picture in OFDM that is connected toward begin of the accompanying.

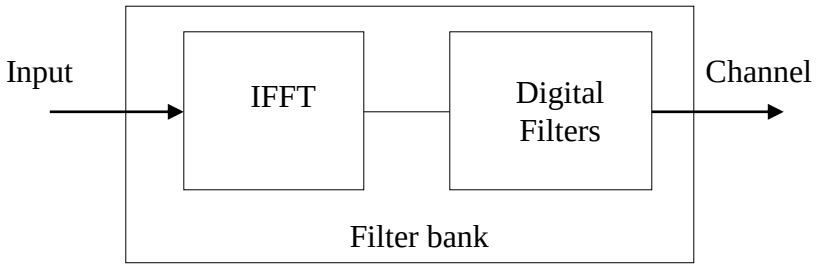

Fig. 3.1: Basic diagram of filter bank multicarrier

This repetition decreases the throughput of the transmission and furthermore squanders control. In FBMC at the input IFFT is used as a modulator and at the receiver side FFT used and it act as a demodulator. A further burden of OFDM is that spooky limitation of the subcarriers is weak and this results in supernatural spillage and impedance issues with unsynchronized signs. Channel bank multicarrier is a change of OFDM. Utilizing banks of channels that are executed, generally using propelled hail getting ready techniques, FBMC. Exactly when transporters were balanced in an OFDM system, side flaps spread out either side. With a channel bank system, the channels are used to empty these and thusly a much cleaner carrier comes to fruition. FBMC is a new waveform technique having few advantages over OFDM a contender for 5G [10]. The main crucial change is the supplanting of the OFDM with a multicarrier framework in light of channel banks at the TX and Rx. Cyclic Prefix augmentation required and along these lines lessens data transfer capacity productivity in OFDM. Cyclic prefix not required and then bandwidth is conserves in FBMC large side lobes in OFDM compared to FBMC for frequency spectrum. For correct detection, multiple access interference cancellation should be performed at the receiver in OFDM [10]. Multiple

access Interference is suppressed due to the excellent frequency localization of the subcarriers in FBMC. Highly sensitive to the carrier frequency offset in OFDM. Less sensitive and hence performs significantly with the increase of the user mobility in FBMC. The High flexibility is in the system while adopting MIMO techniques for OFDM. FBMC is less adaptable for MIMO. Debased go recognizing execution in view of the extraordinary spillage in OFDM hails High range distinguishing assurance in FBMC. OFDM is less unpredictable than FBMC in execution. In FBMC three strategies channels are utilized sifted multitone, cosine tweaked multitone and stunned adjusted multitone. Separated multitone channels are not satisfies the necessities of most extreme transmission capacity. Cosine Multitone and Orthogonal Frequency Division Multiplexing/Offset Quadrature Amplitude Modulation are firmly related through a tweak step and a coordinated mapping of information images. The center of the FBMC framework is the Trans multiplexer design. The primary handling alliances in this immediate frame portrayal are OQAM-preprocessing, amalgamation channel bank, examination channel bank, and OQAM post-preparing.

3.2 FBMC system description

FBMC implies Filter Bank Multicarrier. A channel bank multicarrier means to beat a bit of the inadequacies that were knowledgeable about OFDM, orthogonal repeat division multiplexing. One of the major inadequacies rises up out of the way that OFDM requires the usage of what is named a cyclic prefix [7].

3.2.1 Transmitter of FBMC

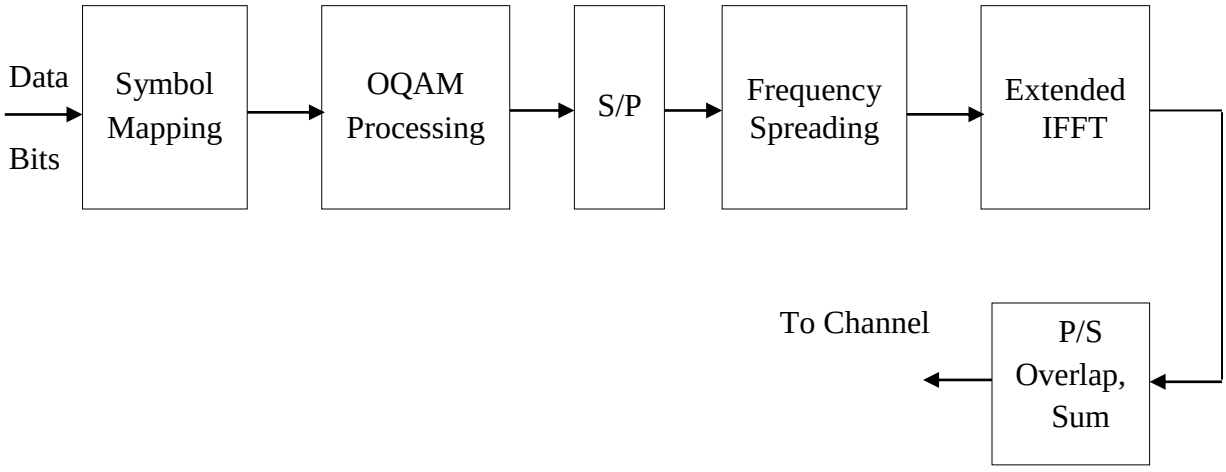

Fig. 3.2: FBMC transmitter

The blocks of filter bank multicarrier are explained below:

- **Symbol mapping:** The modulation symbol map is used to generate 16QAM modulated electrical signals, and then the modulation symbol de-mapper demodulates the signals according to that which type of modulation is used. The symbol mapper's modulation type matches the mapper's modulation type; the original transmitted signal should be matched.

- **OQAM processing:** OQAM pre-handling has two techniques. One is unpredictable to genuine transformation, where the genuine and the fanciful parts of a QAM complex esteemed image. The most vital component is that intricate to genuine change builds the specimen rate by element 2. An operation is the duplication by θ with a specific end goal to keep up orthogonal images.

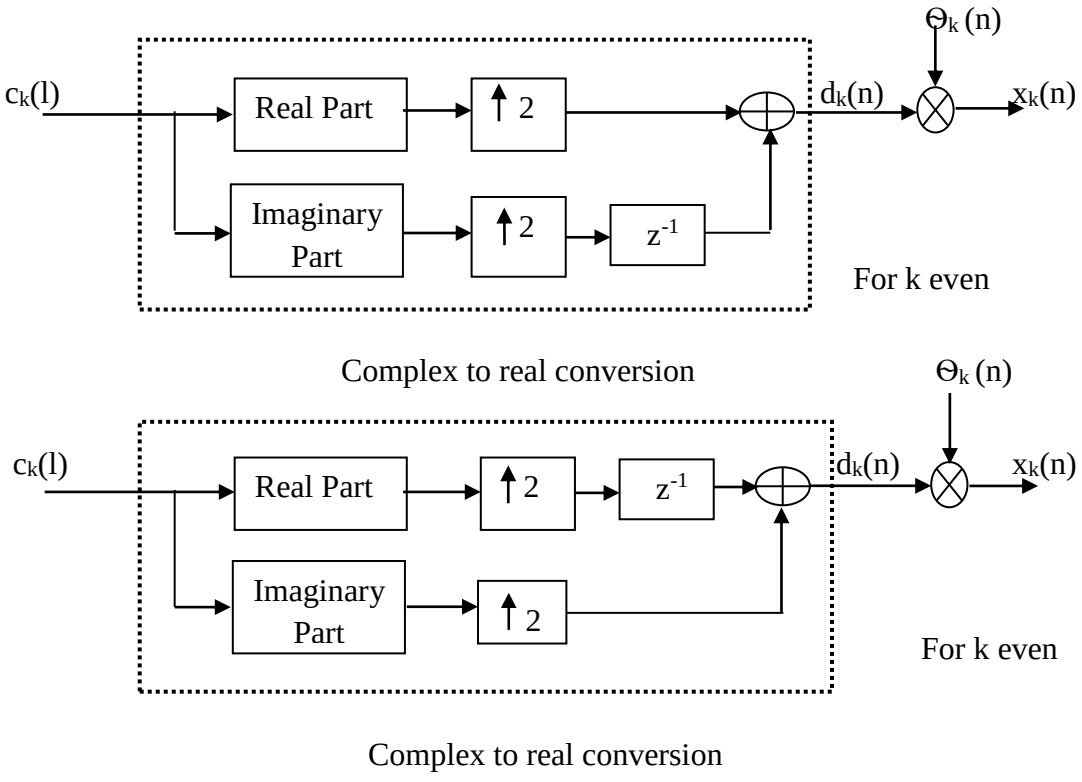

Fig. 3.3: OQAM pre-processing for k even & odd

It comprises of two operations that are double to the preprocessing procedure: the primary operation is the augmentation by θ*k, n* grouping, where * is the intricate conjugate change and a genuine to-complex transformation [7]. Filter bank synthesis consists on N over samplers followed

by N filters. Signals at the input of the filter bank are indeed first oversampled by a factor of N/2, and then filtered by the impulse response of s_k [n] the kth filter and is defined by:

$$sk[n] = s[n].\exp(j\frac{2\pi k}{N}\left(n - \frac{Lp-1}{2}\right)) \quad (3.1)$$

Where s[n] is a low pass filter called the prototype filter, and is of duration L_p. It is common practice to impose that L_p is a multiple or almost a multiple of N (L_p= kN, L_p= kN-1, L_p= kN+1 are possible choices). In which two sorts of channels are utilized, Synthesis and individually examination channel might be actualized with an IFFT taken after by a poly stage arrange structure Poly stage organize took after by a FFT separately [Hirosaki1981, Siohan2002]. In filter bank zero frequency carriers are used, and it is called prototype filter. It reduces the out of band ripples, it is essential to increase the number of co-efficient in the time domain and frequency domain.

- **Serial to Parallel (S/P) Conversion:** Transformation of a flood of information components got in same time arrangement, i.e., each one in turn, into an information stream comprising of different quantities of information components transmitted at the same time. Diverge from parallel-to-serial change.

- **Frequency Spreading:** Spread range is a type of remote interchanges in which the recurrence of the transmitted flag is intentionally changed. This outcomes in a considerably more prominent data transfer capacity than the flag would have if its recurrence were not changed.

- **P/S, Overlap & Sum:** Parallel to serial conversion Contrast of serial to parallel. In which each stream of elements received in different time sequence, that's not at a one time, in to a data consisting of single data elements transmitted once time. It is called parallel to serial conversion.

The overlap defined as when two singles are mixed with each other is called overlap, but in FBMC signals are not overlap with each other.

3.2.2 Receiver of FBMC

At the receiver side, output of transmitter used as an input of receiver and preceded further. The FBMC receiver blocks are explained below:

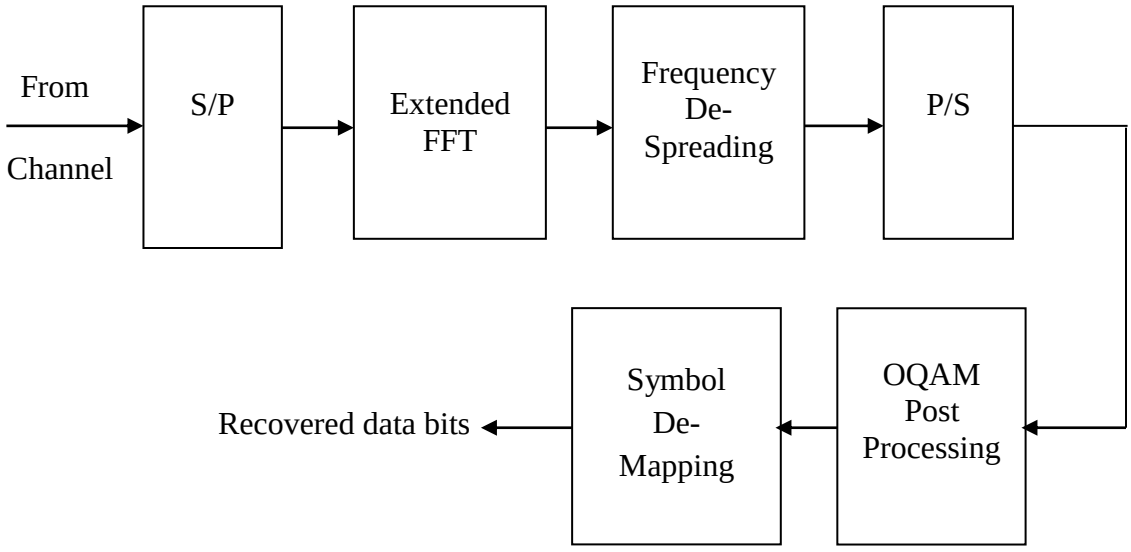

Fig. 3.4: Receiver of FBMC

- **Serial to parallel conversion:** Transformation of a surge of information components got in same time succession, i.e., each one in turn, into an information stream comprising of numerous quantities of information components transmitted at the same time. Contrast with parallel-to-serial conversion. At the receiver side we used serial to parallel conversion, in which data sequences changes from serial to parallel. In which analysis poly phase filters are used. By using this filters the process of decomposition performed by the filter bank.

- **Extended FFT:** It can be adapted to implement the filter bank, it is just sufficient to extend the IFFT and the FFT. For each arrangement of information, the yield of the IFFT is a piece of KM tests and, since the image rate is 1/M, K sequential IFFT yields cover in the time space. The usage of the recipient depends on an augmented FFT, of size KM. All things considered, the FFT input squares cover, it is the established sliding window circumstance. At the yield of the FFT, the information components are recuperated with the assistance of a weighted de-spreading operation. Because of the covering in the time area of the IFFT yields and FFT inputs, a noteworthy measure of excess is available in the calculations. A proficient way to deal with lessen this excess is the purported PPN-FFT conspire.

- **Frequency de-spreading:** It is opposite of frequency spreading. Gotten baseband waveform is the mix of the transmitted waveform and commotion in the channel.

- **OQAM post processing:** In the modulator part, the Synthesis Filter Bank (SFB). The information sources to the SFB are the Offset QAM. The IFFT piece basically plays out the adjustment to the subcarrier frequencies. From the equipment perspective, it performs the calculations in a piece preparing way. That is, an arrangement of tests are encouraged into the N branches of the IFFT obstruct on the double and an arrangement of yield tests are created. After the poly phase filters, the up sampling by an element of N/2 is performed. Through the specific blend of the deferrals and the adders, the subsequent examples from the parallel branches experience a parallel-to-serial transformation [7]. The demodulator part, the Analysis Filter Bank (AFB).The outputs of the parallel branches are the OQAM symbols which must go through OQAM-post processing which reverses the procedure.

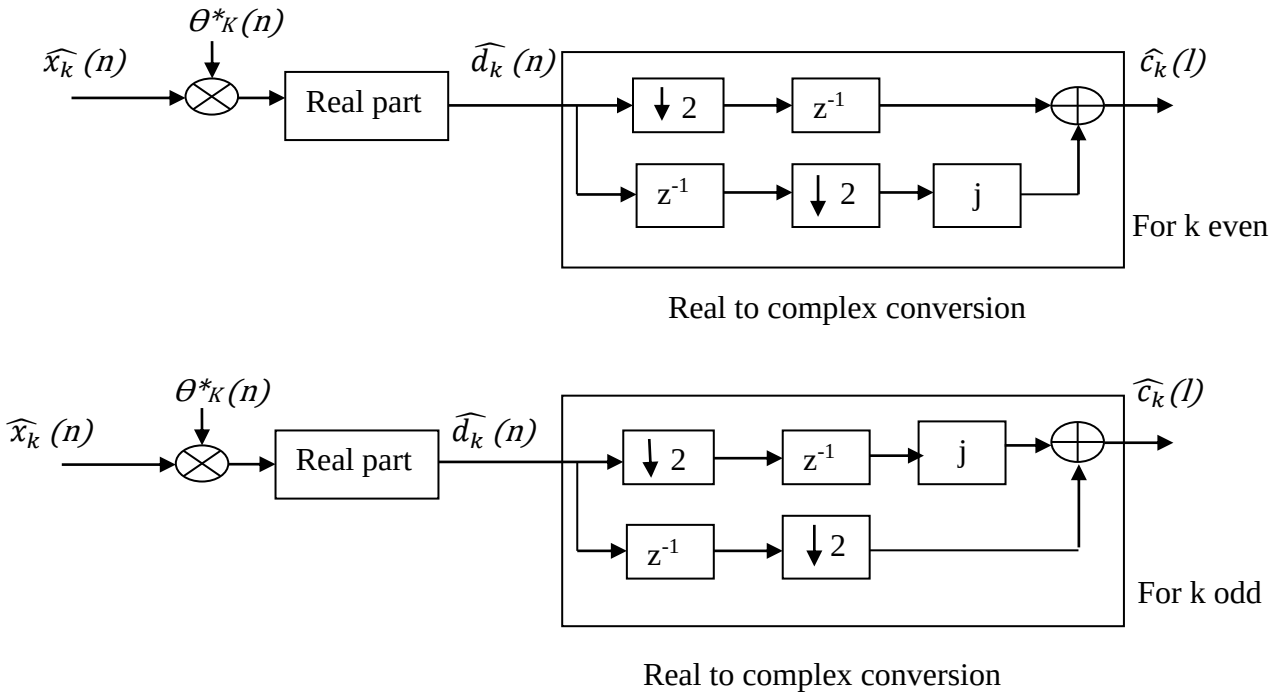

Fig. 3.5: OQAM post processing in FBMC for k even & odd

- **Symbol de-mapping:** The de-mapper modulation type matches the mapper's modulation types, where the original transmitted signal should be recovered.

  At the receiver end data bits are recovered.

3.3 Applications of FBMC

- **Subjective radio correspondence:** As examination of OFDM, FBMC offers higher otherworldly productivity and more material for the psychological radio system with little size of gaps.

- **Different get to networks:** In multiuser setting, the uplink of an OFDM arranges utilizes a strategy called various get to impedance cancelation with a specific end goal to meet its essential operational necessities.

- **Access to TV white space (TVWS):** It has adaptability, low contiguous spillage control proportion; recurrence spryness and sharp range move off are essential elements.

- **Control line correspondence:** It is one the most imperative use of channel bank multicarrier.

- **MIMO correspondence:** In Multiple info various yield FBMC frameworks for direct and exceedingly recurrence specific channels, got signs are adulterated by bury image obstruction and entomb radio wire impedance [8].

3.4 Polyphase implementation in FBMC

The transmit channel G is a limited motivation reaction channel containing LG = KN coefficient, whose z change is [9]:

$$G(z) = \sum_{l=0}^{L_G-1} g[l]z^{-l} \tag{3.2}$$

Overlapping factor is K. G (z) can be deteriorated into N rudimentary channels. In this way, it creates a polyphase system:

$$G(z) = \sum_{l=0}^{L_G-1} g[l]z^{-l} = \sum_{n=0}^{N-1}\sum_{k=0}^{K-1} g[kN+n]z^{-(kN+n)} \tag{3.3}$$

$$G(z) = \sum_{l=0}^{L_G-1} g[l]z^{-l} = \sum_{n=0}^{N-1}\sum_{k=0}^{K-1} g[kN+n]z^{-(kN+n)} \tag{3.4}$$

Here $E_n(Z^N) = \sum_{k=0}^{k-1} g[kN+n]z^{-kN}$ are the polyphase elements of G (z):

$$= \sum_{l=0}^{L_G-1} g[l]z^{-l} = \sum_{n=0}^{N-1}\left[\sum_{k=0}^{k-1} g[kN+n]\, z^{-kN}\right]z^{-n}$$

$$= \sum_{n=0}^{N-1} E_n\,(z^N)Z^{-n} \tag{3.5}$$

Assume G_i (z) the channel reasoned from G (z) by a recurrence move of 1/N:

$$G_i(z) = \sum_{l=0}^{L_{G-1}} g[l]e\frac{j2\pi}{N}ilz^{-l} \tag{3.6}$$

Using polyphase representation, G_i (z) is written as:

$$G_i(z) = \sum_{n=0}^{N-1}\sum_{K=0}^{K-1} g[kN+n]\, e\frac{j2\pi}{N}i(kN+n)z^{-(kN+n)} \tag{3.7}$$

$$= \sum_{n=0}^{N-1} e\frac{j2\pi}{N}ni\; E_n(z^N)z^{-n} \tag{3.8}$$

A uniform channel bank is gotten by moving the reaction of G (z) on the recurrence pivot. It is in this manner concluded from G (z), which is, hence, called the model channel of the channel bank.

In the event that all channels are reasoned from the model channel by recurrence move increases in 1/N, at that point the channel bank has the accompanying articulation:

$$\begin{bmatrix} G_0(z) \\ G_1(z) \\ \vdots \\ G_{N-1}(z) \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & 1 & \cdots & 1 \\ 1 & w^{-1} & \cdots & w^{-(N-1)} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & w^{-(N-1)} & \cdots & w^{-(N-1)^2} \end{bmatrix}}_{IFFT} \begin{bmatrix} E_0(z^N) \\ z^{-1}E_1(z^N) \\ \vdots \\ z^{-(N-1)}E_N(z^N) \end{bmatrix} \quad (3.9)$$

Here $w=e^{-j2\pi/N,}$ N is the N-order inverse Fourier transform matrix is denoted by IFFT.

In which two prototype filters are used ay transmitter side and another at receiver side. For instance:

1. Polyphase Synthesis filter

2. Polyphase Analysis filter

These two filters are explained as:

- **Polyphase Synthesis filter banks:** The transmit signal is accomplished by transmitting in parallel information xk[n]on the balanced channel bank. Increase by the N-orchestrate reverse Fourier change can be exchanged with the upsampling operation. Moreover, applying the important Noble character [FAR 05], upsampling can in like manner be exchanged with the polyphase segments, which suggests supplanting $E_n(z^N)$ by $E_n(z)$.

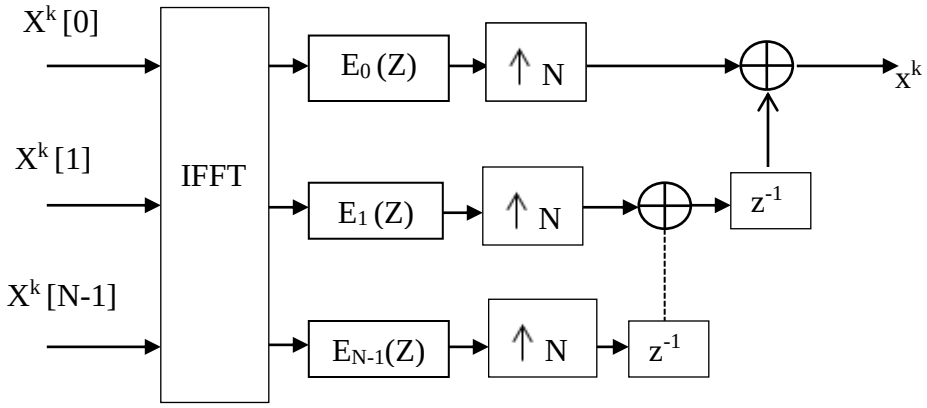

Fig. 3.6: Simplified polyphase synthesis filter bank block diagram

- **Polyphase Analysis filter banks:** At the receiver, Analysis filters are used for demodulate the signals. At the destination side, the source signal is gotten by deteriorating the info motion in the recurrence space with the investigation channel bank. The investigation channel bank has a double structure to that of the union channel bank [7]. It is also gotten.

Assume $G_{-i}(z)$ the channel derived from G (z) by a recurrence move of - 1/N:

$$G_{-i}(z) = \sum_{l=0}^{L_{G-1}} g[l] e \frac{-j2\pi}{N} ilz^{-l} \tag{3.10}$$

Using polyphase representation, $G_{-i}(z)$ is written as:

$$G_{-i}(z) = \sum_{n=0}^{N-1} \sum_{K=0}^{K-1} g[kN+n]\, e \frac{-j2\pi}{N} i(kN+n) z^{-(kN+n)} \tag{3.11}$$

$$= \sum_{n=0}^{N-1} e \frac{-j2\pi}{N} ni\, E_n(z^N) z^{-n} \tag{3.12}$$

In the event that all channels are concluded from the model channel by recurrence move increases in 1/N, at that point the channel bank has the accompanying articulation:

$$\begin{bmatrix} G_0(z) \\ G_{-1}(z) \\ \vdots \\ G_{-(N-1)}(z) \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & 1 & \cdots & 1 \\ 1 & w^{-1} & \cdots & w^{-(N-1)} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & w^{-(N-1)} & \cdots & w^{-(N-1)^2} \end{bmatrix}}_{FFT} \begin{bmatrix} E_0(z^N) \\ z^{-1}E_1(z^N) \\ \vdots \\ z^{-(N-1)}E_N(z^N) \end{bmatrix} \tag{3.13}$$

The information signal initially goes in a chain that creates delays, and is then sifted by the polyphases segments. The filtering operation is trailed by a Fourier change. The Fourier change may be exchanged with downsampling. In addition, the primary Noble character demonstrates that downsampling can be exchanged with the polyphase portions. The examination channel bank thusly has a reworked structure, which is addressed in Fig. 3.7

Here $w=e^{j2\pi/N,}$ N is the N-order Fourier transform matrix is denoted by IFFT.

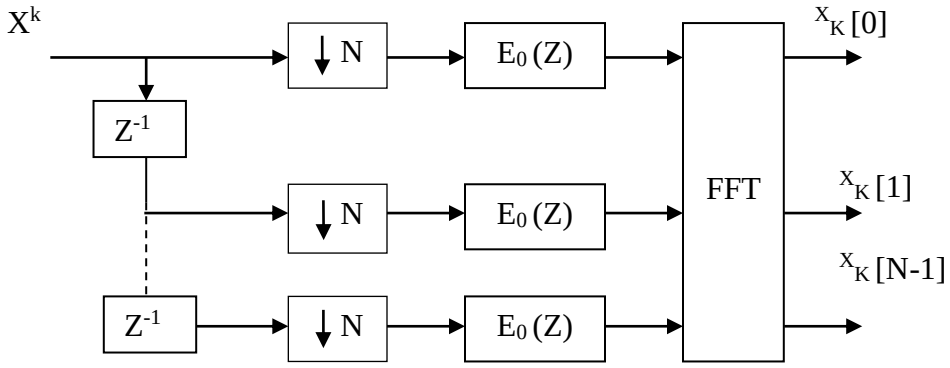

Fig. 3.7: Simplified analysis filter bank

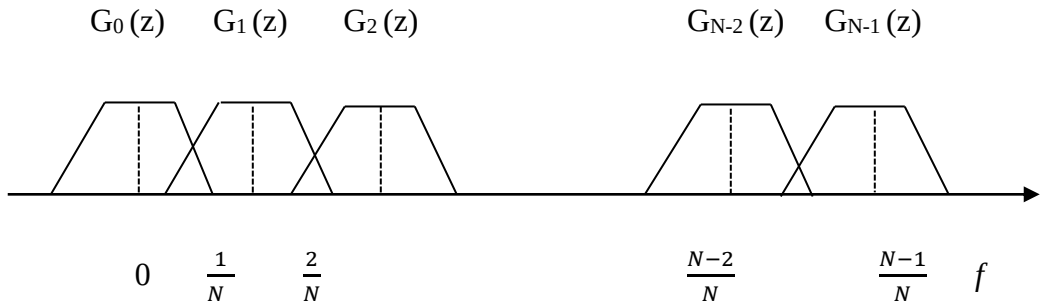

Fig. 3.8: Frequency response of filter banks

Additionally, the square chart of FBMC collector can be partitioned into two subsystems utilizing, separately, the model channels g (t) and g (t+TN/2). The postponement of – N/2 tests can be moved at the contribution of the subsystem.

CHAPTER 4 MIMO

4.1 Introduction

MIMO is defined as multiple-input multiple output. In which multiple number of antennas are used at transmitter side and at receiver side. MIMO, remains for numerous information and various yield and output, is a procedure where diverse gathering contraptions are used at both the transmission and the collector for expand the connection unwavering quality, the ghastly proficiency, or both. MIMO has the capacity to interact with various antennas at a same time which are 2x2, 3x3, 4x4 .This idea has been around for a long time yet its utilization in remote gauges is later. This is likely due to some extent to the way that OFDM (orthogonal recurrence division multiplexing), which encourages the usage of MIMO, is presently normally utilized as a part of today's remote measures. MIMO methods are utilized today in advances like Wi-Fi and LTE, and new strategies are under review for future benchmarks like LTE Advanced. The primary element of MIMO frameworks is space-time preparing. Space-Time Codes (STCs) are the codes intended for the utilization in MIMO frameworks [21]. In STCs, signs are coded in both transient and spatial areas. Here we use encoder at the transmitter side and decoder at the receiver side.

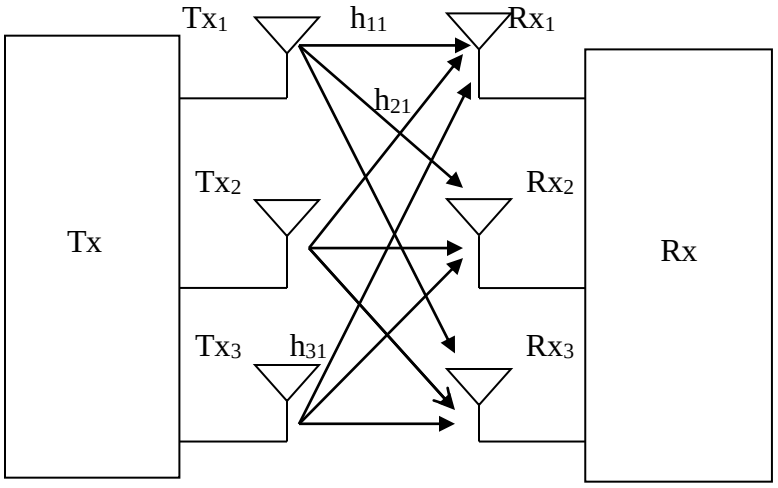

Fig. 4.1: Basic diagram of MIMO

Here h_{mn} represents the impulse channels. An m represents the transmitter impulse channels and n represents receiver impulse channels.

4.2 History

MIMO is frequently followed back to 1970s research papers concerning multi-station advanced transmission frameworks and impedance (crosstalk) between wire matches in a link package: AR Kaye and DA George (1970), Branderburg and Wyner (1974), and W. van Etten (1975, 1976). Despite the fact that these are not instances of abusing multipath expansion to send different information streams, a bit of the logical strategies for overseeing regular deterrent exhibited accommodating to MIMO change [21]. In the mid-1980s Jack Salz at Bell Laboratories made this investigation a walk further, inspecting multi-customer structures working over "generally cross-coupled direct frameworks with included substance uproar sources, for instance, time-division multiplexing and dually-stimulated radio frameworks.

Strategies were delivered to improve the execution of cell radio frameworks and enable more mighty repeat reuse in the mid-1990s. Space-division different access (SDMA) uses directional or splendid radio wires to confer on a comparative repeat with customers in different zones inside extent of a comparative base station. A SDMA structure was proposed by Richard Roy and BjornOttersten, investigators at ArrayComm, in 1991.Their US patent (No. 5515378 issued in 1996[8]) portrays a strategy for expanding limit utilizing "a variety of getting receiving wires at the base station" with a "majority of remote clients".

4.2.1 Standards and commercialization

MIMO advancement has been regulated for remote LANs, 3G mobile phone frameworks, and 4G wirelesses composes and is by in wide business use. Greg Raleigh and V. K. Jones built up Airgo Networks in 2001 to make MIMO-OFDM chipsets for remote LANs. The Institute of Electrical and Electronics Engineers (IEEE) influenced an errand to gather in late 2003 to develop a remote LAN standard passing on no under 100 Mbit/s of customer data throughput. There were two significant fighting suggestions: TGn Sync was supported by associations including Intel and Philips, and WWiSE was reinforced by associations including Air go Networks, Broadcom, and Texas Instruments. The two social affairs agreed that the 802.11n standard would be established on MIMO-OFDM with 20 MHz and 40 MHz channel options. TGn Sync, WWiSE, and a third suggestion (MITMOT, maintained by Motorola and Mitsubishi) were united to make what was known as the Joint Proposal. In 2004, Air go turned into the primary organization to dispatch

MIMO-OFDM products. Qualcomm procured Air go Networks in late 2006. The last 802.11n standard bolstered accelerates to 600 Mbit/s (utilizing four concurrent information streams) and was distributed in late 2009.

Surendra Babu Mandava and Arogyaswami Paulraj set up moved toward becoming Communications in 2004 to convey MIMO-OFDM chipsets for Wi-MAX. The association was secured by Broadcom in 2010. Wi-MAX was delivered as a differentiating choice to cell rules relies upon the 802.16e standard, and uses MIMO-OFDM to pass on quicken to 138 Mbit/s. The further created 802.16m standard engages download quickens to 1 Gbit/s. A the country over Wi-MAX sort out was worked in the United States by Clear wire, a reinforcement of Sprint-Nextel, covering 130 million motivations behind embodiment (PoP) by mid-2012. Run in this way pronounced plans to pass on LTE (the telephone 4G guidelines) covering 31 urban groups by mid-2013 and to shut down its Wi-MAX organize before the complete of 2015.

The underlying 4G cell standard was proposed by NTT Docomo in 2004. Long haul headway (LTE) relies upon MIMO-OFDM and continues being created by the third Generation Partnership Project (3GPP). LTE decides downlink rates up to 300 Mbit/s, uplink rates up to 75 Mbit/s, and nature of organization parameters, for instance, low idleness. LTE Advanced incorporates reinforce for picocells, femtocells, and multi-transporter channels up to 100 MHz wide. LTE has been gotten a handle on by both GSM/UMTS and CDMA administrators.

The principle LTE organizations were pushed in Oslo and Stockholm by Telia Sonera in 2009. Organization is most dynamic in the United States, where each of the four Tier 1 overseers has or is working the country over LTE frameworks. There are starting at now more than 360 LTE sorts out in 123 countries operational with around 373 million affiliations (contraptions).

4.3 Types of MIMO

MIMO has two types:

- Single user-MIMO
- Multiuser-MIMO

These are explained below:

4.3.1 Single user-MIMO (SU-MIMO)

For a single user equipment data rate is to increase is called single user-MIMO.

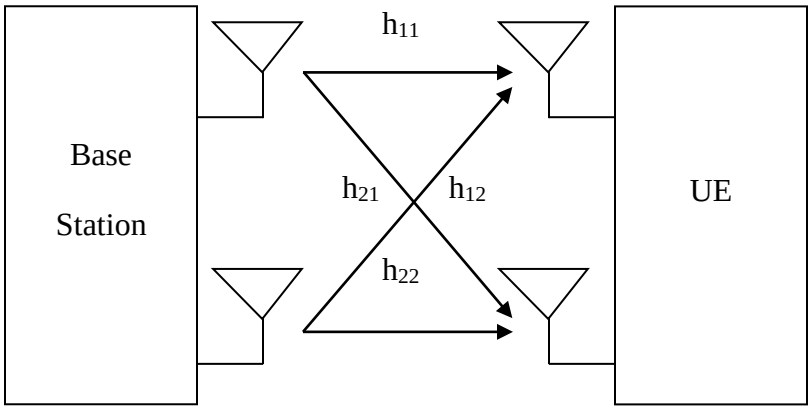

Fig. 4.2: SU-MIMO

4.3.2 Multiple user-MIMO (MU-MIMO)

When an individual streams are given to multiple users, it is called MU-MIMO. It is used in uplink due to complexity on user equipment can be kept a minimum by using only single transmit antenna. It is also called collaborative-MIMO.

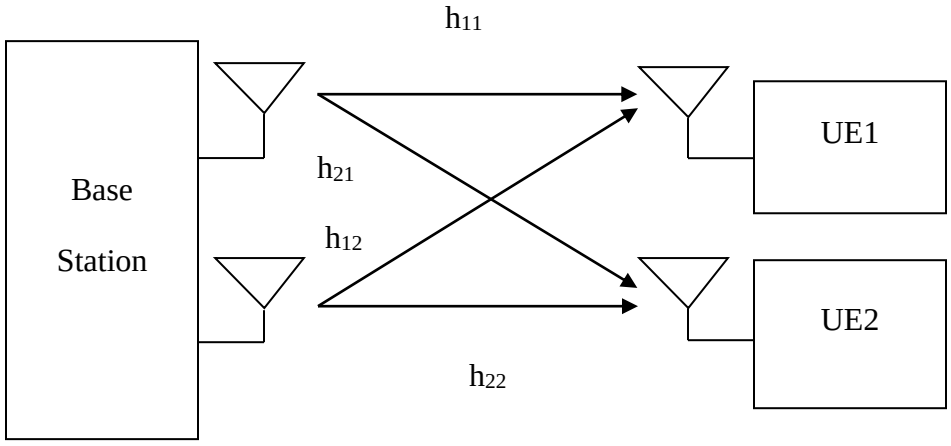

Fig. 4.3: MU-MIMO

4.4 Multi-antenna Types of MIMO

MIMO is multiple-input multiple output. It has different types of antennas are used such as

1. SISO- Single input single-output
2. SIMO- Single-input multiple-output
3. MISO- Multiple-input single-output
4. MIMO-Multiple-input multiple-output

These are explained as:

4.4.1 SISO (Single input single-output)

In which at transmitter and received side only single antenna is used. The Fig. 4.4 shown as

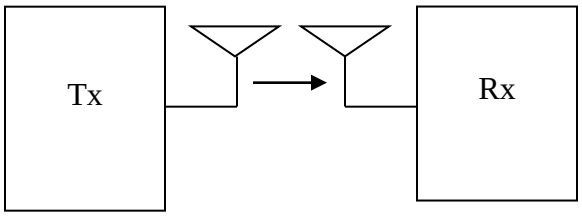

Fig. 4.4: SISO

4.4.2 SIMO (Single input multiple-output)

In which at transmitter only single antenna is used and received side multiple antennas are used. The Fig. 4.5 shown as

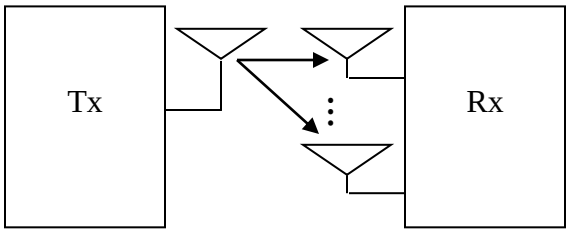

Fig. 4.5: SIMO

4.4.3 MISO (Multiple-input single-output)

In which at transmitter multiple antennas are used and at the receiver side single antenna is used. The Fig. 4.6 shown as

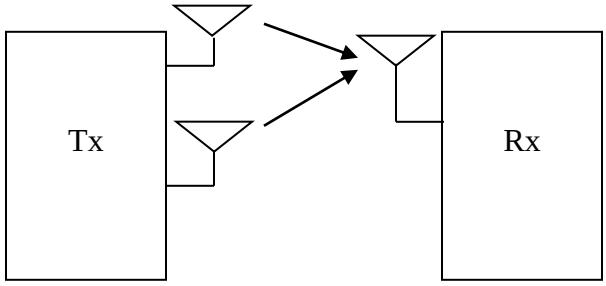

Fig. 4.6: MISO

4.4.4 MIMO (Multiple-input multiple-output)

In which at transmitter and at the receiver side multiple antennas are used. The Fig. 4.7 shown as

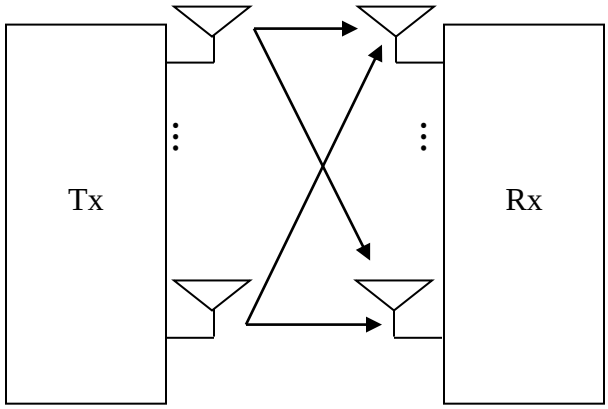

Fig. 4.7: MIMO

4.5 Techniques for MIMO

MIMO further sub-partitioned into 3 primary classes. These classes are

- Beamforming (precoding)
- Spatial Multiplexing technique (SM)

- Spatial Diversity coding.

These three different types of techniques are explained below:

4.5.1 Beamforming

The beamforming technique is also called precoding. Further broad signals, it is thought to be all spatial handling is happens at the transmission side [21]. In precoding and beamforming, a similar flag may be discharged from the both wires at the transmitter and receiver with proper stage or pick up data to such an extent where the flag power is expanded on the collector side. The advantages of precoding use for expand the gotten signal pick up - by making signals produced from various radio wires include helpfully - and to decrease the multipath blurring impact. In viewable pathway spread, beamforming brings about a very much characterized directional example. Be that as it may, traditional pillars are not a decent similarity in cell systems, which are for the most part described by multipath engendering. At the destination when the collector has various receiving antenna, the transmission beamforming or precoding cannot all the while amplify the flag term level at all of the get gathering mechanical assemblies and precoding with various streams is every now and again helpful. Watch that precoding requires learning of channel state data (CSI) at the transmission and the gatherer. To this point we have not used channel learning at the transmitter. Here we consider direct precoding at the transmitter that may rely on upon the channel acknowledgment. The precoder is used to maximizing the SNR at the receiver [26].

4.5.2 Spatial multiplexing

Spatial multiplexing has MIMO radio frequency chain setup. In this technique, a greater-rate divided into different lower-rate streams and every stream is transmitting from other transmitted gathering device in a comparable repeat channel. On the off chance that these signs get together at the recipient radio wire show with enough uncommon spatial engravings has correct CSI, it can isolate these streams into parallel channels. Spatial multiplexing is a talented strategy for stretching out channel restrained higher signal to-change degrees (SNR). The craziest number of spatial streams is confined through the base of the measure of radio wires at the transmitter or beneficiary. Spatial multiplexing can be utilized without CSI at the transmitter, however can be joined with precoding if CSI is accessible. Spatial multiplexing can in like way be utilized for synchronous

transmission to different beneficiaries, known as space-division diverse for acquiring or multi-client MIMO, for this situation Channel State Information is required at the transmission side [27]. The arranging of authorities with different spatial imprints licenses awesome uniqueness.

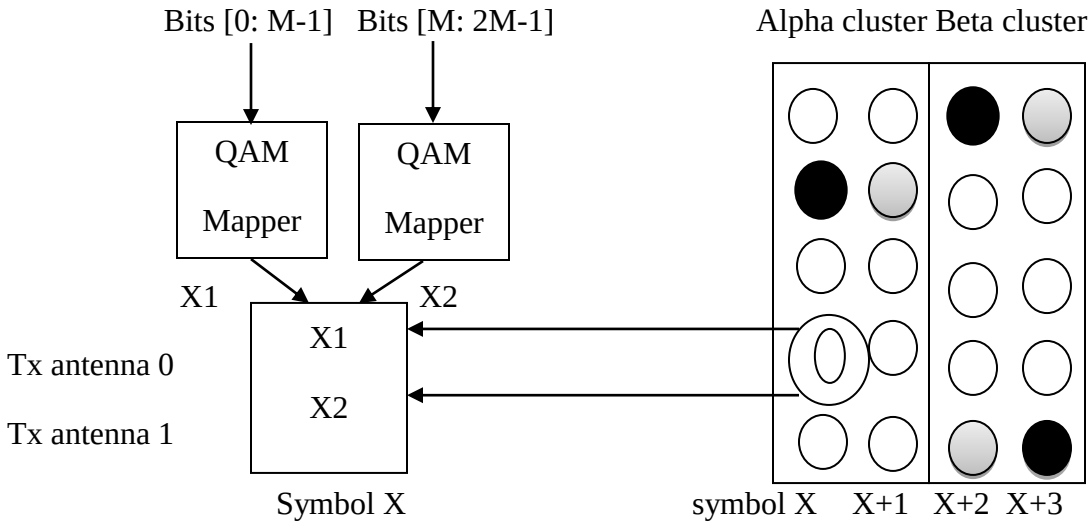

Fig. 4.8: Spatial multiplexing

4.5.3 Spatial diversity coding

Assorted qualities coding or diversity technique frameworks are used when there is no channel data at the transmitter. In this strategy a basic stream is transmitted, yet the flag or information is coded using strategies called space-time coding. The signal is delivered from all of the transmit antenna with full or close orthogonal coding. Assorted qualities coding manhandle the independent obscuring or fading in the various radio wire associations with update hail contrasts. Since there is no channel learning or affirmation, there is no beamforming or show get from grouped qualities coding. This coding can be joined with spatial multiplexing when some channel learning is accessible at the transmitter.

In Fig.4.9 described as data is send from Tx to Rx in the form of bits. Decent variety Coding is the spatial coding procedures for a MIMO framework in remote channels. Remote channels extremely experience the ill effects of blurring marvels, which causes lack of quality in information disentangling.

Fading channels

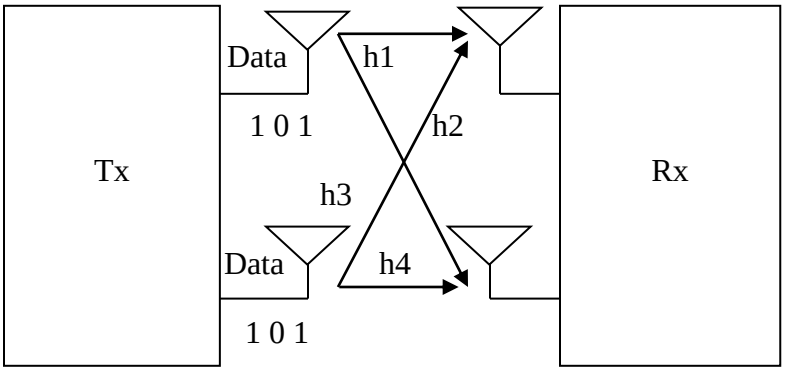

Fig. 4.9: Spatial diversity

On a very basic level, decent variety coding sends numerous duplicates through various transmit radio wires, in order to enhance the unwavering quality of the information gathering. In the event that one of them neglects to get, the others are utilized for information deciphering. MIMO accomplishes spatial assorted variety and spatial multiplexing.

4.6 Diversity combining

Diversity combining is the technique used to combine the multiple received signals of a diversity reception device into a single improved signal.

4.6.1 Techniques used in diversity

Different techniques are used in diversity combining are:

1. Maximum ratio combining
2. Selection combining or switching combining
3. Equal gain combining

These are explained as:

- **Maximum ratio combining (MRC)** defines as it mostly used as a phased array systems. With respect to SNR (signal to noise ratio) the received signals are weighted and summed. The outcomes of SNR yields are:

$$\sum_{K=1}^{N} SNR_k \tag{4.1}$$

Where SNR_k is a signal to noise ratio of the received signal k.

- **Selection combining (SC)** is from the N no. of signals, stronger signal is selected. When the N signals are independent and Rayleigh distributed. Similarly as with exchanging, choice preparing presents just a single reception apparatus' flag to the recipient at any given time. The reception apparatus picked, nonetheless, depends on the best flag to-clamor proportion (SNR) among the got signals. This requires a pre-estimation happen and that all receiving wires have set up associations (at any rate amid the SNR estimation) prompting a higher power prerequisite. The real determination process can occur in the middle of got bundles of data. This guarantees a solitary reception apparatus association is kept up however much as could be expected. Exchanging would then be able to happen on a bundle by-parcel premise if important.

The expected diversity gain has been shown to be expressed as power ratio:

$$\sum_{k=1}^{N} \frac{1}{k} \tag{4.2}$$

The no. of channels is increased then gain is also increased with it.

In fig.4.10 notations are

b= Transmitted bit

E_b= Bit energy

$\alpha 1$= Fading complex envelop on the i-th branch

n_i= Additive white Gaussian noise on the i-th branch

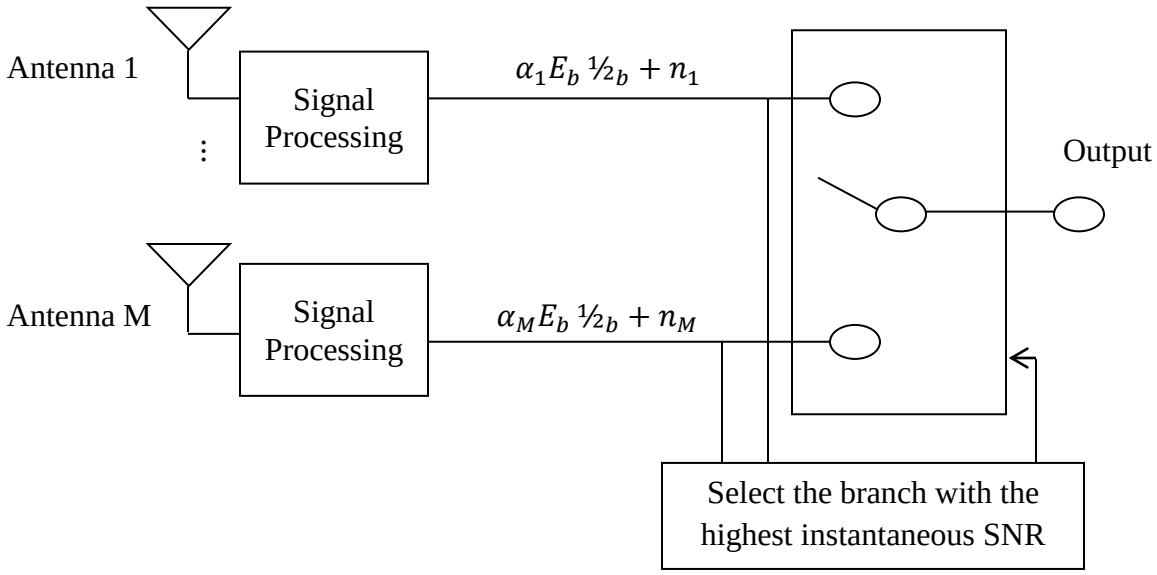

Fig. 4.10: Selection diversity

- **Switching combining (SC)** the receiver signal switches to another signal when the previous signal is dropped below the predefined threshold. It is also called scanning combining. In an exchanging collector, the flag from just a single reception apparatus is sustained to the beneficiary for whatever length of time that the nature of that flag stays over some endorsed limit. In the event that and when the flag corrupts, another radio wire is exchanged in. Exchanging is the most straightforward and slightest power devouring of the receiving wire assorted variety handling methods yet times of blurring and de-synchronization may happen while the nature of one reception apparatus debases and another radio wire interface is built up.

- **Equal gain combining (EGC)** all received signals are summed coherently. In combining, all radio wires keep up set up associations constantly. The signs are then joined and displayed to the beneficiary. Contingent upon the advancement of the framework, the signs can be included straightforwardly (break even with pick up consolidating) or weighted and included reasonably (maximal-proportion joining). Such a framework gives the best protection from blurring yet since all the get ways must remain stimulated; it additionally expends the most power.

4.7 Different schemes of MIMO

It has different schemes to achieve different throughput.

- Alamouti's scheme
- Space time block coding
- Omni directional space time block coding
- Qausi space time block coding

These are explained as

4.7.1 Alamouti's scheme

This method is used to achieve spatial diversity for two antennas in MIMO. We present the Alamouti's scheme coding, the space time code and still a champion among the most typically Used. Here discuss Alamouti's coding for 2transmitters-1receiver system (2x1) and 2transmitter-2receiver system (2x2) [24].

For 2 transmitter and receiving antennas are shown in diagram.

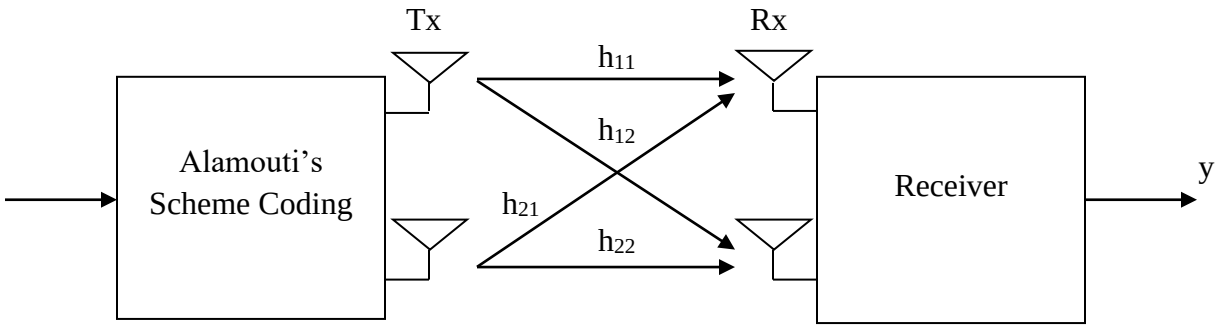

Fig. 4.11: Alamouti's Scheme

Time Slot

Space (antenna) $\begin{vmatrix} X1 & -X2^* \\ X2 & X1^* \end{vmatrix}$

The basic equation of MIMO is:

$$Y = HX + N \tag{4.3}$$

Where y is the receiving signal, h is the multiple channels and x is the transmitted symbols, n is noise.

Assume we have two transmitter antennas as above matrix

I. First we send two transmission symbol in first we transmit x1 in first schedule and x2 in the next time slot.

The first receiving signal is:

$$Y1 = h1x1 + h2x2 \; + \; n1 = [h1 \quad h2]\begin{bmatrix} x1 \\ x2 \end{bmatrix} + n1 \tag{4.4}$$

II. Alamouti's prefer to send the symbols in groups in the first schedule vacancy transmit x1 and x2 and in second time slot send -x2*and x1*.

The second receiving signal is:

$$Y2 = -h1x2* + h2x1* + n2 = [h1 \quad h2]\begin{bmatrix} -x2* \\ x1* \end{bmatrix} + n2 \tag{4.5}$$

This is the simple transmission by Alamouti's space time coding. Alamouti's have some drawback that it does not have much. This is an exceptionally unique STBC. It is the main orthogonal STBC that accomplishes rate -1:

$$\begin{bmatrix} y1 \\ y2 \end{bmatrix} = \begin{bmatrix} h1 & h2 \\ h2* & -h1* \end{bmatrix}\begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} n1 \\ n2 \end{bmatrix} \tag{4.6}$$

That is to express that it is the primary STBC that can fulfill its full varying qualities get without hoping to surrender its data rate. Totally, this is substantial for complex change pictures. Since top pick gathering diagrams rely upon complex numbers in any case, this property ordinarily gives Alamouti's code a basic favored stance over the higher-organize STBCs regardless of the way that they finish a predominant screw up rate execution. Coding rate and can't accomplish constantly most important information rate.

4.7.2 Space time block coding

Space–time block codes (STBCs) follow up on a square of information without a moment's delay (comparably to square codes) and furthermore gives diversity gain however doesn't provide coding gain [24]. It is advance type of Alamouti's plan and it holds all the vital elements of Alamouti's plan also some headway. These summed up codes are orthogonal in nature and transmit receiving wires can accomplish full differences through this:

$$\text{Time slot} \begin{matrix} \\ \\ \\ \end{matrix} \overset{\text{Transmit antennas}}{\begin{bmatrix} S11 & S12 \cdots & S1n \\ S21 & S22 & \vdots S2n \\ Sm1 & Sm2 \cdots & Smn \end{bmatrix}}$$

$$Y = Hs + n \tag{4.7}$$

As of now specified that STBC are the headway of Alamouti's Space time code in which the encoding and disentangling arrangements are the same as there in the Alamouti's on both the transmission and beneficiary sides are used for MIMO systems to enable the transmission of various copies of a data stream over different radio wires and to manhandle the diverse got types of the data to upgrade the reliability of data trade. Space time coding cements every single one of the duplicates of the got development superbly to manage ousts however much data from every one of them as could be normal. Space time square coding uses both spatial and temporary arranged qualities and thusly engage critical augmentations to be made. Space-time coding incorporates the sending of various copies data. This makes up for the multi path issues, for example, blurring and warm commotion. In spite of the fact that there is repetition in the information a few duplicates may arrive less defiled at the recipient. When utilizing space-time square coding, the information stream is encoded in pieces preceding transmission. These information pieces are then appropriated for the numerous reception apparatuses and the information is likewise divided crosswise over time. STBC does not use for more than 2 antenna. There is some drawback that Sensitivity to channel estimation error, Delay Effects, Antenna Configurations.

Transmission by utilization of 2 antennas:

$$H2 = \begin{bmatrix} x(t)1 & x(t)2 \\ -x(t)2* & x(t)1* \end{bmatrix} \tag{4.8}$$

Transmission by utilization of 3 antennas:

$$H3 = \begin{bmatrix} x(t)1 & x(t)2 & x(t)3 \\ -x(t)2 & x(t)1 & -x(t)4 \\ -x(t)3 & x(t)4 & x(t)1 \\ -x(t)4 & -x(t)3 & x(t)2 \\ x(t)1* & x(t)2* & x(t)3* \\ -x(t)2* & x(t)1* & -x(t)4* \\ -x(t)3* & x(t)4* & x(t)1* \\ -x(t)4* & -x(t)3* & x(t)2* \end{bmatrix} \tag{4.9}$$

By utilization of 4 antennas:

$$H4 = \begin{bmatrix} x(t)1 & x(t)2 & x(t)3 & x(t)4 \\ -x(t)2 & x(t)1 & -x(t)4 & x(t)3 \\ -x(t)3 & x(t)4 & x(t)1 & -x(t)2 \\ -x(t)4 & -x(t)3 & x(t)2 & x(t)1 \\ x(t)1* & x(t)2* & x(t)3* & x(t)4* \\ -x(t)2* & x(t)1* & -x(t)4* & x(t)3* \\ -x(t)3* & x(t)4* & x(t)1* & -x(t)2* \\ -x(t)4* & -x(t)3* & x(t)2* & x(t)1* \end{bmatrix} \tag{4.10}$$

4.7.3 Orthogonal space time block coding (OSTBC)

OSTBC stands for orthogonal space time block coding. It gives more advantages then space time coding. OSTBC can be used for more than 2 antennas [25]. The OSTBC accomplish full diversity qualities with low decoding multifaceted nature. The exhibitions of STBC and OSTBC codes are performed in regard of Bit Error Rate (BER) and diversity qualities pick up by the Rayleigh blurring or fading channel. The OSTBC use linear STBC.

All signals orthogonal to each other. The orthogonality empowers us to accomplish full transmit differing qualities. Furthermore, in the meantime, it permits a basic ML de-ciphering. Precoded OSTBC has a higher unraveling many-sided quality and a lower coding pick up than the other two codes, since in the precoded OSTBC the data images should be together planned and decoded.

Additionally, a precoded no-zero-section Toeplitz code and a precoded no-zero-passage covered Alamouti's code are likewise proposed [25]. These two codes can accomplish a higher assorted qualities arrange with straight collectors. The OSTBC Encoder piece encodes the data images from the QPSK Modulator by utilizing either the Alamouti's code for two transmit reception apparatuses or other summed up complex orthogonal codes for three or four transmit radio wires. The quantity of transmit reception apparatuses is given to this square as an information. The yield of this square is a (Ns x Nt) variable-measure network, where the quantity of sections (Nt) relates to the quantity of transmit reception apparatuses and the quantity of columns (Ns) compares to the quantity of orthogonal code tests transmitted over each transmit receiving wire in a casing. So, dimension is Ns/2 × T/2. All info stream created is changed over to images by adjustment QPSK. AWGN (Additive White Gaussian Noise) is added to each channel. They got signs are decoded by Maximum probability strategy. The OSTBC has best performance related to signal to noise ratio than STBC. For transmitted antenna 2 the matrix is:

Table 4.1 OSTBC

Transmitted Antenna	Rate	OSTBC codeword matrix
2	1	$g = \begin{bmatrix} g1 & g2 \\ -g2* & g1* \end{bmatrix}$
3	½	$\begin{bmatrix} g1 & g2 & 0 \\ -g2* & g1* & 0 \\ 0 & 0 & g1 \\ 0 & 0 & -g2* \end{bmatrix}$
3	¾	$\begin{bmatrix} g1 & g2 & g3 \\ -g2* & g1* & 0 \\ -g3* & 0 & g1* \\ 0 & S3* & -g2* \end{bmatrix}$
4	½	$\begin{bmatrix} g1 & g2 & 0 & 0 \\ -g2* & g1* & 0 & 0 \\ 0 & 0 & g1 & g2 \\ 0 & 0 & -g2* & g1* \end{bmatrix}$
4	¾	$\begin{bmatrix} g1 & g2 & g3 & 0 \\ -g2* & g1 & 0 & g3 \\ g3* & 0 & -g1* & g2 \\ 0 & g3* & -g2* & g1 \end{bmatrix}$

Basically we use large numbers of antenna at the transmission side and receiving side to achieve data rate, high capacity and to improve the reliability. So Alamouti's code used to achieve overall rate orthogonal space time block code (OSTBC). One advantage of OSTBC is that it has no requirement of channel state data at the transmission side for obtaining the diversity.

4.7.4 Quasi-orthogonal space time block coding (QOSTBC)

QOSTBC stands for Quasi-orthogonal space time block coding. Another approach for Quasi-Orthogonal space time piece coding (QO-STBC) is proposed, with essential straight translating by methods for most extraordinary likelihood revelation. The proposed MIMO-OFDM signals with QOSTBC using 8X8 reception apparatus arrangement has better execution as far as BER versus SNR than the other system. The regular QOSTBC can accomplish the full correspondence rate, however at the cost of the unraveling many-sided quality and the assorted qualities increase due to the obstruction terms in the discovery framework. It also overcomes the decoding complexity. The QOSTBC can accomplish full rate yet impedance terms will show up from the neighboring signals amid the flag identification and increases the detection complexity and decreases the gain throughput. By utilizing semi orthogonal plan, sets of transmitted images can be decoded autonomously; the loss of assorted qualities in QOSTBC is because of some coupling terms between the evaluated images. When we use more than 2 transmitted antennas than the rate of OSTBC cannot be more than ¾. For obtaining rate more than ¾ for 2 transmitted antennas we use QOSTBC method. Alamouti's code is better for achieving full rate diversity. The usage of Alamouti's code but for more than 2 transmitted antennas. QOSTBC is a full rate STBC for more than one radio wire. To configuration full rate codes with real and imaginary grouping, we assume non-orthogonal codes for the 4 transmit antenna and for 8 transmitted antennas at transmission rate one so QOSTBC constructed by using Alamouti's code. To calculate BER we use QOSTBC with modulation BPSK. If we place greater number of transmitted and receive antenna then the SNR increases and BER performance decreases rapidly so QOSTBC used for transmission rate up to 1, ½ and 3/4. So QOSTBC overcome the disadvantage of OSTBC:

$$\mathrm{A12} = \begin{bmatrix} s_{11} & s_{12} \\ -s_{12}^{*} & s_{11}^{*} \end{bmatrix} \mathrm{A34} = \begin{bmatrix} s_{13} & s_{14} \\ -s_{14}^{*} & s_{13}^{*} \end{bmatrix} \tag{4.11}$$

$$\mathrm{A56} = \begin{bmatrix} s_{15} & s_{16} \\ -s_{16}^{*} & s_{15}^{*} \end{bmatrix} \mathrm{A78} = \begin{bmatrix} s_{17} & s_{18} \\ -s_{18}^{*} & s_{17}^{*} \end{bmatrix} \tag{4.12}$$

- **Matrix for 8*8 antenna using QOSTBC:**

$$B = \begin{bmatrix} A12 & A34 \\ -A34* & A12* \end{bmatrix} = = \begin{bmatrix} s_{11} & s_{12} & s_{13} & s_{14} \\ -s_{12}^* & s_{11}^* & -s_{14}^* & s_{13}^* \\ -s_{13}^* & -s_{14}^* & s_{11}^* & s_{12}^* \\ s_{14}^* & -s_{13} & -s_{12} & s_{11} \end{bmatrix} \quad (4.13)$$

$$c = \begin{bmatrix} A56 & A78 \\ -A78* & A56* \end{bmatrix} = \begin{bmatrix} s_{15} & s_{16} & s_{17} & s_{18} \\ -s_{16}^* & s_{15}^* & -s_{18}^* & s_{17}^* \\ -s_{17}^* & -s_{18}^* & s_{15}^* & s_{16}^* \\ s_{18}^* & -s_{17} & -s_{16} & s_{15} \end{bmatrix} \quad (4.14)$$

On Combined equation (4.12) and (4.13) the antenna configuration is:

$$Q = \begin{bmatrix} B & C \\ -C* & B* \end{bmatrix} =$$

$$\begin{bmatrix} s11 & s12 & s13 & s14 & s15 & s16 & s17 & s18 \\ -s12* & s11 & -s14* & s13* & -s16* & s15 & -s18* & s17* \\ -s13* & -s14* & s11* & s12* & -s17* & -s18* & s15* & s16* \\ s14* & -s13 & -s12 & s11 & s18* & -s17 & -s16 & s15 \\ -s15* & -s16* & -s17* & -s18* & s11* & s12* & s13* & s14* \\ s16 & -s15 & s18 & -s17 & -s12 & s11 & -s14 & s13 \\ s17 & s18 & -s15 & -s16 & -s13 & -s14 & s11 & s12 \\ -s18* & s17* & s16* & -s15* & s14* & -s13* & -s12* & s11* \end{bmatrix} \quad (4.15)$$

This method to improve Quasi-Orthogonal-STBC execution with iterative disentangling, which obviously accomplishes higher unwavering quality however builds deciphering intricacy. In some new translating techniques were proposed to lessen the computational many-sided quality.

4.8 Disadvantages of MIMO

- Complexity
- More power consumption
- Costly
- Limited number of antennas

4.9 Applications of MIMO

- It is efficient for OFDM when multipath fading will occur
- It gives reliable communication
- It also increase capacity

CHAPTER 5 RESULTS & DISCUSSIONS

The simulation results for illustrating the impact of using MIMO sytems on the BER vs SNR performance of FBMC system are presented in this chapter. In the simulation work AWGN and Rayleigh channels are used for analyzing the performance of FBMC system augmented with MIMO system. In MIMO-FBMC, different diversity combining techniques are used to analyze the performance of system.

5.1 MRC augmented FBMC:

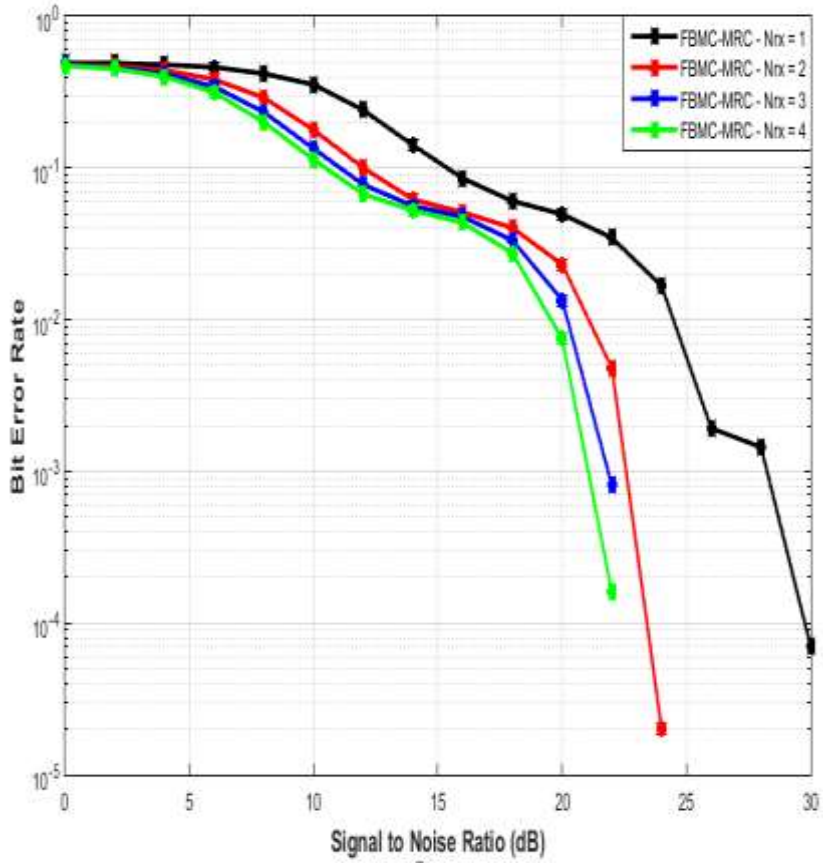

Fig. 5.1(a): SNR vs BER performance of FBMC-MRC in AWGN channel.

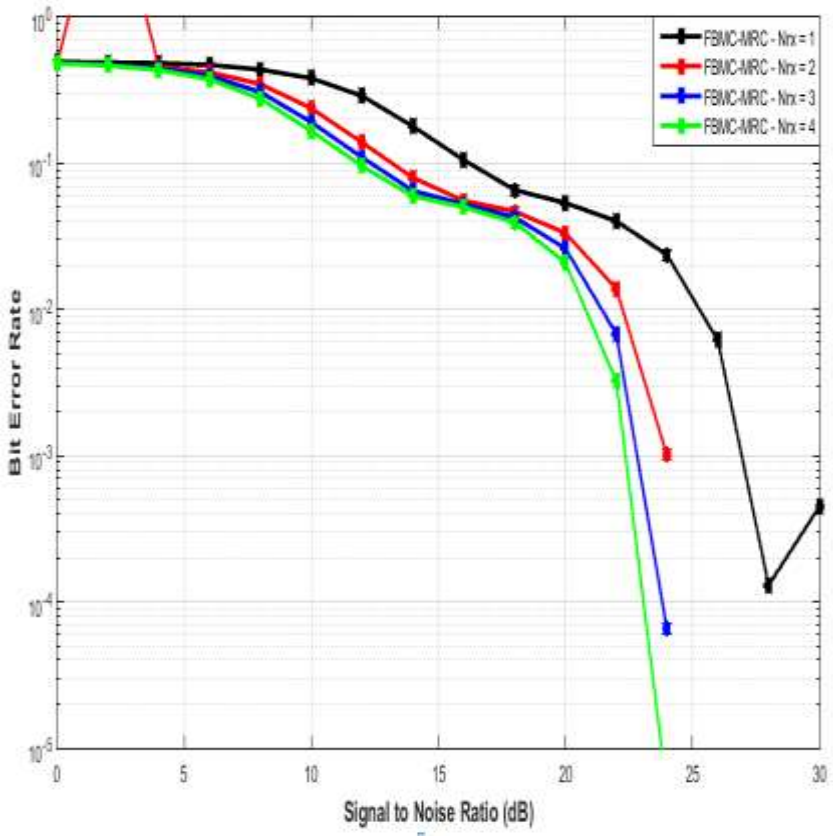

Fig. 5.1(b): SNR vs BER performance of FBMC-MRC in Rayleigh channel.

In Fig. 5.1 (a-b) FBMC- Maximum ratio combining (MRC) diversity technique is used with varying number of receiving antennas N over AWGN and Rayleigh channel. Here, the number of receiving antennas are varried from 1 to 4 i.e. N = 1, 2, 3 and 4 . By using different antennas at receiver side, BER performance of FBMC varrying. When number of receiving antennas are increasing, the Bit Error Rate keeps on decreasing and thus this system would provide better Bit Error Rate performance with respect to a specified value of SNR. The performnace of FBMC-MRC is better in case of AWGN channel in comparison to Rayleigh channel, as in case of Rayleigh channel no line of sight path is available in between the transmitter and receiver, moreover the effect of multipath fading also comes in to play in case of rayleigh fading channel.

5.2 SC augmented FBMC:

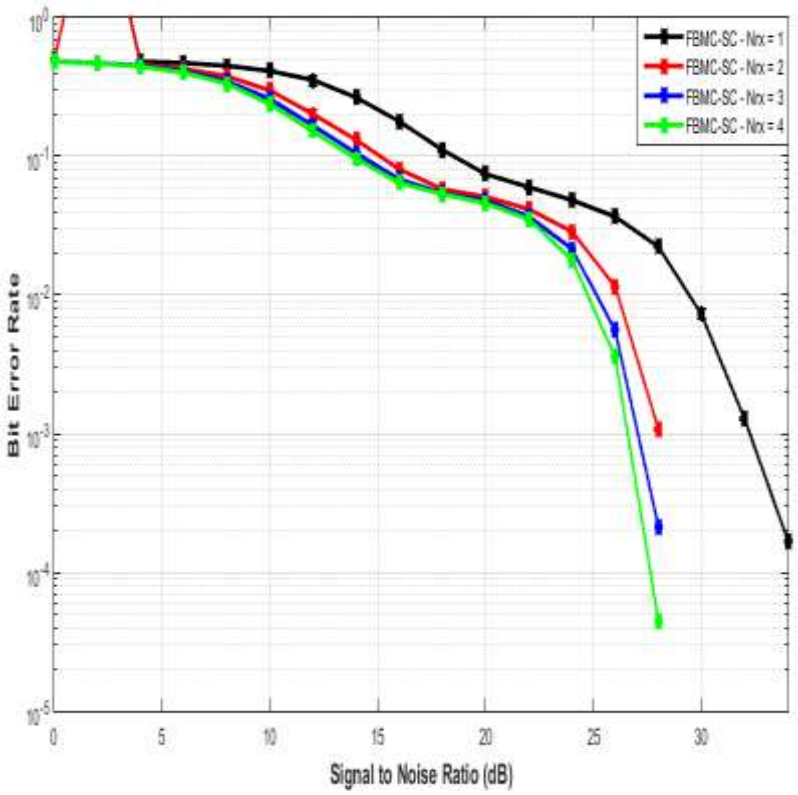

Fig. 5.2(a): SNR vs BER performance of FBMC-SC in AWGN channel.

In Fig. 5.2 (a-b) FBMC-Selection combining (SC) diversity technique is used with varying number of receiving antennas N over AWGN and Rayleigh channel. In Selection combining number of signals are present but stronger signal is selected. Here, the number of receiving antennas are varried from 1 to 4 i.e. N = 1, 2, 3 and 4 . By using different antennas at receiver side, BER performance of FBMC varying.

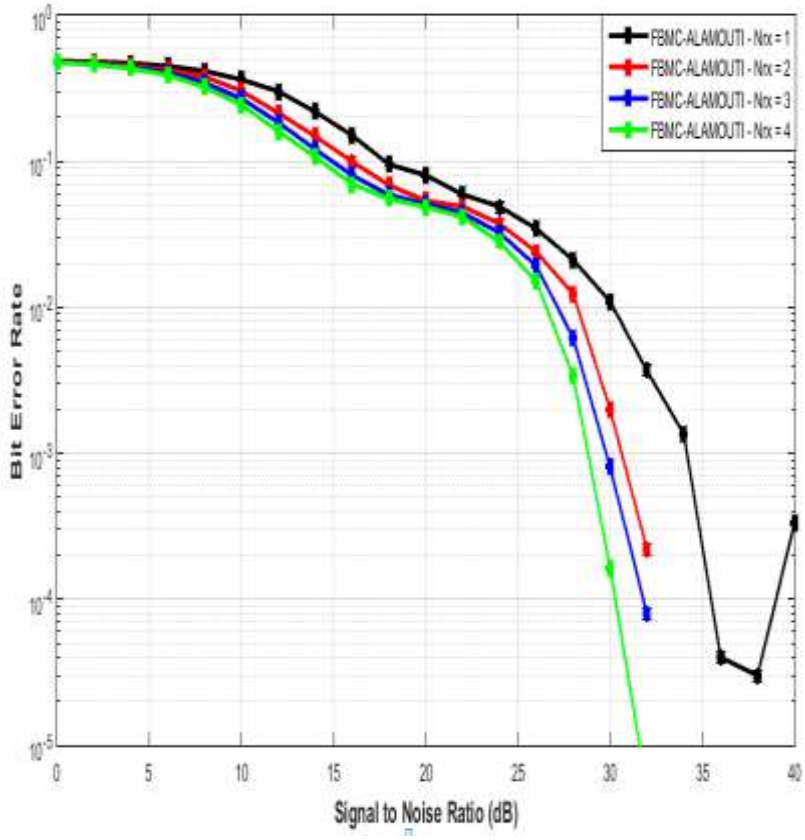

Fig. 5.2(b): SNR vs BER performance of FBMC-SC in Rayleigh channel.

When number of receiving antennas are increasing, the Bit Error Rate keeps on decreasing and thus this system would provide better Bit Error Rate performance with respect to a specified value of SNR. The performance of FBMC-SC is better in case of AWGN channel in comparison to Rayleigh channel, as in case of Rayleigh channel no line of sight path is available in between the transmitter and receiver, moreover the effect of multipath fading also comes in to play in case of rayleigh fading channel.

Here, from graphs 5.1 and 5.2 observed that using MRC and SC diversity techniques, MRC gives better performance than SC in case of AWGN and Rayleigh channels.

5.3 Alamouti augmented FBMC:

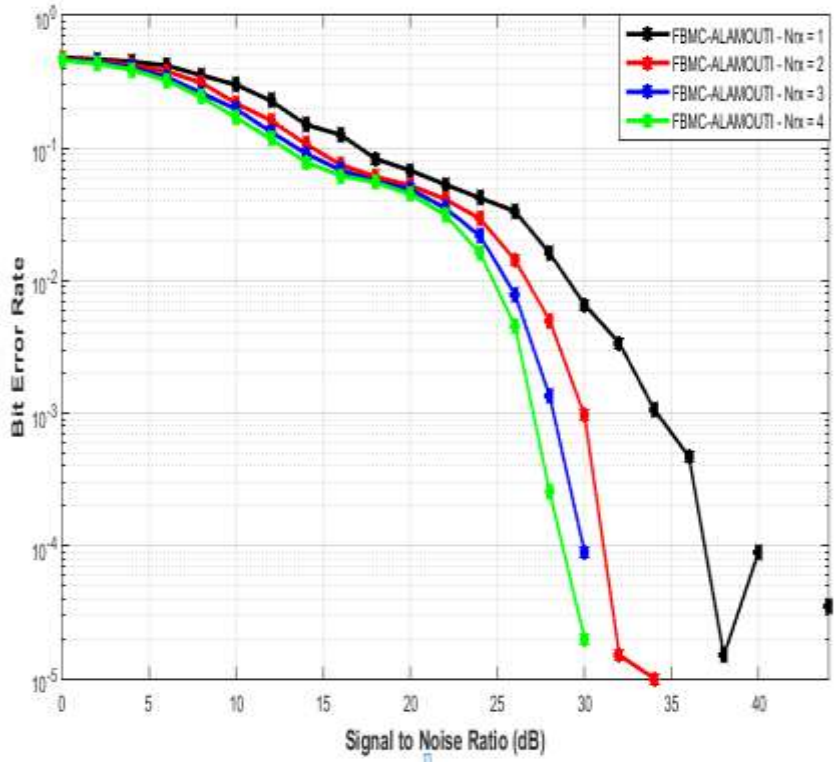

Fig. 5.3(a): SNR vs BER performance of FBMC-Alamouti in AWGN channel.

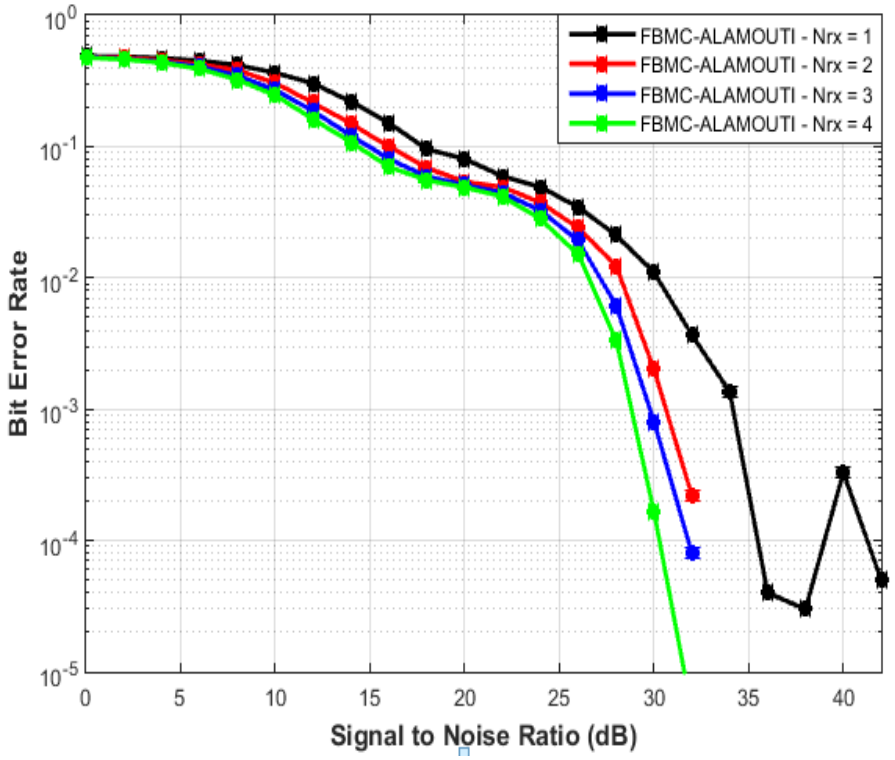

Fig. 5.3(b): SNR vs BER performance of FBMC-Alamouti in Rayleigh channel.

In Fig. 5.3 (a-b) FBMC- Alamouti diversity technique is used with varying number of receiving antennas N over AWGN and Rayleigh channel. Here, the number of receiving antennas are varried from 1 to 4 i.e. N = 1, 2, 3 and 4 . By using different antennas at receiver side, BER performance of FBMC varrying. When number of receiving antennas are increasing, the Bit Error Rate keeps on decreasing and thus this system would provide better Bit Error Rate performance with respect to a specified value of SNR. The performnace of FBMC-Alamouti is better in case of AWGN channel in comparison to Rayleigh channel, as in case of Rayleigh channel no line of sight path is available in between the transmitter and receiver, moreover the effect of multipath fading also comes in to play in case of rayleigh fading channel.

5.4 STBC3 augmented FBMC:

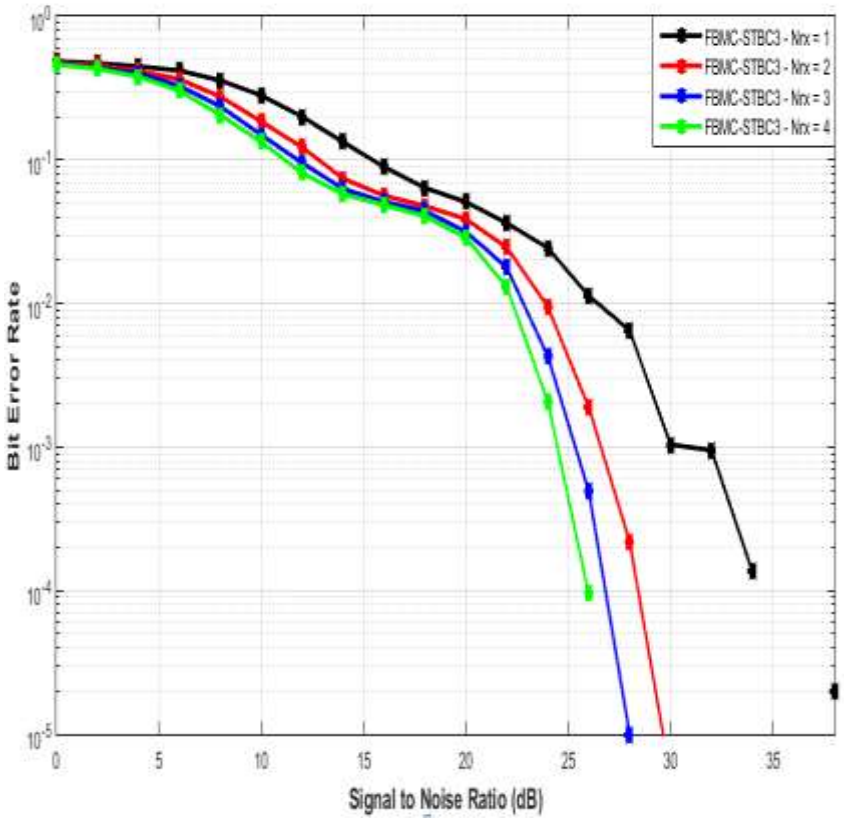

Fig. 5.4(a): SNR vs BER performance of FBMC-STBC3 in AWGN channel.

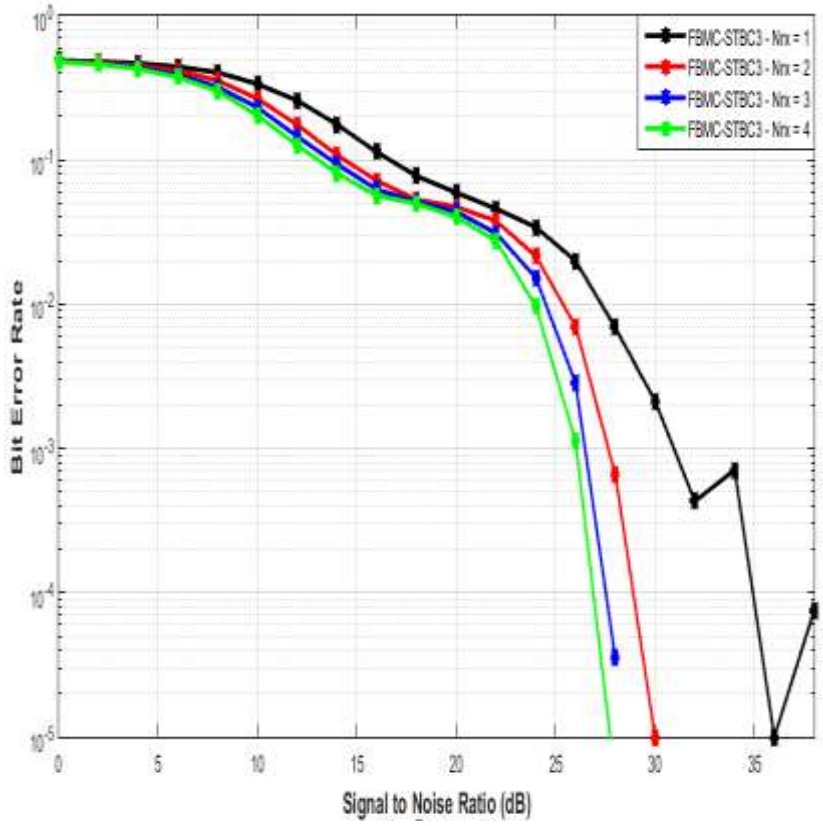

Fig. 5.4(b): SNR vs BER performance of FBMC-STBC3 in Rayleigh channel.

In Fig. 5.4 (a-b) FBMC- Space Time Block Code-3 (STBC3) diversity technique is used with varying number of receiving antennas N over AWGN and Rayleigh channel. Here, the number of receiving antennas are varried from 1 to 4 i.e. N = 1, 2, 3 and 4 . By using different antennas at receiver side, BER performance of FBMC varrying. When number of receiving antennas are increasing, the Bit Error Rate keeps on decreasing and thus this system would provide better Bit Error Rate performance with respect to a specified value of SNR. The performnace of FBMC-STBC3 is better in case of AWGN channel in comparison to Rayleigh channel, as in case of Rayleigh channel no line of sight path is available in between the transmitter and receiver, moreover the effect of multipath fading also comes in to play in case of rayleigh fading channel.

5.5 STBC4 augmented FBMC:

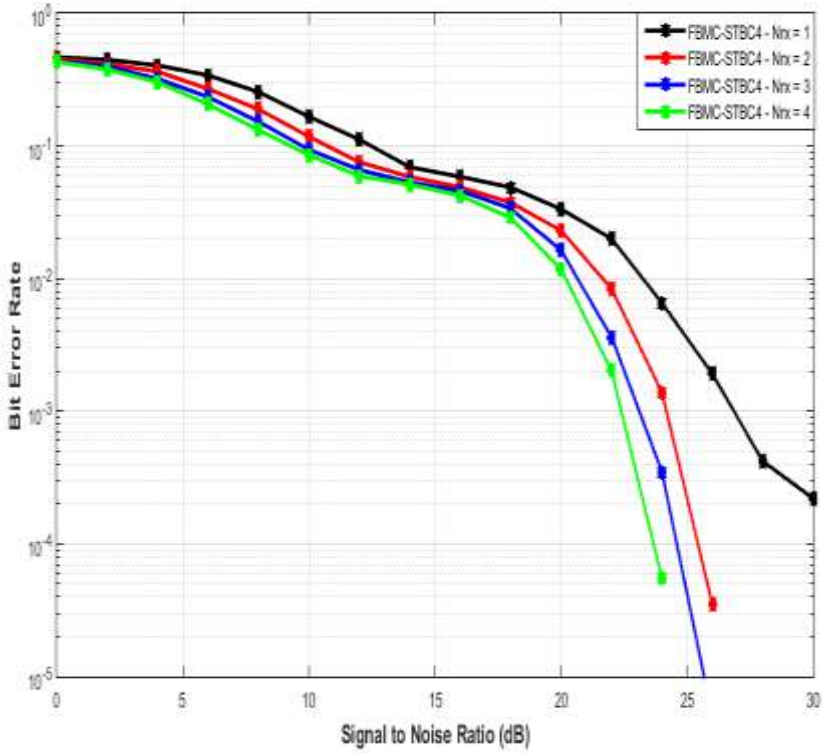

Fig. 5.5(a): SNR vs BER performance of FBMC-STBC4 in AWGN channel.

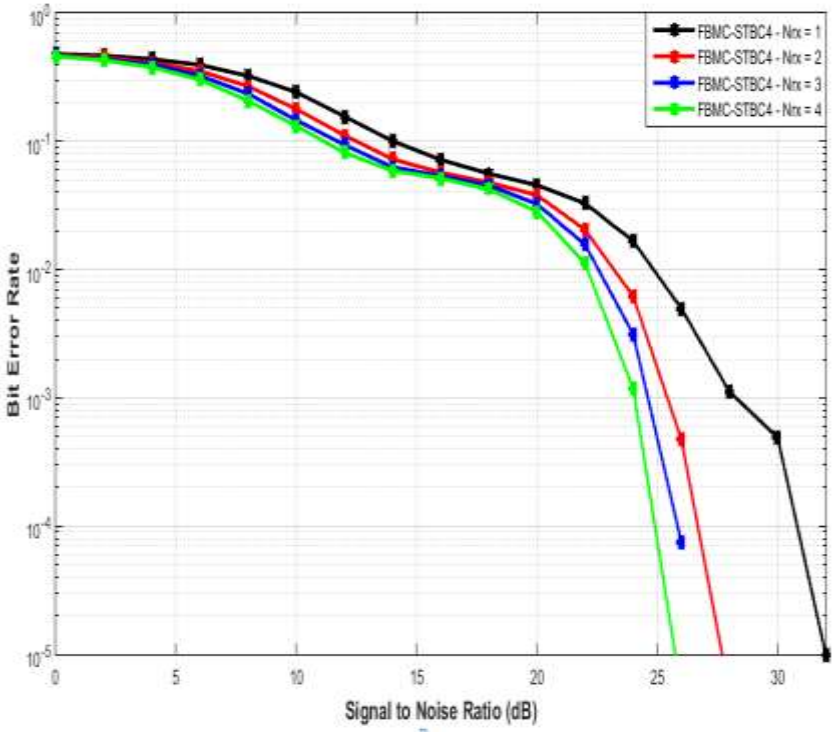

Fig. 5.5(b): SNR vs BER performance of FBMC-STBC4 in Rayleigh channel.

In Fig. 5.5 (a-b) FBMC- Space Time Block Code-4 (STBC4) diversity technique is used with varying number of receiving antennas N over AWGN and Rayleigh channel. Here, the number of receiving antennas are varried from 1 to 4 i.e. N = 1, 2, 3 and 4 . By using different antennas at receiver side, BER performance of FBMC varrying. When number of receiving antennas are increasing, the Bit Error Rate keeps on decreasing and thus this system would provide better Bit Error Rate performance with respect to a specified value of SNR. The performnace of FBMC-STBC4 is better in case of AWGN channel in comparison to Rayleigh channel, as in case of Rayleigh channel no line of sight path is available in between the transmitter and receiver, moreover the effect of multipath fading also comes in to play in case of rayleigh fading channel.

Here, from graphs 5.4 and 5.5 observed that using STBC3 and STBC4 diversity techniques, STBC4 gives better performance than STBC3 in case of AWGN and Rayleigh channels.

CHAPTER 6 CONCLUSIONS & FUTURE SCOPE

6.1 Conclusion

FBMC is considered as a candidate waveform for 5G networks, as its inherent properties provide the flexibility needed to respond to the diverse service requirements expected in future communication scenarios. In MIMO-FBMC system, the use of multiple antenna in case of different technique such as MRC, SC, Alamouti, STBC3 and STBC4 the performance of system is improved. The simulation results depicts that when the number of receiving antennas is increasing, the BER keeps on decreasing due to and thus this system would provide better BER performance in comparison to other antenna configuration.

Here the system is evaluated for different channels such as AWGN and Rayleigh for the comparison of SNR with BER using different MIMO diversity combining schemes.

6.2 Future scope

FBMC-MIMO requires further development and the better performance analysis for the solution. In future diverse MIMO methodologies can be analyzed for improvement in performance of FBMC system. FBMC system can also be analyzed using diverse filters for better performance and less complexity.

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