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A NEW TECHNIQUE FOR PEAK-TO-AVERAGE POWER RATIO REDUCTION IN 5G COMMUNICATION

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Master's Thesis

Supervisor

Prof. Dr. Osman Nuri UÇAN

Istanbul, 2022

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The thesis A NEW TECHNIQUE FOR PEAK-TO-AVERAGE POWER RATIO REDUCTION IN 5G COMMUNICATION prepared ZAID YOUSIF and submitted on 16/12/2022 has been **accepted unanimously** for the degree of Master of Science in Information Technology.

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Zaid Abdulazeez Yousif YOUSIF

Signature

DEDICATION

In the name of the gracious ALLAH.

I would like to thank God Almighty for granting me the opportunity to complete my master's degree.

To my angel in life, the meaning of love, the meaning of mercy and devotion, the smile of life and the secret of existence, to whom your invitation was the key to my success and affection.
Respectful Father**.**

To a glowing lamp that illuminates my life's gloom. For the one who has achieved unlimited strength and love. For the one who understood the significance of life
My loving Mother.

To the one who is closer to my soul, to the one who shares with me the embrace of pain, and through them I draw my strength and determination. my brothers and sisters Which paved the way for me to reach the pinnacle of science to. my teacher I was in the midst of my studies, and I shared my thoughts as a reminder
Expression of gratitude to. my friends

ABSTRACT

A NEW TECHNIQUE FOR PEAK-TO-AVERAGE POWER RATIO REDUCTION IN 5G COMMUNICATION

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Recently, due to the ongoing growth rising demand for a wide range of services and an increase in the number of devices with the highest level of reliability and the shortest possible delay, there is a rising need to achieve high data rates. As a result, the fifth generation (5G) is developed to deliver improved services at a high data rate, is then developed as a result of this. Instead of filtering the full band, it does it for sub-carriers. Out-of-band emissions (OOB) are reduced using sub-band filtering, which also minimizes carrier interference (ICI) between nearby users. The UFMC's fast latency, strong frequency offset, and low out-of-band (OOB) emission help to improve spectrum efficiency. However, the high peak-to-average power ratio (PAPR) problem at UFMC could impede the functionality of high-power amplifiers and lead to nonlinear distortion.

The universal filtered multicarrier (UFMC) waveform has quasi-orthogonal properties among subcarriers and is cheap in complexity. Additionally, unlike orthogonal frequency division multiplexing (OFDM) system, it can achieve significantly greater out-of-band emission performance. As a result, we suggest the Whale Optimization Algorithm in this study (WOA), which helped to greatly enhance the performance of the UFMC system by achieving a large reduction in PAPR. The UFMC system's BER and PAPR performance is assessed through simulation. MATLAB is used to run every simulation.

Keywords: 5G, UFMC, Whale Optimization Algorithm (WOA), PAPR.

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ABBREVIATIONS

BER	:	Bit Error Rate
CCDF	:	Cumulative Complementary Distribution Function
FBMC	:	Filter Bank Multi Carrier
LTE	:	Long Term Evolution
OFDM	:	Orthogonal Frequency Division Multiplexing
MIMO	:	Multiple Input Multiple Output
PAPR	:	Peak to Average Power Ratio
UFMC	:	Universal Filter Multi Carrier
5G	:	Fifth Generation
4G	:	Fourth Generation
mmWave	:	millimeter wave
DAS	:	Distributed antenna system
BS	:	base stations
UWB	:	ultra wide band
VLC	:	Visible light communication
IFFT	:	Inverse Fast Fourier Transform
M-QAM	:	M-array quadrature amplitude modulation
SLM	:	Selected Mapping

LIST OF SYMBOLS

~Q	Inverse Fourier matrix
H	Toeplitz matrix having dimensions (N+L-1)
L_f	filter of length
$f_b(l)$	FIR filter coefficients
L_{cp}	cyclic prefix length
H	the equivalent channel convolution matrix
$X(t)$	prey position vector
N	zero mean AWGN with variance σ^2at the receiver
$\overline{D}$	demodulation matrix
d[n]	Amplitude
E	denote the expectation of the signal
T	current number of iterations
X^*(t)	prey position vector
A, D	surrounding step size
Rand	random number between [0, 1]

1. INTRODUCTION

1.1 FIVE GENERATION

Fifth-generation technology (5G), The most recent iteration of cellular technology is intended to greatly improve the responsiveness and speed of wireless networks. With 5G, data can be transmitted through wireless internet connections at speeds up to several gigabits, with top peak speeds expected to approach 20 (Gbps). These rates are quicker than landline networks and have a latency of no more than 5 milliseconds, which makes them perfect for applications that need real-time input. Wireless networks will be able to carry a lot more data owing to 5G because of greater bandwidth availability and improved antenna technology. Whenever the technology is introduced, numerous new applications, uses, and business cases are anticipated.

Cell sites that are segmented into sectors and transfer data via radio waves make up wireless networks. Fourth-generation Long-Term Evolution (LTE) cellular technology is the foundation for 5G. (4GAs opposed to 4G, which uses enormous, powerful cell towers to transmit data across great distances, many tiny cell stations are used to transmit 5G wireless signals mounted on light poles or building roofs. Many micro cells are required for 5G, It utilises the mmWave spectrum, a range of frequencies between 30-300 gigahertz (GHz), to enable rapid speeds.

Lower-frequency regions of the spectrum were utilised in earlier iterations of wireless technology. The wireless sector is also looking into how 5G networks could use a lower-frequency spectrum in order to address the issues with mmWave related to distance and interference, Network operators must expand their new networks in order to use the spectrum they now possess. even though the coverage area of lower-frequency spectrum is larger, mmWave outperforms it in terms of speed and capacity.

Most nations throughout the world currently utilise wireless communication technologies of the fourth generation. However, there are still certain difficulties, such as an increase in wireless mobile devices and services that even 4G cannot handle, such as the scarcity of spectrum and excessive energy utilise [1]. Due to the continuous demand for high data rates and mobility from new applications, wireless system designers have begun development on 5G wireless systems, which are expected to be utilized around 2020.

The following generation of mobile technology is referred to as "5G technology", is utilised in place of 4G and LTE Advanced. In order to solve the various problems in 5G, we need fresh innovations and cutting-edge technology. visible light communications, Massive MIMO, cognitive radio, green communication, spatial modulation and mobile femtocells are a few of the technologies for 5G communications that show promise. New cellular architecture is also necessary for 5G.

Challenges facing the fifth generation:

a. Efficiently utilise of spectrum

b. To serve extremely large amount of users

c. To support high mobility

d. Reduce power consumption

e. 1000 × data volume

f. To accommodate a 1000 percent increase in traffic in ten years

g. Up to 10 Gbps end user data rate

h. Fifth generation features:

i. Ultra dense networks

j. Massive MIMO

k. Higher frequencies.

l. Moving networks

m. Ultra reliable communication

n. Massive machine communication

o. Device to device communication.

p. Fiber like user experience

q. Ultra-fast switching.

r. Necessary breakthroughs:

s. Modern waveform technologies, coding, and modulation algorithms are necessary for great spectral efficiency.

t. To enable a novel air interface that is adaptable and computationally intensive, new designs are needed.

u. To reap the benefits of the efficient and adaptable utilization of spectrum, an improvement in RF domain processing will be necessary. The development of single-frequency full duplex radio technology will significantly increase spectrum efficiency.

v. To support a wide range of capabilities in radio technology, including ultra-low energy and ultra-fast devices with long battery lives

w. Radio access infrastructure that is cloud-based and virtualized.

1.2 A POSSIBLE WIRELESS CELLULAR DESIGN FOR 5G

We need to drastically change the way cellular architecture is designed in order to resolve the aforementioned problems and fulfil the needs of the 5G system [1]. Separating outside and indoor scenarios is one of the major concepts for the 5G cellular architecture. Because buildings lose a significant amount of penetration, and we spend 80% of our time indoors. Therefore, we must avoid this circumstance. Massive MIMO and distributed antenna systems (DAS) will be connected to this.

This architecture calls for large antenna arrays to be installed on exterior base stations (BSs), some of which will be dispersed throughout the cell, and they will be linked to one another through optical fibers, utilising both huge MIMO and DAS technologies. There are frequently fewer antenna elements for mobile customers outside, but they can work together to create virtually huge MIMO networks. Every building will also have a large antenna array erected outside of it to link to outdoor BSs or DA parts of BSs, potentially with LOS components with this cellular architecture, the only requirement for users within buildings was communication with internal access points that were established outside of the structures. High data speeds over short distances are possible using a variety of technologies. Examples include visible light communication (VLC) mm-wave communication, Wi-Fi, ultra wide band (UWB) and the femtocell. In addition to looking for unused spectrum, we can aim to make better utilise of the frequency spectrum that is already in use, for instance using cognitive radio networks. The mobile femtocell concept should be used in cars and high-speed trains to accommodate people with high levels of mobility. To connect with exterior BSs, a car has a large antenna array outdoors, However, mobile femtocells are installed inside the cars so that users can connect with one another there. A mobile femtocell and each user connecting to it are seen as a single entity by the base station (BS). A mobile femtocell is viewed as a normal BS from the perspective of the user. A potential 5G wireless cellular architecture shown in (Figure 1.1).

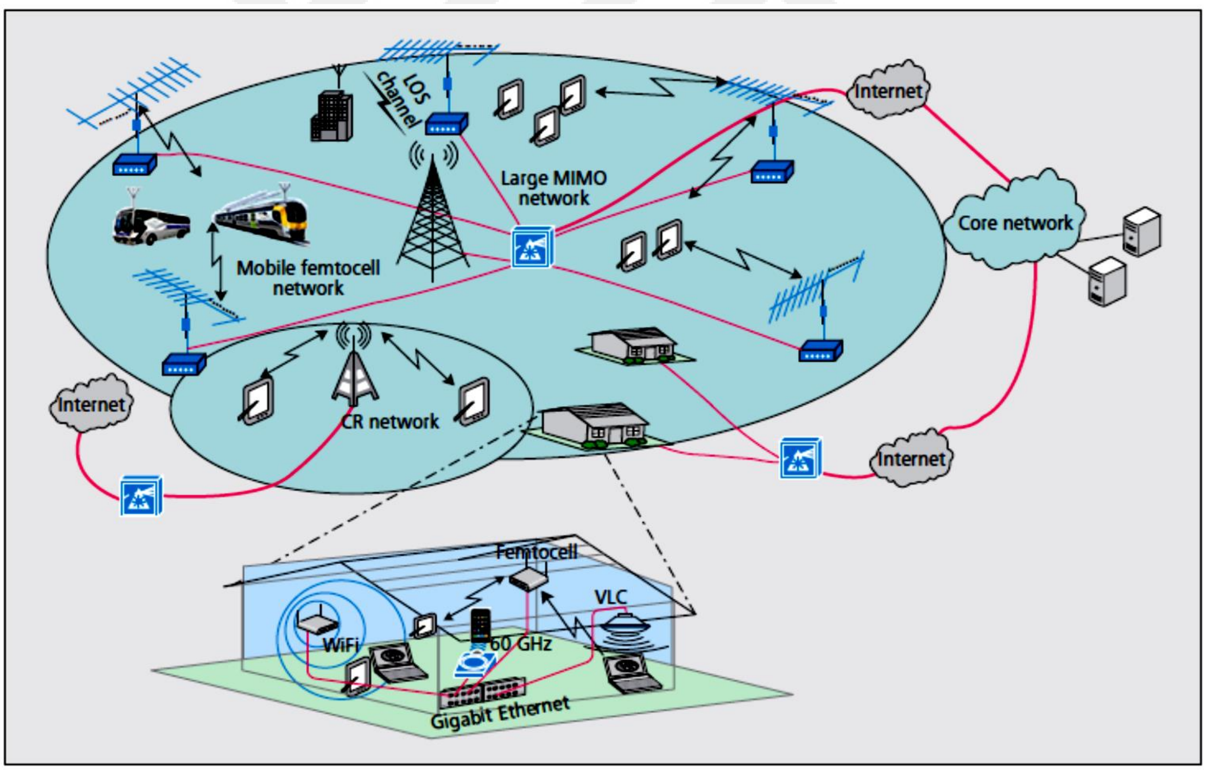

Figure 1.1: A potential 5G wireless cellular architecture.

1.3 KEY 5G WIRELESS TECHNOLOGIES THAT ARE EXCITING

Massive MIMO systems have many antenna elements in both the transmitter and reception sectors (even hundreds or generally ten). These antenna parts could be dispersed or placed close together. The spectral and energy efficiency of the system can be greatly enhanced by massive MIMO in addition to standard MIMO. Additionally, the impact of noise and rapid fading disappears.

networks for cognitive radios CRN: To better utilise the crowded RF spectrum, cognitive radio is a cutting-edge software defined radio technology. A secondary system in CR systems has the option of sharing spectrum either interference-free or with a certain level of tolerance.

a mobile femtocell is a tiny cell having the capacity to move about and change how it connects to a mobile operator's core network on the go It can be used to improve the level of service provided to passengers inside of public buses, trains, or private autos. The mobile femtocell also boosts the network's overall spectral efficiency. It aids in the network's decrease of signaling overhead.

Visible light communication (VLC) uses avalanche or PIN photodiodes or white light LEDs as the signal receivers and transmitting white light LEDs as the signal transmitters. Infrared LEDs can also be used if illumination is not needed. In VLC, the strength (intensity) of the light carries the information. A single LED has recorded a data throughput of 3.5 Gbps.

Future challenges facing 5G wireless communication networks

i. Optimizing performance matrices.
ii. Interference management for CR network.
iii. models for realistic channels in 5G wireless systems.

1.4 WAVEFORM CONTENDERS FOR 5G COMMUNICATION

Due to its poor spectrum efficiency and synchronization issues, OFDM is unsuitable for 5G. Therefore, we must look for new waveform candidates for 5G communication. Generalized Universal Filtered Multicarrier, Biorthogonal Frequency Division Multiplexing, Frequency

Division Multiplexing and Filter Band Multicarrier are some of the intriguing waveform candidates (BFDM).

GFDM: generalized frequency division multiplexing (GFDM), multicarrier communication technology, a non-orthogonal that is made to meet updated specifications for cellular communications technologies such as machine-to-machine communication systems that place a focus on asynchronous low duty cycle transmission, non-continuous bandwidth research, as well as effective spectrum utilise Multiple symbols can be sent per sub-carrier in GFDM, However, OFDM forbids this. The circular pulse shaping of the individual sub-carriers allows GFDM to utilise block-based transmission.

Different length pulse shaping filters are employed to reduce out-of-band radiation, to lower ISI and ICI, cyclic prefix is used. For applications that require quick bursts, GFDM is a sensible choice. When the number of symbols per subcarrier is set to 1, which is an expansion of OFDM, GFDM and OFDM are compatible. When used in cognitive radio applications, GFDM can match the BER performance of OFDM while reducing out-of-band emission by confining interference to the pulse-shaped subcarriers of the legacy system.

In contrast to filter bank multicarrier (FBMC), orthogonal frequency division multiplexing (OFDM) only filters the signal once. A middle ground between these two approaches is UFMC. Instead of using a single subcarrier or the entire band, UFMC applies filtering on subsets of the entire band. In this way, we can benefit from FBMC's improved subcarrier separation and OFDM's reduced complexity. UFMC performs better than FBMC and OFDM in some communication-related areas, but not all of them.

FBMC: Filter Bank A bank of filters is used in a multicarrier system on both the transmitter and reception sides. These filters are a modified, phase- and frequency-shifted version of a filter prototype. The FBMC system's prototype filter serves as its foundation, separating two symbols with the least amount of out-of-band radiation possible. A prototype filter is made to catch low out-of-band radiation between subcarriers. By using a sophisticated prototype filter design, Subcarriers can be more accurately targeted in time and frequency by removing the CP in filter bank multicarrier (FBMC). It is now a top contender for 5G communication because of this.

BFDM: By utilising the bi-orthogonality technique, Bi-orthogonal frequency division multiplexing (BFDM) allows for the accurate recovery of symbols. An inferior version of orthogonality is called bi-orthogonality, where the receive and transmit pulses are no longer parallel. Long symbol pulse transmission is a good fit for this strategy. Its drawback is that the bi-orthogonal pulses can't be calculated without periodic setup, spectrum regrowth is possible.

1.5 PROBLEM STATEMENT

In OFDM systems, the instantaneous to average power ratio, or PAPR, gauges the signal's strength.

$$\text{PAPR(p)}= \frac{peak\ power\ x(p)}{average\ power\ x(p)} \tag{1.1}$$

In the pre-processing stage of OFDM, PAPR takes place, the process of signal amplification. High-power amplifiers must be used because of high PAPR, It makes the system more complex. Various methods of lowering PAPR exist, including companding and clipping, which worsen bit error rate and cause self-interference.

1.6 OBJECTIVE

The selection of a waveform filter for utilise with 5G networks is the aim of this thesis. High spectrum efficiency and little out-of-band radiation are goals, is one of the major objectives of 5G communications. Thus, we must select a waveform that meets the two requirements. Because OFDM employs a cyclic prefix that lowers the system's spectral efficiency, it is a poor candidate for 5G communications. Another difficulty with OFDM is its high out-of-band radiation. Multi-carrier systems have always had a problem with high PAPR, which lowers the system's power amplifier's effectiveness. The effectiveness of the power amplifier is directly influenced by the PAPR. Therefore, lowering the PAPR of the signal will increase the power amplifier's efficiency while lowering the system cost and power consumption. This message's primary goal can be summed up as follows:

i. the investigation and evaluation of various PAPR reduction methods that can be used in 5G communications.

ii. To enhance the PAPR performance of the system we'll be using in this study; we'll modify current PAPR reduction strategies.

2. LITERACTURE REVIEW

Because of the use of multi-carrier transmission, UFMC has a high PAPR [37]. The literature contains several methods for reducing PAPR. These methods fall under the categories of probabilistic methods, encoding, or signal distortion. The PAPR is decreased in the first technique by limiting the maximum level of the signal through clipping or filtering. As a result, the transmitted signal is distorted, which negatively affects the system's bit error rate (BER) performance. [21]. Low data rate efficiency is another effect of the encoding systems [27], [28]. On the other hand, probabilistic techniques like partial transmit sequence and the selected mapping (SLM) [29],[31] (PTS) [28],[32], apply random phase shifts to the transmitted signals as a pre-coding step, taking care to avoid creating any noticeable distortions. However, because the receiver received side information in order to obtain the original symbol vector, However, this is at the expense of spectrum efficiency (SE). In this regard, the literature has offered several recommendations to improve the SE by taking use of opportunities to get side information from the receiver side [33].

In order to solve the problem of PAPR in the presence of UFMC system, numerous studies have been published. In [34], The divided data sub-blocks are multiplied by phase factors as part of the PTS approach and then applied to the UFMC waveform. Due to the intensive use of inverse fast Fourier transform (IFFT) operations, this approach has a greater computational complexity. In [35], For UFMC systems, a low-complexity PTS technique is devised. In [21], two substitute PAPR lowering methods in order to compare the PAPR and BER performances, a hybrid strategy has been created using pre-coding and non-linear companding techniques. Additionally, a method known as a piecewise non-linear companding transform has been suggested to lower PAPR in the UFMC system in [36], where decreasing PAPR and other system performance measures like BER and OOB radiation are successfully traded off using the provided balancing strategy. The OFDM system as shown as below figure in the (Figure 2.1).

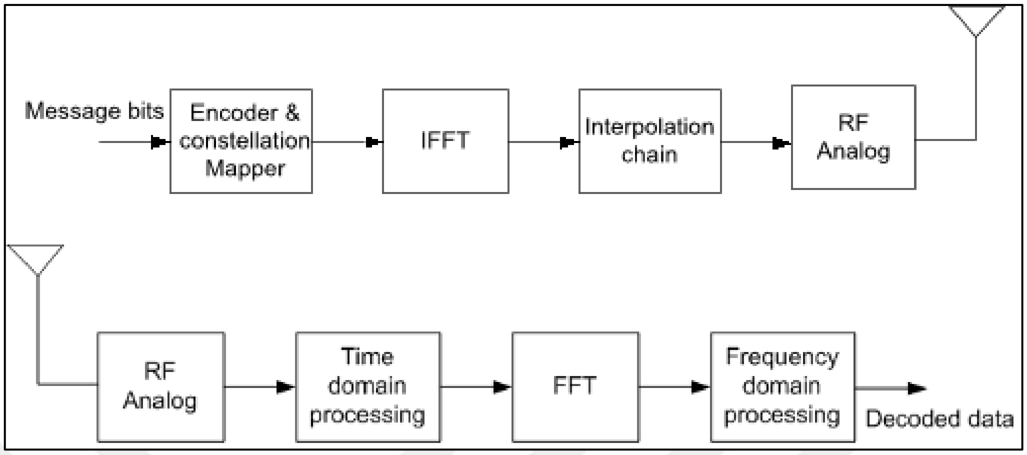

Figure 2.1: OFDM system.

The available bandwidth is divided into several sub-carriers by OFDM, which are then broadcast simultaneously in order to extend symbols, achieve high data speeds, and decrease ISI. The total of all subcarrier signals that are modulated at subchannels with the same bandwidth is an OFDM signal [1].

High BER and PAPR values are the main drawbacks of OFDM. DAC and HPA are two devices used in the OFDM transmitter side that are very sensitive to the signal processing loop, which has an impact on the system's performance. Because OFDM has a lot of side lobes that could pick up competing signals, its spectrum utilization is subpar. As a result, the receiver's noise level increases. MIMO technology is supported by both FBMC and OFDM, but OFDM has some limitations [16]. To prevent Inter Symbol Interference (ISI) in OFDM and split the channel into several sub-carrier channels, a "Cyclic Prefix" is required. However, Cyclic Prefix is not employed in FBMC, despite the fact that it has the potential to split a channel into a number of sub-carrier channels and reduce ISI. MIMO systems are supported by both FBMC and OFDM. To overcome some of the issues with OFDM is the main objective of FBMC. To minimize interference, OFDM is primarily used in MIMO systems. FBMC is an improvement to OFDM. Therefore, FBMC is the same as OFDM's derivative [22]. Both have a big impact on the world of wireless communication modulation methods. We were successful in achieving our goals without using OFDM by using filter banks. The Massive MIMO FBMC idea will be made simpler and more efficient by reducing the number of sub-carriers. Analysis and synthesis can both be done in a Massive MIMO FBMC system, on the receiver and transceiver sides, respectively [5] Due to inadequate sub-carrier spectral localisation in OFDM, it’s possible for spectral leakages and interference issues to arise with unsynchronized signals [48].

HUAWEI's suggestions for increasing spectrum efficiency have provided answers to up the spectrum's effectiveness Coordination of refarming with Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD). Refarming entails the elimination of current radio spectrum allocation bands and the more advantageous repurposing of the spectrum into narrower bands.

Operators may significantly and affordably boost spectrum efficiency and network coverage using refarming solutions [33].

The use of fragments is maximised via TDD/FDD coordination through optimization and a global network simulation Centre [16]. The different types of waveforms and filter operations of OFDM, FBMC and UFMC as shown as in (Figure 2.2).

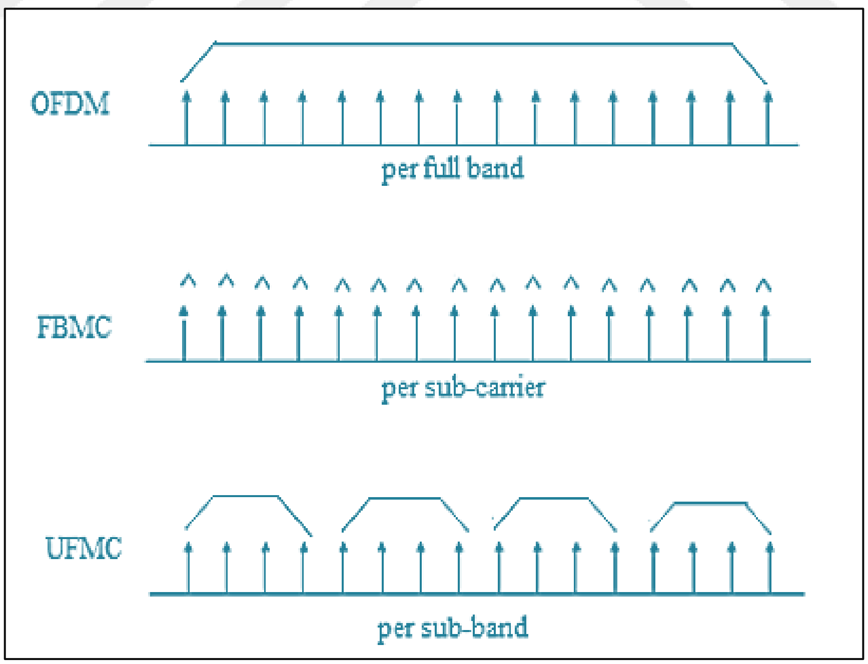

Figure 2.2: OFDM, FBMC and UFMC different types of waveforms and filter operations.

3. METHODOLOGY

3.1 UNIVERSAL FILTERED MULTI CARRIER

Through the utilise of UFMC modulation, High data rate signals are transformed into parallel streams of lesser data rates using this type of multi-carrier technology. Contrary to OFDM, which divides the entire Nsc sub-carrier band into B sub-bands that each contain a Nb sub-carrier, the UFMC system operates in the opposite manner, with b = 1, 2, ... B. Then, sub-band finite impulse response (FIR) filters and N-point IFFT are employed, respectively, to process the data in each sub-band. The time domain UFMC signal is created by combining the filtered signals from each sub-band.

the UFMC, a multi-carrier modulation technology that combines FBMC and Filtered OFDM. In filtered OFDM, the entire band is typically filtered, whereas in FBMC, just specific subcarriers are filtered. However, UFMC filters a set of sub carriers [6]. The primary distinction between Filtered UFMC multi-carrier, FBMC and OFDM is this. The length of the filter in UFMC can be decreased by grouping the sub carriers. In the UFMC, QAM is utilised, which is compatible with the current MIMO, here, the band of "N" sub carriers as a whole gives rise to a number of sub bands. Each sub band has a specific number of sub carriers. Not all of the sub frequencies must be broadcast by the transmitter component. Inverse rapid Fourier transform is used to remove the sub band carrier interference (IFFT). At each N-point IFFT, unallocated carriers receive zeros and subbands are calculated. Conversion of the frequency domain (Xi) to the time domain using the IFFT (xi). This is how the N-point IFFT's output can be expressed:

$$Yi=IFFT\ (xi) \tag{3.1}$$

Current transmission of IFFT time domain signals uses a band filter with a length "L" block. Each output from a subband is filtered by the band filter, which has length "L". It is written as

$$Y=H.\sim Q.Yi) \tag{3.2}$$

Where:

H: Toeplitz matrix having dimensions (N+L-1).

~Q: Inverse Fourier matrix.

Actually, Chebyshev window/filtering is used by band filters. The IFFT outputs are filtered in this case using parameterized side lobes attenuation. The channel now receives the whole output of all band filters.

The UFMC receiver receives the data bits via the channel. Fast Fourier Transform of 2N-points for UFMC receiver (FFT). Frequency-domain data are created by the FFT from time-domain data. It appears as an equation on screen.

$$\sim Y = FFT \{ [yT, 0, 0, \ldots\ldots\ldots, 0] \}) \tag{3.3}$$

Inter Symbol Interference (ISI), an issue, is removed by putting zero guard intervals between each IFFT symbol after it. What causes ISI is the delay in the transmitter filter. Even sub carriers are neglected in order to receive the N-length frequency domain signal "Y". After data equalization, symbol demapping is used to get the original data bits. The universal filtered multi carrier system model shown in (Figure 3.1).

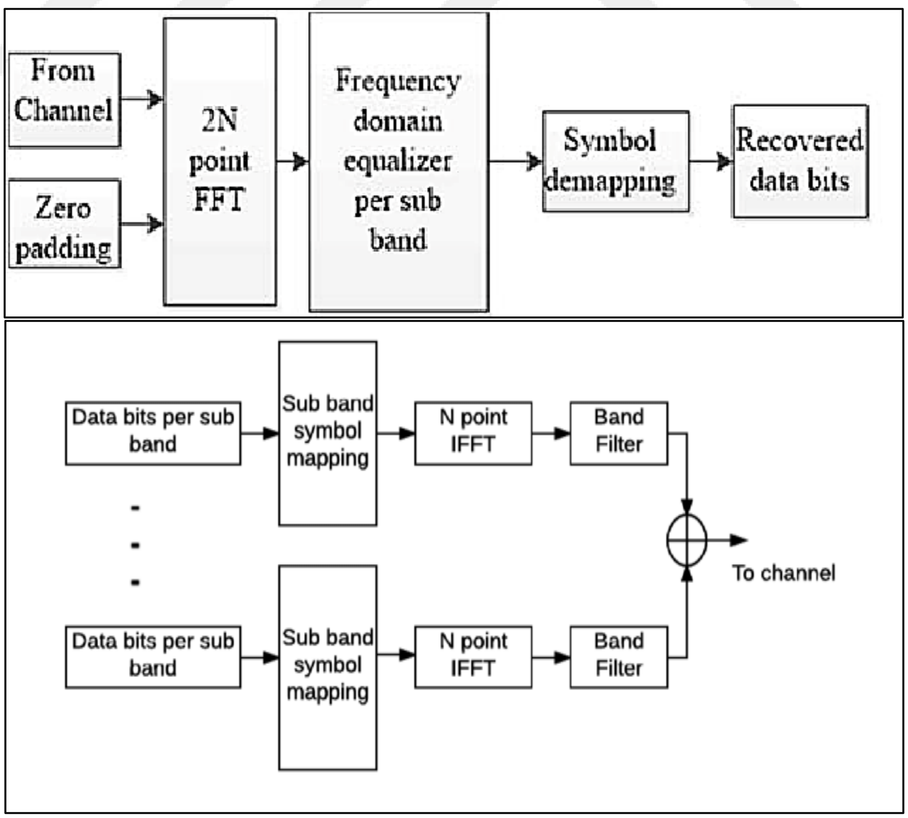

Figure 3.1: Universal filtered multi carrier system model.

3.2 UFMC TRANSMITTER

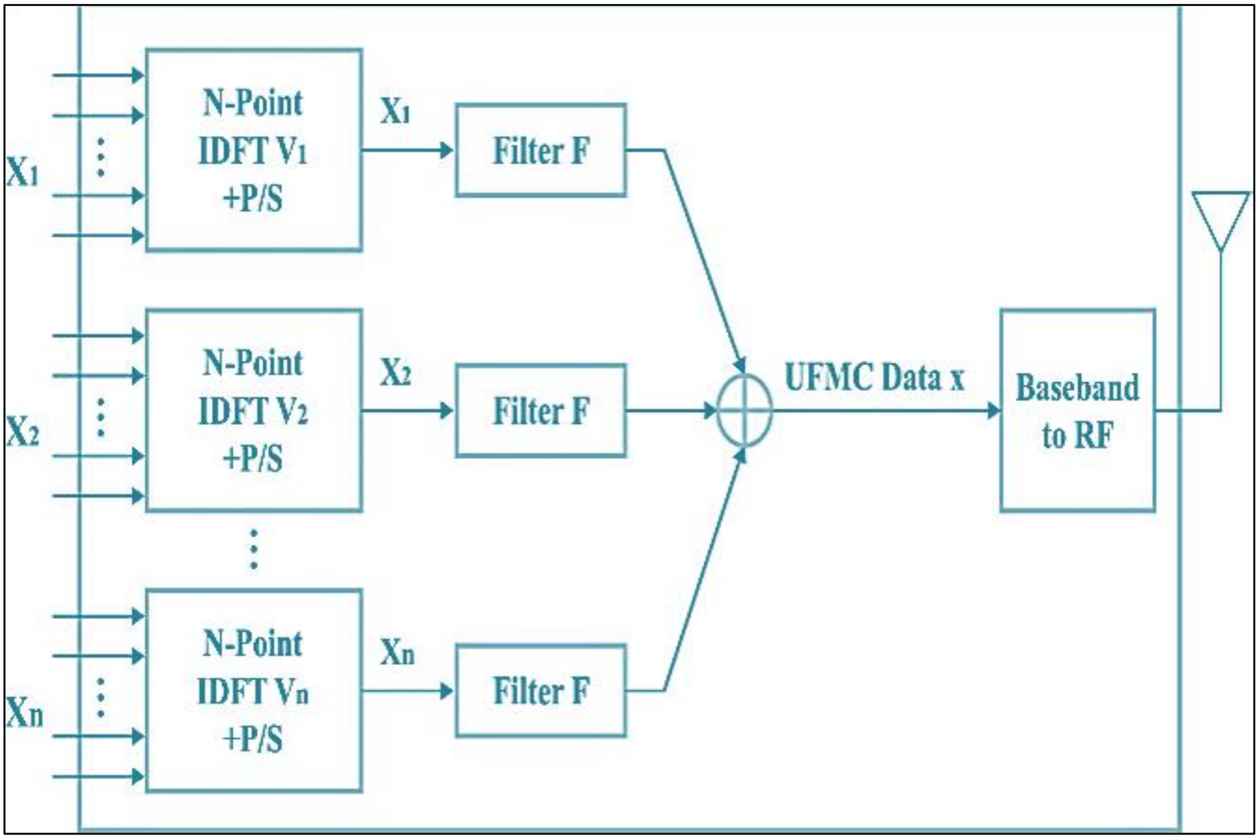

Figure 3.2: UFMC transmitter.

Figure 3.2 shows the UFMC transmitter, and it works as follows:

The data bits are transformed into symbols for M-array quadrature amplitude modulation (M-QAM) (M= 16, for example).

The entries of vector S are then formed by grouping Nsc symbols where:

S=$[S(0), S(1), S(2) \ldots \ldots . . S(N_{sc}-1)]^T$

To create B parallel new sub-sequences, the symbols of S are split into B sub-sequences, each with length Nb = Nsc/B

S_b(b=1,2…B)

$$S_b=\begin{bmatrix} 0 & : & 0 \leq k \leq N' + (b-1)(\text{Nsc/B}) - 1: \\ S(K) & : & N' + (b-1)\left(\frac{\text{Nsc}}{\text{B}}\right) \leq k \leq N' + b\ \left(\frac{\text{Nsc}}{\text{B}}\right) - 1 \\ 0 & : & N' + b\ \left(\frac{\text{Nsc}}{\text{B}}\right) \leq k \leq N - 1 \end{bmatrix} \quad (3.4)$$

Where:

N'=(N- Nsc)/2

$S_b(n) = \frac{1}{N}\sum_{K=0}^{N-1} S_b(K)\, e^{\frac{j2\pi nk}{N}}$ where: 0≤ $N \leq N - 0\ and\ \ 1 \leq b \leq B$

Each sub-N-point band's IFFT output is filtered with digital filter of length L_f to form a UFMC signal of length (N+L_f-1):

$$X(k)= \sum_{b=1}^{B}\sum_{l=0}^{L_f-1} f_b(l)\, S_b(K-1) \qquad \text{k=0,1, N+}L_f\text{-1} \quad \text{/ l=0,1, } L_f - 1\text{)} \quad (3.5)$$

Where:

$f_b(l)$: FIR filter coefficients

sub-band signals between N to N+ L_f+L_{cp}-1

L_{cp}: cyclic prefix length

$$\text{PAPR (db)=10}\log 10\,\frac{0<n<N+L_{cp}+L_f\ |\ s(n)|^2}{E(|\ s(n)|^2)}) \quad (3.6)$$

3.3 UFMC RECEIVER

In the figure below (Figure 3.3) shows the receiver model system of universal filter multi carrier.

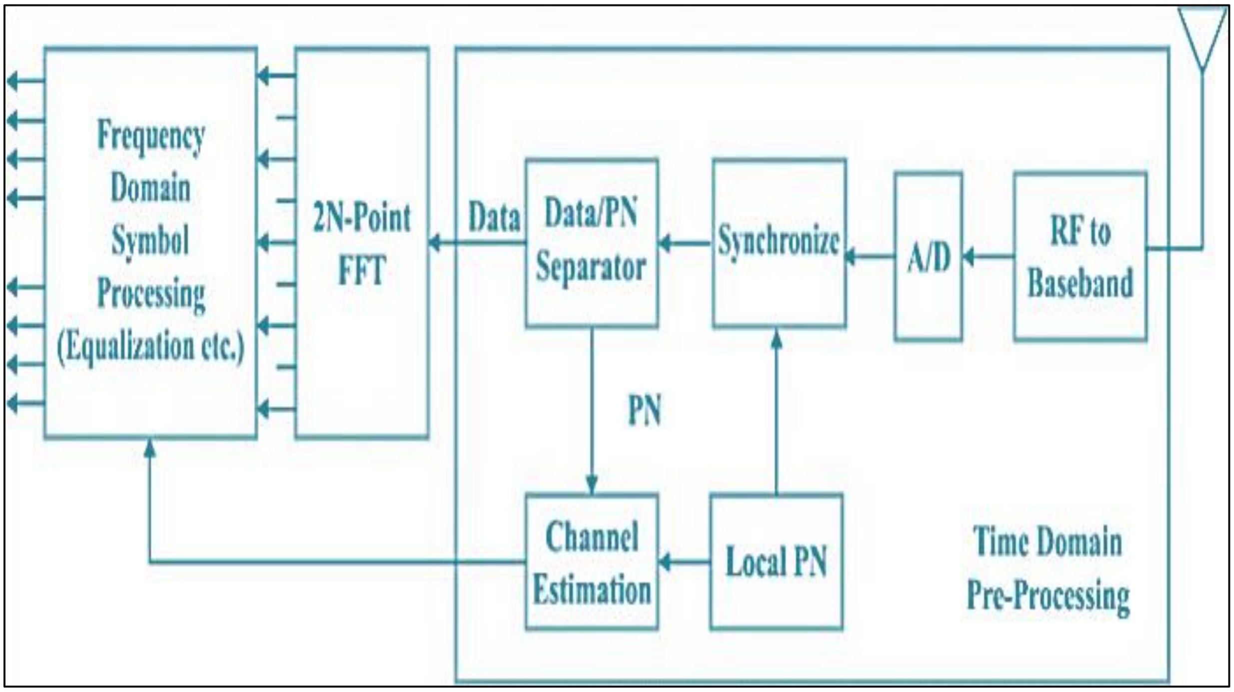

Figure 3.3: UFMC receiver model system.

Following CP removal and zero forcing channel equalization, the signal Y at the receiver side will be delivered as:

$$Y = \bar{D}^{H} H^{-1} H x + \bar{D}^{H} n) \tag{3.7}$$

Where:

The corresponding channel convolution matrix is H.

N: AWGN with variance and zero mean σ^2 at the receiver

$\bar{D}$: demodulation matrix

the output signal y is zero padded with N - L_f + 1 zeros to avoid ISI. The received sequence is then extracted using a 2N-point FFT, only using the even index samples out of a total of 2N complex samples, while the odd indices are discarded Finally, frequency domain equalization is applied to the output to identify any transmitted symbols $\hat{s}$and to recover the estimated bit sequence, The equalised signal's output signal is demodulated by the symbol de-mapping.

3.4 PEAK TO AVERAGE POWER RATIO

High peak to average power ratio (PAPR) is a significant problem in the UFMC system since it lowers the circuit's power amplifier's efficiency. Any MCM system has a PAPR problem since the output symbol is an accumulation of symbols modulated on different subcarriers, there is a probability that every symbol will have the same phase, which results in a very high peak relative to the symbol's average value. An FBMC system is measured by its PAPR [7].

Typically, the PAPR of a complicated envelope d[n] of length N can be expressed as follows:

$$\text{PAPR}=\{\frac{\max|d(n)|^2}{E(|\,d(n)|^2)}\} \tag{3.8}$$

where is the d[n] signal's amplitude and E stands for the signal's expectation. PAPR in dB can be written as: d[n]

$$\text{PAPR (dB)} = 10\log10\ (\text{PAPR}) \tag{3.9}$$

3.4.1 Effect of High PAPR

A linear power amplifier is used on the transmitter side of every communication system. The linear zone of operation for linear power amplifiers should be the operational point. The operating point advances to the saturation zone due to the high PAPR; as a result, the signal peaks clip, both in-band and out-of-band distortion is the outcome. In order to keep the operating point within the linear zone, we must consequently increase the power amplifier's dynamic range because doing otherwise reduces efficiency and drives up costs. Therefore, nonlinearity and efficiency are trade-offs. In order to increase the power amplifier's efficiency, we should decrease PAPR value.

3.4.2 PAPR Reduction Techniques

There are numerous methods available for lowering PAPR. The following examples of crucial PAPR lowering techniques:

a. Filtering and Clipping.

b. Clipping results in signal distortion, which lowers the performance of the bit error rate.

c. Clipping also involves out-of-band radiation, which is the cause of channel interference. It is possible to lessen this out-of-band radiation using filtering.

d. The peak grows again when the clipped signal is filtered. That indicates that, as a result of the clipping process, after filtering, the signal level could be higher than the clipping level.

Thus, we learned that distortion happens when data is sent using the clipping and filtering techniques:

a. Coding:

Some code words are employed in the coding strategy to reduce or minimize the signal's PAPR. It does not create distortion or out-of-band radiation, but as the data rate is decreased, the bandwidth efficiency decreases. Additionally, it has problems with complexity, because it needs a lot of memory to keep the enormous lookup tables and determine the optimum codes, especially for a lot of subcarriers.

b. Partial Transmit Sequence:

The Partial Transmit Sequence method is called PTS [11], Each sub-block of an N-symbol input data block is independent. A phase factor is used to weigh the sub-carriers in each sub-block for that sub-block. Carefully adjusting the phase parameters reduces the combined signal's PAPR. Utilizing this strategy, however, causes data rate loss.

c. Selected Mapping (SLM):

The SLM approach creates many FBMC signals from the input data block, selecting the one with the lowest PAPR for transmission. This method's two drawbacks are complexity and data rate loss.

d. **Active Constellation Extension (ACE):**

The ACE method and the Tone Injection approach are comparable. The data block's PAPR decreases as a result of this method's dynamic extension of several of the sites in the outer signal constellation away from the starting constellation [12]. Additionally, the transmitted signal's power is increased using this technique.

e. Companding:

The purpose of the companding approach is to strengthen the small signals' resilience to noise by making the little signals larger and compressing the big signals [13]. This compression is done at the transmitter end after the output of the IFFT block has been extracted. There are two types of companders: μ-law and A-law companders. When a signal is compressed, high peaks in the signal are diminished, which causes a PAPR reduction of the input signal. This approach to lowering PAPR is simple and low complexity.

3.5 MIMO TECHNOLOGY

Compared to single-input and single-output wireless technologies, MIMO is an excellent wireless technology that can deliver excellent performance. MIMO refers to the installation of numerous transmitting antennas on the receiver side and a large number of receiving antennas on the transmitter side. Multiple input, multiple output is referred to as MIMO in short. Massive usually refers to an extremely big size. Massive MIMO is the term for building enormous antenna arrays at each base station to provide service to a large number of clients at once, as depicted in the figure below (Figure 3.4).

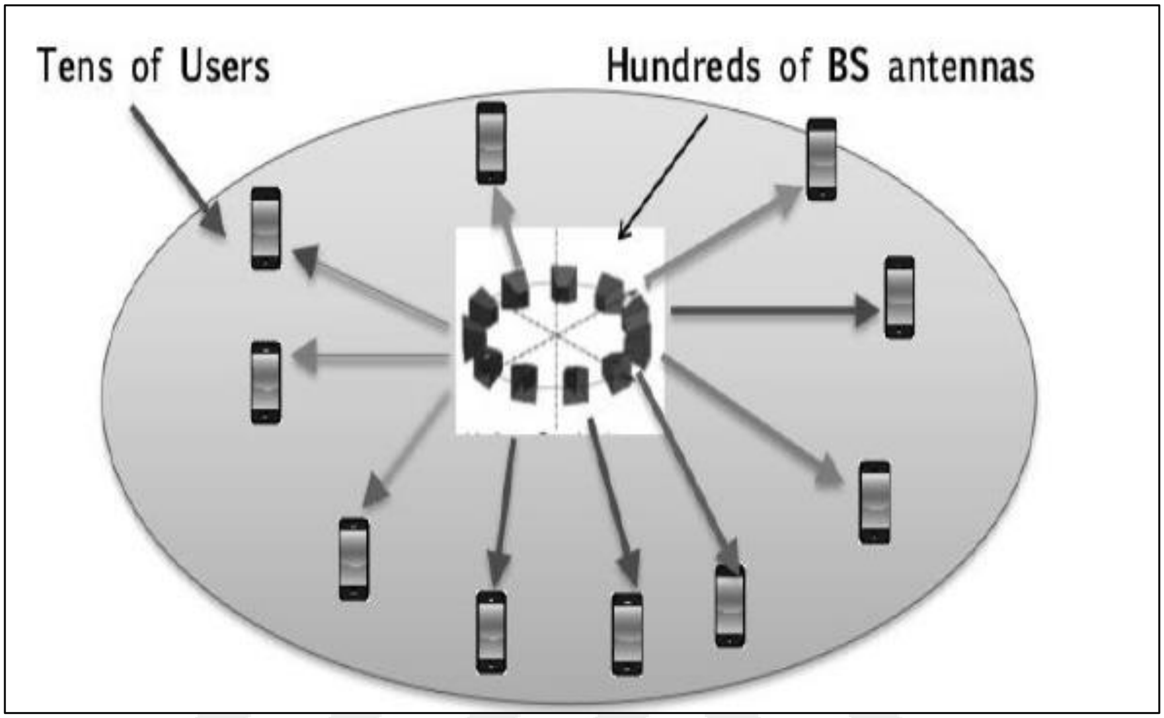

Figure 3.4: A large number of clients in Massive MIMO.

Massive MIMO is a key component of the 5G mobile communication technology. The biggest issues with 4G continue to be high energy usage and the spectrum dilemma (the fourth-generation mobile communication). All telecoms' companies have started working on 5G research since there is a big need for increased data rates. The technology behind MIMO systems primarily focuses on increased spectral efficiency and large coverage area for all cell edge users. Fading and multiple path delays in a communication system are causing issues, which lead to errors and have an impact on the system's performance. To address the aforementioned communication system problems, It is possible to use methods like Orthogonal Frequency Division Multiplexing (OFDM) and Filter Bank Multi Carrier (FBMC). Figure (3.4) depicts the UFMC MIMO model, which comprises of UFMC modulators, UFMC demodulators, MIMO encoders, and MIMO decoders.

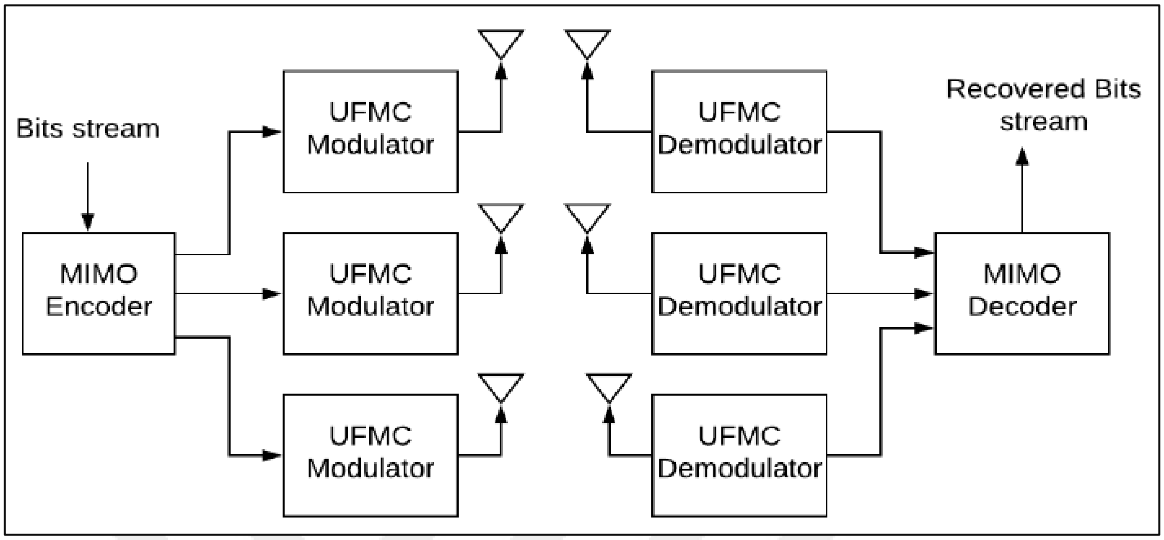

Figure 3.5: Massive MIMO system.

Typically, ultra-linear 50watt amplifiers are used in Massive MIMO systems. In any event, professionals are increasingly using low-effort speakers with milliwatt yield adjustments. The multi-carrier strategy was created twenty years ago by the two authors and academics who were discussing Chang and Saltzberg at the time. Multi-carrier systems like OFDM, FBMC generate excursions in the non-linear component of the signal when utilising power amplifiers, which causes distortions. The transmitter side prediction algorithm technique is used to compensate for the spectrum leakage, which cannot be adjusted or repaired. The FBMC technology is used in both the 4G/5G and the aeronautical communication systems. In this case, air-to-ground communication was carried out using L-band. They presented a cutting-edge concept known spectrally shaped Filter Bank Multi Carrier to deliver results with no mistake flow (SS-FBMC). Organization for Civil Aviation Around the World (ICAO) is making advancements or upgrades to the SS-FBMC-based aeronautical communication system.

3.6 WHALE OPTIMIZATION ALGORITHM (WOA)

Whales are graceful creatures. They are thought to be the biggest mammals in the world. A mature whale can grow up to 30 metres long and 180 tones in weight. This huge mammal has seven primary species, including the killer, e, Sei, Minkm blue, humpback, finback and right. Most people think of whales as predators. Since they must breathe ocean surface air, they are unable to sleep. Actually, the other half of the brain is asleep. The fascinating thing about whales is that they are thought to be very intelligent, feeling animals. In specific regions of their brains, whales have a type of cell known as a spindle cell that is comparable to human common cells. Human judgement, emotions, and social behaviours are controlled by these cells. In other words, we are different from other organisms because of our spindle cells. The key factor contributing to whales' intelligence is the fact that they have twice as many of these cells as an adult human. It has been established that whales are capable of thinking, learning, judging, communicating, and even feeling emotions, but obviously to a far lesser extent than humans. It has been noted that whales, primarily killer whales, can create their own vernacular. The social interactions amongst whales are another fascinating topic. They either live alone or with others. They are generally seen in groups, though. Some of them, like killer whales, may sustain a family unit for the whole of their lives. The humpback whale is one of the largest baleen whales (Megaptera novaeangliae). A humpback whale in its adult form is almost as large as a school bus. Krill and tiny fish herds are their preferred food sources. This mammal is seen in the figure below (Figure 3.6).

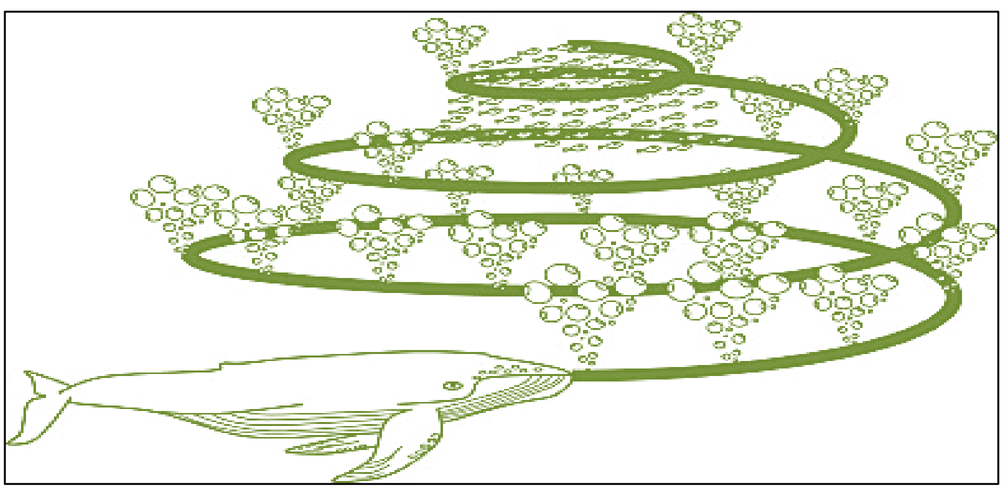

Figure 3.6: Whale Optimization Algorithm

Two maneuvers associated with bubble net feeding are and ‘double-loops’ and ‘upward-spirals’

a. In the "upward-spirals" movement, humpback whales descend to a depth of about 12 meters, begin to bubble around their prey in the shape of a spiral, and then swim up toward the surface.
b. The "double-loops" movement consists of three stages: the lobtail the coral loop and the catch loop.

The unique way that humpback whales hunt is what I find most fascinating about them. The bubble-net feeding method is the name of this foraging technique. Hunting krill or small fish in schools near the surface is preferred by humpback whales. This foraging has been seen to involve the formation of unique bubbles along a circular or '9'-shaped path, as depicted in figure 3.6, prior to 2011, this tendency was only investigated based on surface observations. Nevertheless, tag sensors were used to explore this behavior. Using bubble nets and tags, they documented 300 feeding activities of nine different humpback whales. They discovered two moves connected to bubble and gave them the names "upward-spirals", "double-loops". In the first technique, humpback whales dive to a depth of around 12 meters, begin to bubble around their prey in the shape of a spiral, swim up toward the surface. Three distinct phases make up the latter manoeuvre: the coral loop, lobtail, and capture loop.

It's vital to remember that the only species known to utilise bubble-net feeding is humpback whales.

3.6.1 Mathematical Model Of WOA:

a. Only humpback whales have been documented to engage in bubble-net feeding, which is a distinctive behavior. In order to accomplish optimization, the spiral bubble-net feeding movement is described analytically by the whale optimization algorithm (WOA).
b. WOA mimicked hunting behavior by pursuing the prey with either the best search agent or a random search agent.

To mimic humpback whales' bubble-net assault technique, WOA employs a spiral.

The whale constructs a bubble net along the spiral path after locating its target and then travels upstream to the prey. This is the basic idea behind whale bubble-net foraging. There are three phases to this predation behaviour: encircling the prey, bubble-net attack, and hunting the victim.

There stages are

a. Surrounding prey stage

In the WOA algorithm, the whale initially spots the prey's location before surrounding it, however in reality, the whale cannot anticipate the prey's location. Therefore, if the target prey is at the current ideal position, the other members of the group all move to that location. The following mathematical model can be used to represent the enclosing stage:

$$X(t+1) = X^{*}(t) - A.\ D) \tag{3.10}$$

Where t: the current number of iterations

$$D= |C.\ X^{*}(t)\ X(t) X^{*}(t)\text{: the prey position vector} \tag{3.11}$$

$X(t)$: prey position vector

A, D: surrounding step size

$A = 2a\ rand\ a\ \ , C = 2\ rand$

is a control parameter that, as the number of iterations increases, drops linearly from 2 to 0

Where:

$$a = 2 - \frac{2t}{T_{max}} \tag{3.12}$$

rand: is a random number between [0, 1]

b. Bubble-net attack stage

The humpback whale uses a spiral path to travel near its meal in a confined space as part of its bubble-net foraging strategy. Therefore, two methods-shrinking and encircling mechanism and spiral update position—are developed in WOA to characterise the predation behaviour of whales. by lowering the convergence factor an in equations, one can shrink and surround mechanisms.

$A = 2a\, rand\, a\ \ , C = 2\, rand$

$$a= 2-\frac{2t}{T_{max}} \quad (3.12)$$

Location update for a whale in a spiral: first calculate the distance between each whale and the ideal position. It is possible to express the mathematical model as follows:

$$X(t+1)=D'.e^{bl}.\cos(2\pi l)+ X^{*}(t) \ \ ; D'=|X^{*}(t)-X(t)| \quad (3.13)$$

c. Hunting prey stage

If |A|> I choose the whale at random to replace the existing best option; The algorithm's global exploration capabilities can be improved, the whale can be kept away from the present reference target, and a better prey must be found to take the place of the current reference whale. This is the mathematical model:

$$X(t+1)= X_{rand} - A.D \ \ ; D = |C.X_{rand} - X(t)\ | \quad (3.14)$$

Where: X_{rand}:

choosing the whale′s location vector at random

In the figure below (Figure 3.7) displays the WOA flowchart.

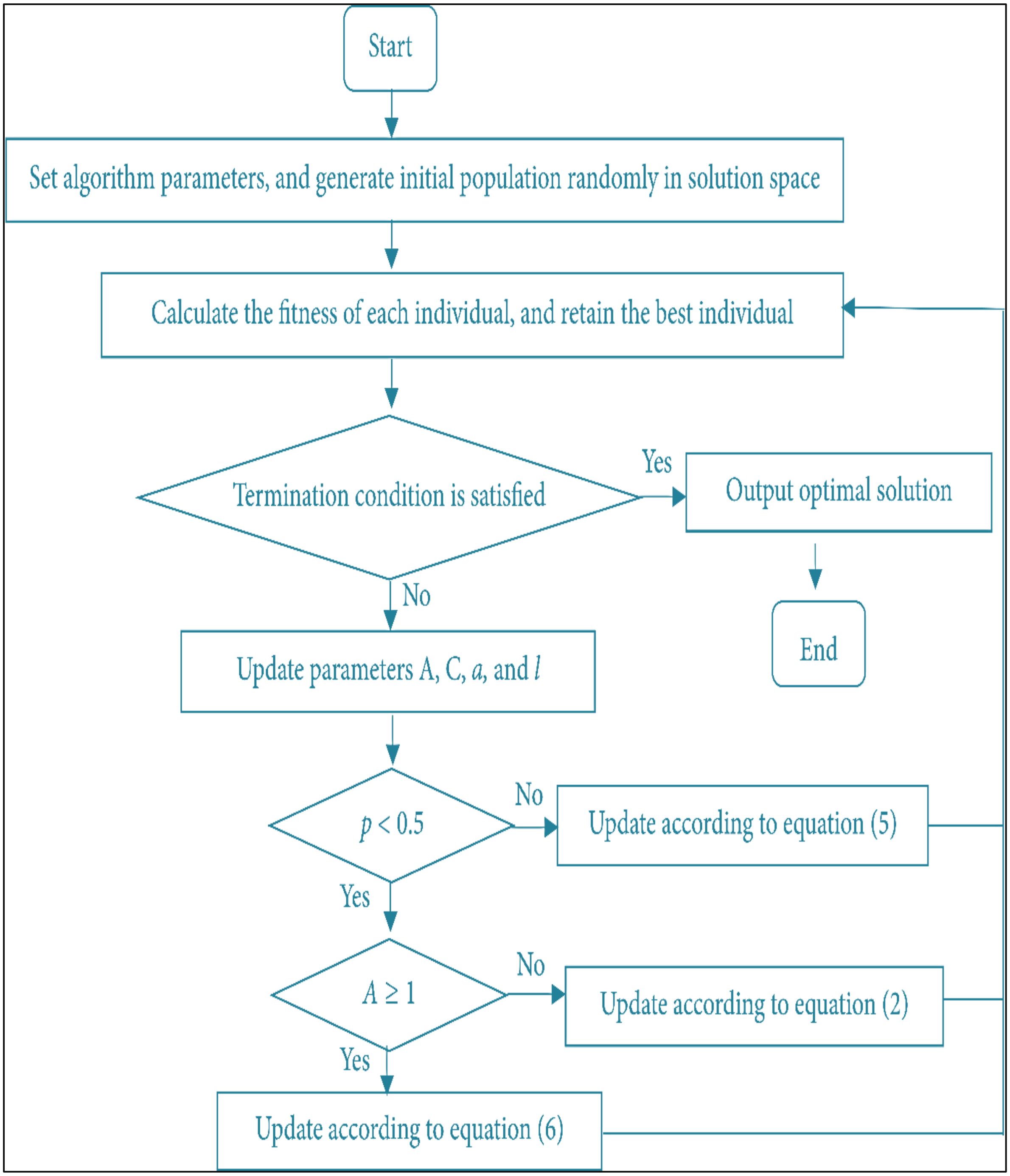

Figure 3.7: The flowchart of the WOA.

3.6.2 The code of WOA:

Step1: Initialize the whales population

Step2: Calculate fitness of each search agent

= the best search agent

Step3: while (t < maximum number of iterations)

for each search agent:

Update

if(p<0.5):

if(|A|<1):

Update current agent by eq

D=|C X_{best} (t)-X(t)|

else:

Select a random agent

update current agent by eq :

X(t+1)= $X_{rand}(t) - A.D$

else:

update search agent by eq :

X(t+1)=D.e^{bl}.cos(2πl)+ X_{best}(t)   L∈ $[-1,1]$

end-for

Check if any search agent goes beyond the search space and amend it

Calculate fitness of each search agent

Update if there is a better solution

t = t+1

end-while

Step4: return

THE UFMC SYSTEM PARAMETERS

The parameters of UFMC system shown in Table 3.1 below.

Table 3.1: WOA Parameter mat (MAT-file).

Name	Value
FFT	256
Fitness Evaluation	2140*3305*3 unit8
Fitness Function	901*1717*3 unit8
Iteration Number	500
L	2
Leader Wales	5
Number of Whales	30
PAPR Score	2074*3487*3*unit8
Whales	872*1617*3 unit8

4. EXPERIMENTAL RESULTS

4.1 THE PSD PERFORMANCE

The proposed method's power spectral density performance in relation to OOB emission has been investigated.

The Power Spectral Density (PSD) values for 200 subcarriers are shown in figure below (Figure 4.1). Each of the 10 sub-bands that make up the main band has 20 subcarriers with fewer side lobes. For wireless communication systems, power efficiency is a crucial need.

In comparison to OFDM, UFMC has a better spectrum usage rate.

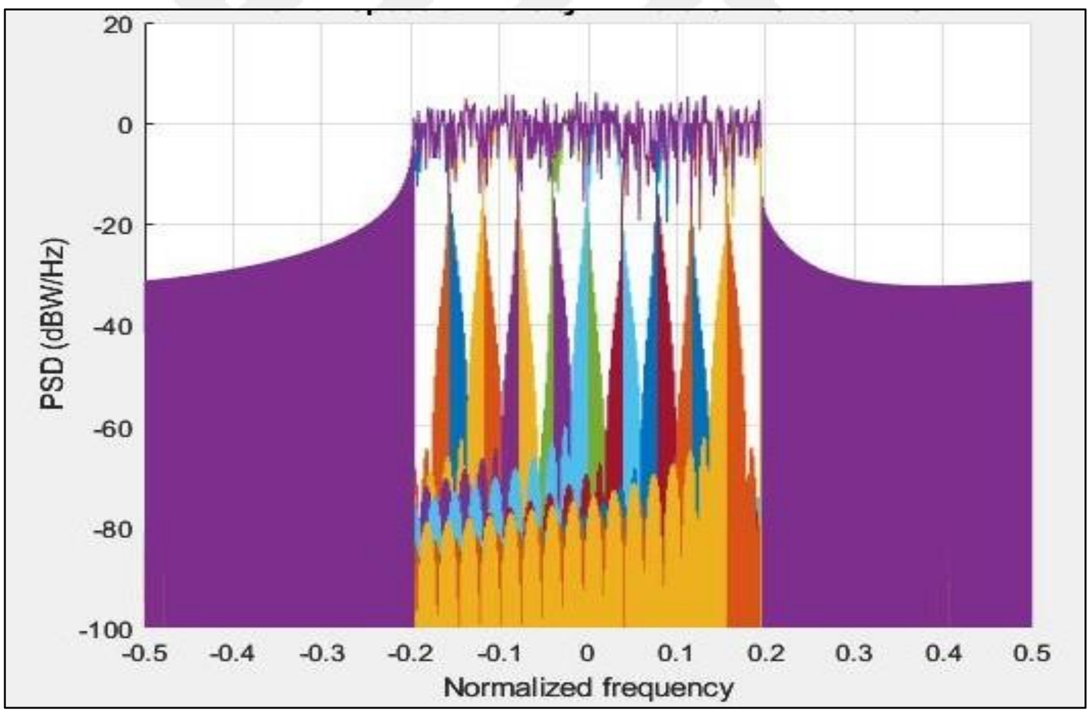

Figure 4.1: PSD of UFMC

4.2 MIN SECRECY THROUGHPUT

In the figure below (Figure 4.2), the suggested WOA-based method and the path-following technique's convergence evolution are displayed against the iteration index. As the number of iterations rises, the min secrecy throughput also rises.

As illustrated in figure 4.2, two techniques can converge extremely quickly at 0.75; the path-following procedure requires three iterations, while the WOA-based algorithm requires five. However, it should be noted that the path-following approach requires the solution of a convex problem at each iteration.

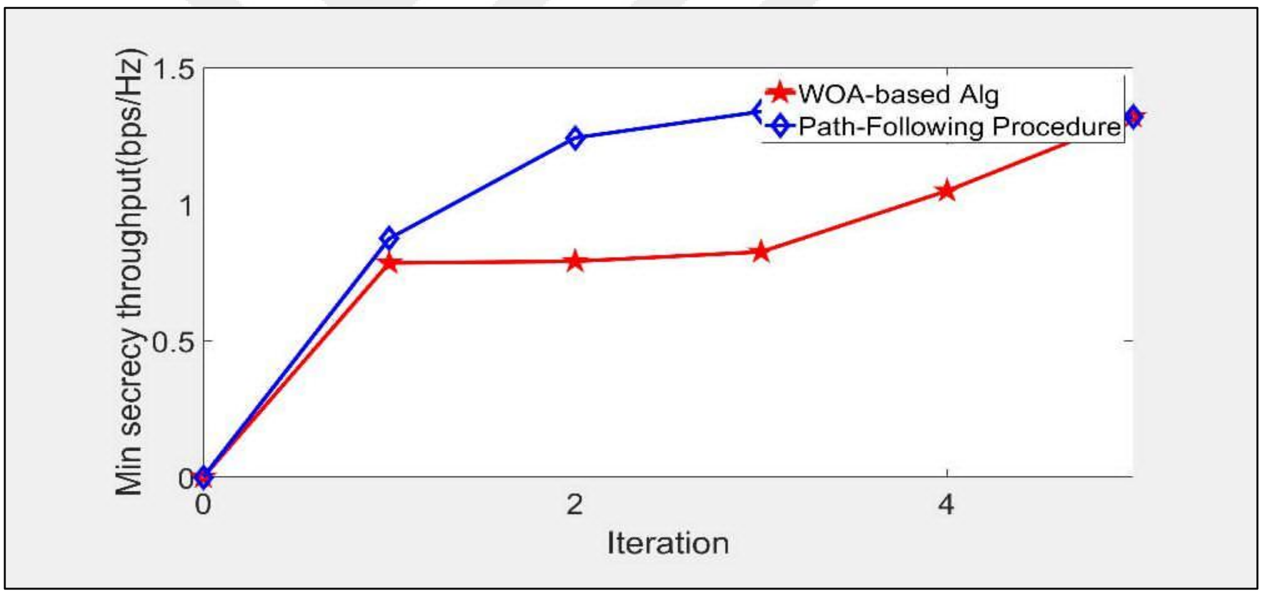

Figure 4.2: Min secrecy throughput.

4.3 BIT ERROR RATE (BER)

The graph depicts the Bit error rate (BER) values in relation to the signal-to-noise ratio is shown in the figure below (Figure 4.3). SNR and BER are also used in communication protocols as standards. The simulation is performed with a 256 point FFT SNR of 2dB. We see the signal-to-noise ratio rises, spectral efficiency rises and BER performance falls. In previous studies, the proposed design performed significantly better than the real UFMC.

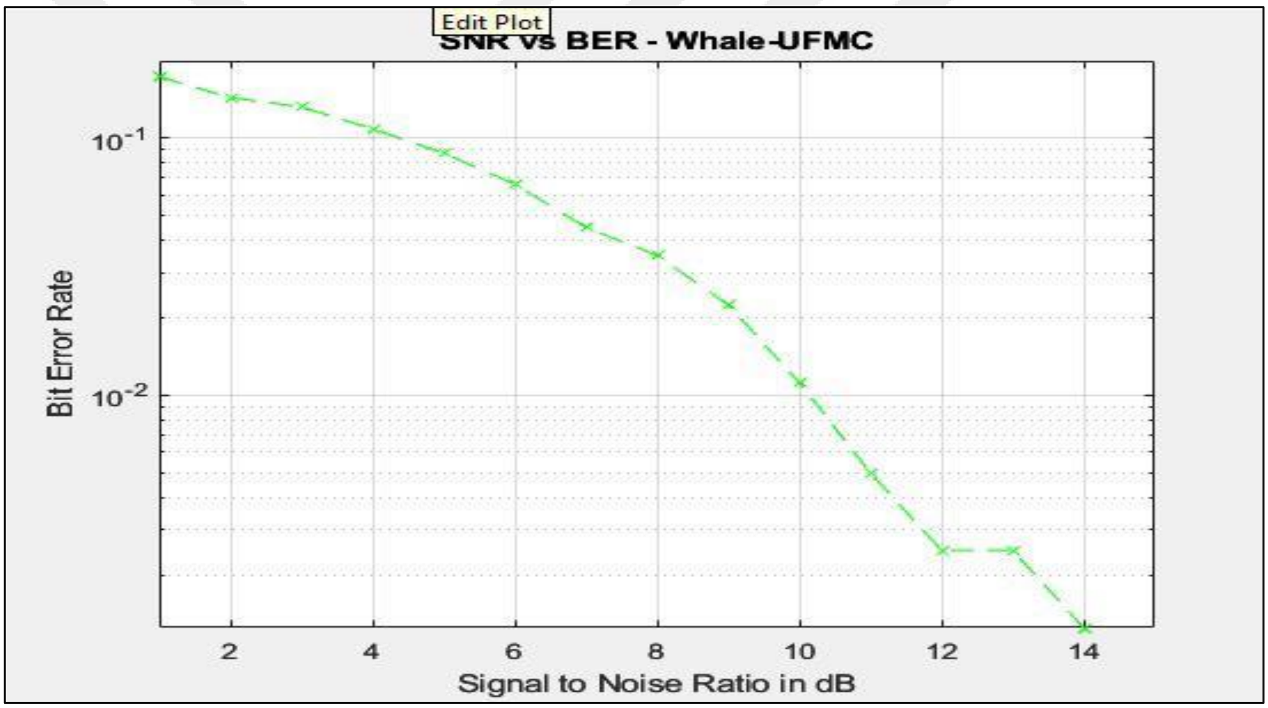

Figure 4.3: Bit Error Rate

4.4 AVERAGE FITNESS VALUES

The figure below (Figure 4.4) shows the average fitness values using the whale optimization algorithm compared with the algorithms (PSO, GOA, FA, GWO) in relation to the number of fitness assessments, which the more it increases, we notice a decrease in the average indicator of fitness values for all algorithms, but its value When compared to other algorithms, the whale optimization algorithm (WOA) maintains its superiority.

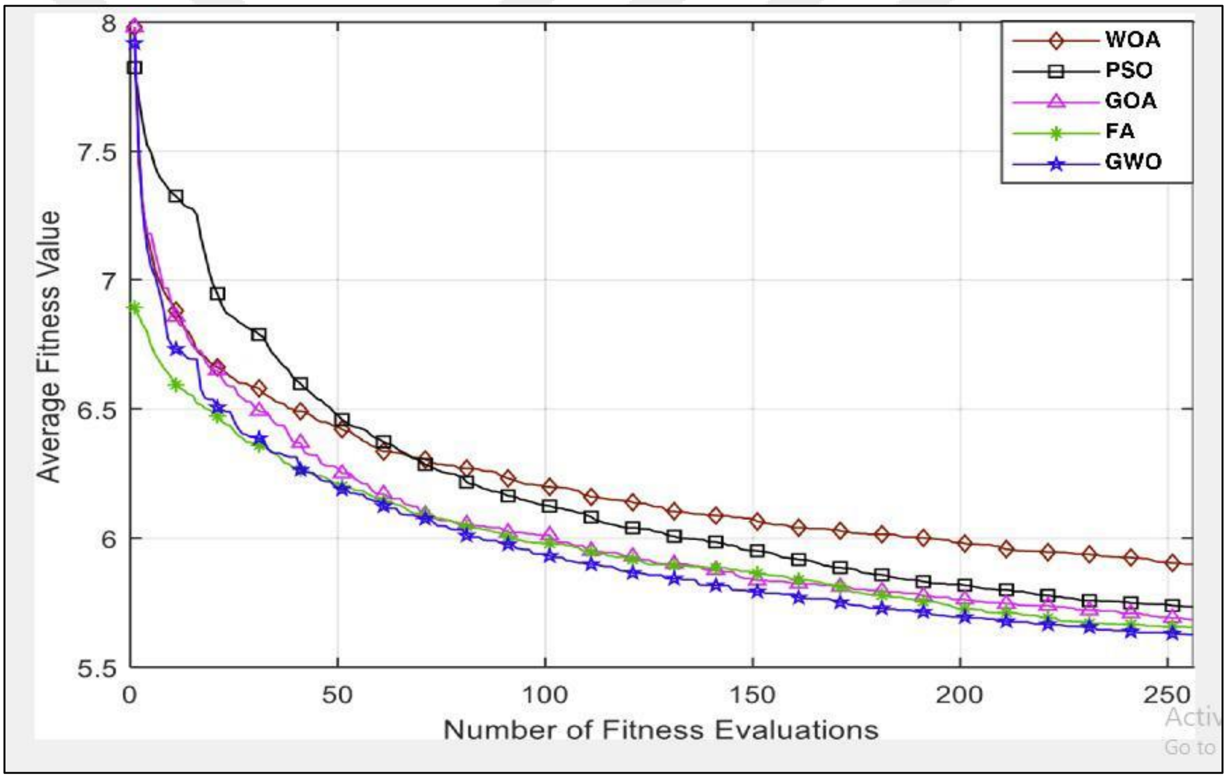

Figure 4.4: Average fitness values

4.5 PAPR ANALYSIS

The figure below (Figure 4.5) shows The PAPR analysis of OFDM, UFMC and signal scramble based UFMC systems is evaluated.

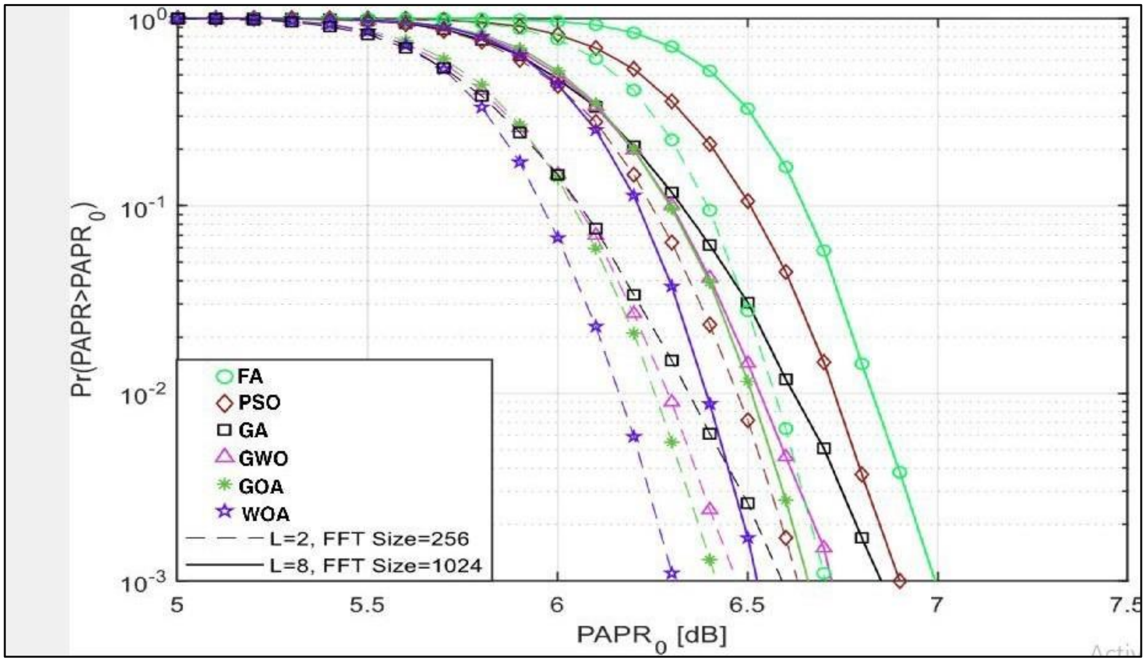

Figure 4.5: The PAPR analysis.

The cost function given to the optimizer is PAPR (p) which evaluates the PAPR value of time domain signal (x) with respect to phase factor vector (p). The ability to reduce PAPR is measured by the CCDF value (Complementary cumulative distribution function).

CCDF is described as follows:

CCDF (PAPR(X)) = prob (PAPR(x) > PAPR 0)

PAPR increases in multi carrier transmission.

1024 points and 256 points FFT with 4-QAM modulation are both simulated.

The comparison of PAPR for UFMC with different optimizers (PSO, FA, GA, GWO, GOA).

The UFMC with FA getting around 7 dB and with PSO is 6.9 dB but Two cases have been studied with WOA:

first case: L=2, FFT Size 256, CCDF -PAPR IS 6.3 dB.

second case: L=8 , FFT Size 1024 ,CCDF -PAPR IS 6.51 dB.

5. CONCLUSION

5.1 CONCLUSION

The OFDM strategy is no longer effective due to the introduction of the Internet of Things (IOT) and the move towards user-centered computing. As a result, UFMC is the strongest candidate for 5G.

This thesis provided an introduction to the Universal Multicarrier Filter (UFMC). It is an attractive environment for 5G systems due to its flexibility and versatility. This thesis introduces the whale optimization algorithm, which is an evolutionary method that avoids interference transmission while providing high data rates for non-contiguous subcarriers. The main aim of this study was to explore ways to reduce PAPR. PAPR reduction simulation results show that this approach is superior to other algorithms and techniques. According to the BER measurements, a higher value of SNR is required to obtain the same BER since increasing the BER reduces the complexity of the UFMC system, simplifies implementation, and improves power consumption.

5.2 FUTURE WORK

Recommendations for Future work:

Modulation methods for 5G networks were covered in this thesis. These methods can be used to 5G's PAPR, BER, and spectral efficiency issues. However, there are still a lot of unresolved problems in this field. this thesis makes the assumption that baseband waveform design will be used. The usage of millimeter waves frequencies, nevertheless, is a hypothetical 5G communication technology that has been considered. In this way, signals designate larger bandwidths for speedier transmission. Additional analysis on higher frequencies may be useful to determine how well modulation techniques perform.

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