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Architecture Optimization for Filtered Multicarrier Waveforms in 5G

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Abstract

Wireless communication network is the backbone of each and every organization of today modern globe. The rapid emergence of smart devices, smart homes, internet of things and clean energy become key sources in today society. In result the data traffic, emerging of new service and application are increase every year. Hence, there is a growing demand for 5G technology in all above mentioned fields. Therefore, better waveform types for 5G technology is needed, which has ability of high spectral efficiency, lower latency and less complexity. It is predicted that the data traffic will arise 1000x in near future. In this work filtered orthogonal frequency division multiplexing (F-OFDM) and universal filtered orthogonal frequency division multiplexing (UF-OFDM) techniques will be discussed to degrade key issues such as computational complexity, peak average power ratio (PAPR), lower spectral efficiency, and higher latency. The suggested work will clearly overcome the drawbacks faced by previous work like limited capacity and complexity. We also analyze algorithms and simplification for F-OFDM and UF-OFDM waveforms from an implementation perspective towards low complexity and efficient transceiver design. Moreover, F-OFDM and UF-OFDM will be mainly based on multicarrier modulation and will be enabled to reduce to out-of-band power leakage (OOBPL) of OFDM.

Keywords: UF-OFDM, F-OFDM, Multicarrier, 5G wireless communication framework

1 Introduction

The Wireless communication network is the heart of each and every organization of today modern globe and the fast emergence of smart devices internet of things clean energy and the smart homes become key sources in today society. The data traffic in result emerging of new service and the application are increase every year. So, there is a growing demand for 5G technology in all above mentioned fields [1]. Therefore, good waveform types for 5G technology is required which has the power of high spectral efficiency less complexity and lower latency. The data traffic is predicted that it will increase by 1000x in near future. The work filtered orthogonal frequency division multiplexing (FOFDM) and the universal filtered orthogonal frequency division multiplexing (UFOFDM) techniques will be explained to degrade key issues such as lower spectral efficiency peak average power ratio (PAPR) higher latency and computational complexity [2]. The drawbacks faced by previous work like limited capacity and complexity would clearly vanish by this suggested work. For FOFDM and UFOFDM waveforms we also analyze algorithms and simplification from an implementation perspective towards low complexity and the efficient transceiver design [3]. Furthermore FOFDM and UFOFDM will be mainly based on multicarrier modulation and this will be enabled to reduce to out of band power leakage OOBPL of OFDM.

1.1 Background of OFDM

The OFDM modulation procedure was firstly developed by Weinstein [4] and due to various properties is widely applied in communication networks. Moreover, OFDM is a multicarrier modulation system which splits the bandwidth into multi narrow band of waves called subcarriers. These subcarriers are then modulated with complex valued symbols from digital modulation system like quadrature amplitude modulation (QAM) for transmission. As a result each propagated subcarrier takes the shape of sin function spectrum, including side lobes that overlapping on each other as declared in Figure 1. The Δf represents the frequency spacing and the orthogonally outcomes provides symbols with less distortions. The inverse fast Fourier transform (IFFT) is implemented for OFDM transmitter with N number of size.

Figure 1 OFDM: - orthogonal subcarriers and cardinal sin function spectrum.

To transmit the latter are the allocated subcarriers. Here input indexes of the IFFT are directly related to the subcarrier indexes. NC QAM symbols are therefore feed to the corresponding input

The IFFT obtains time domain of N samples, where then CP is inserted before the first sample of the time domain signal. Thus, obtained time domain signal is written as LCP + N. These steps are repeated for each OFDM symbol for transmitting [5,6]. The time duration of one OFDM symbol is derived as

$$T = (N + CP)/f_s \quad (1)$$

Where f_s is the frequency sampling in Hz.

The used bandwidth is represented by $N\Delta f$, and list of elements used by 4 G are explained in Table 1 with their classification. The duration of each symbol of OFDM is recorded 70.45 μs ,

which is minimum resource size and is provided for a customer in one resource block (RB). The effective bandwidth as presented in Table 1 is measured as

$$N\Delta f = 12 N_{rb} \Delta f \quad (2)$$

Where N_{rb} is used for number RB. The classification of bandwidth in Table 1.1 explains that OFDM parameters must be selected for the propagation in the available bandwidth. This concludes that effective bandwidth in 4G LTE is recorded less and available bandwidth as a guard band is limited.

The received baseband signals from OFDM symbol are then transmit to radio frequency (RF) interface which include the following elements.

To minimize the OOBPL analog filter is applied

To induce analog signals digital to analog converter is used.

To amplify the power of signal high power amplifier (HPA) is installed. To attain radio form of signals Antenna is selected.

Table 1: 4G LTE setting parameters for all available configurations

Classification of Bandwidth in MHz	1.5	2.25	4.8	9.5	14.5	18
Sampling in MHz	1.25	3.84	7.68	15.36	23.04	30.72
The magnitude of IFFT in M	64	128	256	512	1025	1500
RB quantity	12	24	48	60	72	88
Length of CP	18	36	72	104	124	148
The range of effective bandwidth in MHz	1.04	2.08	4.0	8.5	12.0	16.2

The attained signals $r(t)$ by antenna are defined as

$$r(t) = \int_0^{\tau_{ds}} h(\tau)s(r - \tau)d\tau \quad (3)$$

Where τ_{ds} is the difference among 1st and last signals. The RF waves are calculated as

$$RF(k) = \sum_{i=0}^{l_{ds}-1} h(it_s)s((k-i)t_s) + z(k) \quad (4)$$

The term t_s is the duration in no of sample of the delay and is equal to $1/f_s$, the noise z term is added in Eq (1.4) due to unbalance among electronic component and RF waves. The multipaths channels introduce a new phenomenon called inter symbol interference (ISI) which cause of the delay samples coming out from OFDM. Furthermore, the CP helps in the compensation of ISI

so, for shorter duration the ISI can be ignored. Linear convolution of the FFT is equivalent to circular convolution by reason of CP and can be estimated as

$$FFT(s \circledast h) = FFT(s)FFT(h) \quad (5)$$

The term $\circledast$ defines the circular convolution. After FFT the achieved signals ($X(n)$) in the frequency domain are written as

$$X(n) = Z(n)Y(n) + \alpha(n) \quad (6)$$

The orthogonal behavior of time and frequency domains are strengthen for multipath channel transmission with linear implementation applying FFT scheme the OFDM methodology is considered a highlighted solution for IMBB scenario. Furthermore, OFDM has ability to support spatial multiplexing and MIMO services. Suggesting the new multiple services and need of upcoming 5-G technology it is noted that is OFDM has quality of ability to support the 5-G massive data rates challenges?

For 5-G scenario several modified form of OFDM like filtered bank multi carrier (FBMC), UF-OFDM, F-OFDM, and zero tail-OFDM (ZT-OFDM) are analyzed from last decade. This work investigates the F-OFDM and UF-OFDM mechanisms to filter the transmitted symbols.

1.2 Background of UF-OFDM modulation form

This approach was first developed through the name of universal filtered multi carrier (UFMC). The UF-OFDM aiming to divide the complex samples into sub bands groups, where each group consists of W subcarriers. These complex samples are provided by QAM constellation, using K/W subbands, where K means total number of subcarriers [7]. With addition each sub band uses filter with length D samples and integral process of filtering of all sub bands is defined as

Figure 2 : Principle of the UF-OFDM transmitter.

$$F_T = N + I - 1 \quad (7)$$

The block description of UF-OFDM transmitter is mentioned in Figure 2, where sub band mapping inserts the complex samples, carrying data into subcarrier. Then N numbers of IFFT size are allocated for each sub band. After IFFT the filtering process is started for each sub band using linear convolution system [8]. The whole filtering procedure are then summed to make UF-OFDM symbol. The important point is in the UF-OFDM mechanism that there is no need of CP.

A communication system main objective is to transmit information in a safe way from a source to destination. In digital communication information is conveyed by a sequence of bits as shown in Figure 3. The role of the transmitter is to turn the bit stream into a waveform called a continuous time signal $x(t)$, which has energy and can be propagated by an impulse response $h(t)$ through a physical tube. The channel allowed the received signal $r(t)$ to differ from the transmitted signal $x(t)$ because of it negative effect. The primary task of the receiver is to restore the transmitted bit stream with a few errors as possible [9,10].

The bits to symbol mapping block at the transmitter, takes several inputs bits and maps them to a real or complex modulation symbol $x(n)$ where n is the index of the symbol. The symbol sequence is then transformed into a continuous time signal $x_b(t)$. as its spectrum is about 0Hz. The signal $x_b(t)$ is a base band signal. The base band signal is up converted for radio transmission to a pass band signal $x(t)$ whose spectrum is based around some carrier frequency. The transmitted signal $x(t)$ propagates through the $h(t)$ channel which is a device of continuous time [11].

Figure 3: Basic model of communication system.

The received signal $r(t)$ is first down converted to a base band signal $r_b(t)$ at the receiver. Before the receiver takes a decision on the transmitted symbols and obtains $x(n)$, $r_b(t)$ is then transformed to the discrete time signal $r(n)$. Finally the symbol to bits block maps the $x(n)$

symbols back to the bit stream. There is a discussion of the constraint of a signal carrier scheme which then motivates the development of multicarrier systems.

Figure 4 Block Diagram of Digital communication system

The feasible framework of communication is the main goal of this thesis. The Previous discusses the basic introduction of OFDM and their limitations. Moreover, it is studied that new approach based on F- OFDM and UF-OFDM is necessary to fulfill current demands and decrease the magnitude of losses. This chapter includes the literature review, that how the researchers have investigated for upgrading the current system.

1.3 Related Work

For the development of the property of the current wireless communication system a range of research processes are investigated. There are some of them discussed as follow.

The authors in [12] compare the most favorite candidates for the 5G air interface thoroughly and fairly. The waveform candidates consider are Universal filtered Multicarrier (UFMC), generalized frequency division multiplexing (GFDM), resource block filtered orthogonal Frequency division Multiplexing (RBFOFDM) and Filter bank Multicarrier (FBMC) are called wave form candidates.

These are matched to OFDM used in 4G in form of spectral efficiency numerical complexity toughness towards multi user interference (MUI) and the resilience to power amplifier nonlinearity. The FBMC shows the best spectral containment and to reveals to be almost insensitive to multi user interference. Therefore it suffers from its bad spectral efficiency for short bursts and due to its poor multiple input multiple output (MIMO) compatibility. The GFDM reveals to be the most favorable candidate with the best spectral efficiency and its smallest complexity overhead compared to OFDM. It is also the toughest to multi user interference after FBMC and is MIMO well-matched as soon as the interference can be managed. The UFMC and RB-F-OFDM are lastly the next to OFDM and advantage so form a better compatibility with existing systems even if their performance is normally lower than FBMC and GFDM.

The development in wireless communication the applications inspires the use of active and well-organized channel estimation (CE) methods because of the fluctuating behavior of the Rayleigh fading channel is analyzed in [13]. Mainly the importance of most proposed CE arrangements is to recover the CE presentation and complication for guaranteeing quality signal reception and better-quality system throughput. The Contender waveforms whose enterprises are based on FBMC modulation methods such as Filter bank orthogonal frequency division multiplexing centered on OFDM-OQAM, UFMCand GFDM-OQAM are no compromise to the use of these offered CE methods in the literature. These activities are considered as potential waveform contenders for the physical media access control layer of the developing fifth generation (5G) networks. So, these pinpoint techniques reflect a huge need for this wave form to reach their maximum potential. In this respect this paper analysis the concept of CE is true for these wave forms and other candidates for waveforms considered in the emerging 5G technology. . So the plan of the majority of the waveform contenders is filter based analysis of the general filter design considerations is presented in this paper. Furthermore we examine general CE methods for contender waveforms of next generation networks and categorize some of the studied CE methods. Especially we categorize the CE activities used in filter bank OFDM-OQAM and GFDM-OQAM based transceivers and present a presentation comparison of some of these CE activities. Similarly for two FBMC Based waveform candidates assuming near perfect

reconstruction (NPR) and the non-perfect reconstruction (non NPR) filter design over slow and fast frequency selective Rayleigh fading channel, we examine the presentation of two linear CE activities and three adaptive based CE activities. The findings are recorded through computer simulations, where the efficiency of the studied CE operation is analyzed in term of the normalized mean square error (NMSE). Lastly we summaries the verdicts of this work and propose possible research directions in order to advance the abilities of the studied contender waveforms over Rayleigh fading channels.

The authors proposed an assessment under the main key metrics of various 5G waveform entrans OFDM, UPMC, FBMC, and GFDM (KPIs). The scientists and developers are analysing the specifications of 5G networks for ideal waveform, which will lead to high performance and lower stunted growth with less device complications. This assesses that the main KPI specifies the numerical complexity of the spectral latency and duration from the average power ratio. In the last study, the authours highlighted the strengths and disadvantages of any waveform contain based on the factors of KPI for improved results in the enterprise. The authors also addressed KPI factors in different 5G waveforms. Indecision The current analysis recommends the use of optimised FBMC and UPMC waveforms to improve the stiffness of early studies to resolve the disadvantages. As regards FBMC and UPMC, the coexistence in 4G networks with a new framework has improved for the CPOFDM.

The discovery of the new OFDM dependent waveform in 5G and the new modulation scheme should mainly allow for higher specimen performance than the predecessor studied in [14] are among the major open problems of successive wireless networks. Here the key contenders of 3GPP are a new version of OFDM called Filtered OFDM similar to OFDM but with additional filtering, with the goal of reducing OOB emissions from Out Of Band and achieving a better spectral position. The second choice is the OFDM window which is essentially a classic OFDM system with a window and overlap of each symbol in the time domain. In this work we compare classic OFDM signals, each with a number of parameter options and numerologies with the use of Cyclic prefix OFDM with OFDM and WOFDM. A multirate transmitter operating simultaneously with various numerologies is considered to evaluate and interpolate the transmitted sub bands to generate signal. Sliding window is generalized by time domain linear minimum mean square error (TD-LMMSE) method for 5G waveform in [15]. In another work [16], the researchers analyzed (F-OFDM) and UF-OFDM based on key performance indicators technique. Finite impulse response (FIR) filter technique is implemented in [17] for F-OFDM waveforms to enhance suitability of 5G in terms of complexity and vehicle to vehicle communication.

All these mentioned trends are limited either by the complexity or less analyzed techniques. Hence forth, in this proposal, multiple candidate waveforms for 5G will be investigated, such as Universal-Filtered Orthogonal Frequency-Division Multiplexing (UF-OFDM) and Filtered- Orthogonal Frequency-Division Multiplexing (F-OFDM). These two candidate waveforms are mainly based on multicarrier modulation with specific filtering scheme used on the top of the OFDM basis. The filtering operation is applied in digital domain, before transmitting the baseband discrete signal to the Digital-to-Analog Converter (DAC).

2 Novel short prototype filter for FBMC

Recent research groups have found the OQAM or FBMC to be one of the most effective rivals in waveform to meet the requirements for new 5G communication channel, which produced excellent spectral form and boosts support for mobility in comparison to OFDM using a frequency and time localised PF. In fact, in response to the edge structure in the communication system, the choice of this philtre will affect the changed level of performance knowingly. The length of the prototype philtre also greatly impacts the complication and expectation of the transceiver. The careful design of new prototype philtres is therefore extremely useful in increasing FBMC and OQAM intensity against channel deficiencies and in fulfilling the new requirements imposed by 5G scenarios. A new short prototype philtre is developed and provided in this chapter. In this context, the proposed philtre enables almost complete reconstruction and has the same size as the 1 OFDM symbol.

2.1 Transceivers FBMC/OQAM

The multicarrier FBMC is a transmission pattern that presents a filter bank to enable well-organized pulse shaping for the signal taken on each individual subcarrier. The additional element signifies a collection of band pass filters that distinct the input signal into numerous components or subcarriers each one carrying a sole frequency sub band of the original signal. For instance a promising variant of filtered modulation patterns FBMC originally proposed in [18] and also known as OFDM and OQAM [24] or Stunned Modulated Multirole (SMT) [19] can possibly achieve a developed spectral efficiency than OFDM since it does not require the insertion of a CP. The Further benefits include the toughness against highly irregular fading channel conditions and faulty synchronization by selecting the appropriate PF type and coefficients [20].

The practice of digital poly phase filter bank structures [21] [22], together with the rapid growth of digital processing capabilities in recent years have made FBMC a practically possible approach and in this literature 2 types of implementation for the FBMC modulation exist each having different hardware complexity and performance. The first one is the PPN implementation [23] which is based on an IFFT and a PPN for the filtering stage and enables a low complexity implementation of the FBMC transceiver.

The 2nd type of implementation is the FS implementation suggested in [24], with the PF with a corresponding factor equal to 4 considered for FBMC during PHYDYAS Project [25]. The unique idea was to shift the filtering stage into the frequency domain in order to enable the use of a low difficulty per subcarrier equalizer as in OFDM. And the hardware difficulty is supposed to be higher than the difficulty of the PPN implementation as a minimum for long PFs. In fact, it requires one FFT of size $L = KM$ per FBMC symbol, where K is the overlapping factor of the PF and where M is the total no of available subcarriers. But in the short PF case ($K = 1$) the size of the FFT is same as for the PPN implementation.

2.2 Fundamentals of CP-OFDM with Spectral Enhancement Techniques

The start of OFDM in wireless networks has changed telecommunications in a way that OFDM is fundamental to most wireless technology today. The OFDM separates the range into orthogonal and overlapping minor bands known as subcarriers. If the difference between the subcarriers is small with respect to the coherence of the channels bandwidth, on each subcarrier simplifying the equalisation phase, the channel properties could be approximated as constant [26]. In addition, OFDM transmits cyclic prefix (CP) information with circular extension, allowing us to model the frequency selective channel effect as a circular convolution. This further simplifies the method of channel equalization.

In addition, OFDM is efficiently applied with the fast Fourier transformation (FFT) leading to very basic machine complexity multiaccess schemes. Therefore, OFDM based on FFT will simplify the manipulation of bandwidths and central frequencies between various users. OFDM also makes it easy to incorporate MIMO deployments directly [27].

OFDM has its own drawbacks, however which threaten its use in 5G NR. The OFDM usually leaks highly powered side lobes around the active bands, ensuring that high power OOB leakage forces hold guard bands around active bands on every OFDM channel. In order to prevent ISI and ICI, OFDM should also ensure a timely and frequency synchronisation. In addition, OFDM performance has a significantly high PAPR, which results in spectrum development due to nonlinearity of the power amplifier (PA).

2.3 CP-OFDM implementation

The arriving low rate specific samples of rated orthogonal alternating subbands which are usually referred to as subcarriers are modulated by Normal CP-OFDM transmitters. The CP-OFDM transmitter is only used by IDFT, which modulates input data at cheap rates to orthogonal frequencies. The Fourier Rate Transform (ITFT) algorithms like radix2 or break radix can be used to apply the IDFT block efficiently. Using the IFFT block, the categorization of the block sample stream into blocks of IFFT size N is required. After the IFFT, the samples are repeated at the end

Figure 5: Implementation of the CP-OFDM, transmitter and receiver.

The block P/S and S/P apply to parallel-to-serial and serial-to-parallel operations, respectively [28]-[32].

$$Y_l[n] = \frac{1}{N} \sum_{k=0}^{N-1} X_l[k] W_N^{-k(n-NCP)} \quad (8)$$

To build a CP-OFDM the N sample block is appended to the start of the N sample block Figure 5 shows a mathematical display CP-OFDM sender implementation where l is the CP-OFDM symbol index.

$n = 0, 1, \dots, N+NCP-1$ is the index of time, k is the index of frequency, $W_N = \exp(-2\pi j/N)$ is a twiddle factor, NCP is the length of the CP, $X_l[k]$ is the low-rate input at the k th subcarrier and l th CP-OFDM symbol, and $y_l[n]$ is the CP-OFDM output at the n th time index and l th CP-OFDM symbol [33]. The processed CP-OFDM symbols are finally concatenated in serial form as

$$\psi[m] = \sum_l w_T[m-lN_s] y_l[m-lN_s], \quad (9)$$

Where N_s is the OFDM symbol length and $w_T[m]$ is the transmitter time-domain window used to represent mathematically the block-wise processing due to IDFT. This time-domain window is a rectangular function with value of one when $0 \leq m \leq N_s - 1$ and zero otherwise. The receiver side is a dual of the transmitter as illustrated in Figure 2.1(b). The CP-OFDM receiver removes the CP and divides the received signal $\hat{\psi}[m]$ to OFDM symbols of size N samples in the following way [34,35]:

$$Y_l[n] = w_R[n] \hat{\psi}[n + NCP + lN_s]. \quad (10)$$

The transmitter time domain window for N_s , which is the OFDM symbol long and $w_T[m]$, is used to describe the block-wise processing of IDFT mathematically. This time domain window is a rectangular function with a value of one whether 0 to 1 or 0 to 1 or 0. As shown in Figure 2.1 the receiver hand is double of the transmitter. The receiver of the CP-OFDM eliminates the CP and breaks the signal $\hat{\psi}[m]$ into OFDM sample symbols [36,37]:

$$Y_l[n] = w_R[n] \hat{\psi}[n + NCP + lN_s]. \quad (11)$$

in the absence of disturbances of a channel and of noise, the broadcast low-rate inputs $X(l)[k]$ are equal to $y_l[m] = y_l[m]$. The orthogonality of DFT bases allows this equality to be avoided by vectors which prevent overlap between subcarrier. For each subcarrier, the distribution of CP-OFDM performance IDFT shows in Figure 2.2(a). Notably, a sinc-type response is given for each subcarrier resulting from $w_T[m]$ time domain window. Overlapping subcarriers have frequency nulls.

Figure 6: Subcarrier indexes

The DFT performance range displays each subcarriers individually. The DFT size consists of 16 for a) NCP = 0 and (b) NCP = 3 with eight active subcarriers. Points that complement most subscribers' core frequencies. Consequently, regardless of orthogonality ICI is therefore zero. This example, however, is only valid if CPOFDM lacks the orthogonality of the CPOFDM form as seen in Figure 6. The orthogonality is maintained by extracting the CP from the recipient hand. This is not significant. The timedomain transmitter window, $w_T[m]$, is used for splitting the CP-OFDM symbols [38].

This means that the windows operation is almost not used on the CPOFDM transmitter output, but naturally occurs because of blockwise IDFTs. DFT (2.2) is a sum of the frequencyshifting equation Dirichlet $\sin(N\pi k/N)/\sin(\pi k/N)$, for instance). For eg, the maximum power of the first side label is around -13 dB less than the main lamp power [39], the Dirichlet function is strong side labels. The combination of Dirichlet functions results in highperformance side lobes in the CPOFDM system around the active band. It is also recommended to use security bands around active CPOFDM bands to discourage interruption. This decrease in transmit power can be viewed as a direct decrease in CPOFDM device output. For instance, 5 MHz reserves system LTE 0.5 MHz of spectrum as guard strip; for example, 10% of the bandwidth allotted is reserved as a security strip.

Given the lack of the available spectrum below 6 GHz, the unused spectrum as a guardbelt is quite useful. In addition, highside lobes face drastic problems in unscrupulous spectral usage scenarios for the OFDM system. The power which leaks as in active bands, mainly between active subcarriers, simplifies the utilization of the spectrum. These problems in the CPOFDM impact the creation into the 5G NR, taking the critical aspects of 5G NR into account asynchronous connectivity and opportunistic spectral application[40,41].

3 Results and Discussion

Acceptable framework of communication system is the key goal of current era, which can provide high data rate and high capacity services to the users with less error rate. This research work proposes the achievements of F-OFDM and UF-OFDM schemes based accurate transmission, including high capacity and less error rate. In the previous sections the background and proposed models are studied for F-OFDM and UF-OFDM in detail with mathematical approaches. The performance assessments of F-OFDM and UF-OFDM related with current methodologies are analyzed in this section using simulation setups.

In order to explore the outcomes of the projected objectives MATLAB simulation software is used in this research work, which gives the results related to real world applications and can be applied for practical implementations. Table 2 explains the list of parameters used for simulation analysis.

Table 2: List of parameter applied for simulation analysis.

Parameter	Values
FFT/IFFT size	512-2048
Number of resources blocks	50
Number of subcarriers per resource block	12-24
Cyclic prefix length	40
Filter length	513
Channel model	AWGN
Channel bandwidth	5 (MHz)

Figure 6 contains the results related to F-OFDM, UF-OFDM and OFDM in terms of normalized signal to noise ratio and bit error rate (BER). The results clarify that results of UF-OFDM and F-OFDM are efficient than current OFDM format.

Figure 6: Performance of comparison of the proposed F-OFDM, UF-OFDM with OFDM.

The symbols of UF-OFDM and F-OFDM are less interrupted from the ripples as compare to OFDM format. Thus, due to these reason the performance of the OFDM and other modulation schemes are slower. Moreover, above one normalized signal to noise ratio difference is recorded among the presented and modulation formats and current modulation formats. In order to investigate the PAPR of the proposed technique the complementary cumulative distributed function (CCDF) is described. The CCDF is probabilistic mechanisms includes further several methods for evaluating the PAPR for the model which are clipping, coding and signal processing. In this work the PAPR is estimated utilizing the properties of OFDM, UF-OFDM and F-OFDM signals. PAPR is actually however the ratio among maximum instants power and average power.

Figure 7: PAPR reduction comparison for UF-OFDM, F-OFDM, OFDM and UPMC formats.

Figure 7 elaborates the performance comparison of UF-OFDM, F-OFDM, OFDM and UPMC techniques for reduction of PAPR using CCDF methodology. The efficient reduction in PAPR is noted for the system working on UF-OFDM based modulation scheme. About 6.5 dB is recorded while 9 dB PAPR is attained using the F-OFDM system. So, it is found from Figure 7 that UF-OFDM and F-OFDM based communication frameworks are designed less complex as discussed in chapters 3 and 4 which in turn gives fast response as compare to complex OFDM and UPMC procedures. The highest PAPR noises are included in UPMC based model which is about 12 dB; it takes huge amount of input power to transmit the high capacity data.

Power spectral density (PSD) is widely used for calculating modulated carrier signals and orthogonally properties. The PSD is measure as

$$PSD_x(t) = \sum_{i=-\infty}^{\infty} c(i)p(t - iT) \quad (13)$$

Where $c(i)$ is infinite number of symbols, $PSD_x(t)$ is the random process of stationary signals.

Figure 8: Power spectral density results for UF-OFDM methodology.

Based in the valuable properties of the PSD the proposed is analyzed and compared with current used techniques in terms of PSD. Figure 8 presents the PSD against the frequency, which shows the smooth orthogonal behavior of the proposed UF-OFDM signals. As to the PSD characteristics of UF-OFDM technique the F-OFDM gives a bit distort PSD as depicted in Figure 9.

Figure 9: Power spectral density results for F-OFDM methodology.

Similarly, Figure 10 and 11 include the PSD performance of the current OFDM and UPMC procedures, and clarify that is model provides worst orthogonally as compare to F-OFDM and UF-OFDM. The quality of the achieved are distorted badly, hence, more filter process and modification mechanisms are required to improve the quality of the signals. As a results the system efficiency, cost, latency and complexity is increased several folds as compare to proposed model.

Figure 10: Power spectral density results for OFDM methodology.

Figure 11: Power spectral density results for UFMC technique.

Another fruitful methodology known as impulse response is use for the estimating the channel estimation to check the response and quality of the achieved signals. Figures 12 to 15 simulate the efficiency of the impulse response for UF-OFDM, F-OFDM, OFDM and UFMC techniques. The results in Figures 12 and 13 conclude that the efficient response is attained by the UF-OFDM and F-OFDM while the diverse response is noted by the techniques like OFDM and UFMC as mentioned in Figures 14 and 15.

Figure 12: Impulse response of F-OFDM.

Figure 13: Impulse response of UF-OFDM.

Figure 14: Impulse response of OFDM.

Figure 15: Impulse response of UPMC.

4 Conclusion

The demands of high capacity and securable wireless communication are increasing exponentially from last decade. To facilitate users with these demands the current system induces huge amount of impairments such as peak to average power ratio, and signal degradation etc. This thesis elaborates the background of wireless communication and issues which are generated in current 4 G wireless technology. The fundamental elements of orthogonal frequency division multiplexing (OFDM) modulation schemes, including limitations to support current demands are investigated. The proposed filter-OFDM (F-OFDM) and universal-F-OFDM (UF-OFDM) are discussed briefly in this chapter. The problem statement and key objectives of the proposed approach are analyzed in detail. This thesis explains the background of OFDM modulation schemes and its functions in 4-G technology. It is studied that demands of massive capacity, lower latency and high reliable communication set up are increased. The current OFDM system is insufficient to accommodate the high capacity users. The upcoming 5-G technology is explained in detail with outstanding features. In this thesis the background of the study is

discussed. It is conducted from related work that the current model contains complex and costly structures. The mechanisms like MIMO-OFDM, UFML, RB-F-OFDM and GFDM are limited to support current demands. During this thesis f-OFDM was studied. OFDM was compared to other techniques and the main feature f-OFDM was studied. The process to analyze f-OFDM filter which are characterized and Interpretation of f-OFDM was shown. The new UFOFDM method with little computational difficulty is presented and the major characteristics of this new method is that different from the ones proposed in the literature it does not present any estimate of the original signal and additionally suitable results have been complete to back up any small bands size as distinct in 4G LTE numerology. The Comparisons were done with the methods existing in the literature utilizing altered sets of small bands allocations and the subbands sizes. So, this effects show that the suggested UF OFDM method offers significant computational difficulty decrease in utmost cases and at last power spectral density appraisals were performed displaying that the suggested method reserves the spectral confinement of UFOFDM, differing from the newly presented TDW UFOFDM method Which proves that for the 1st time the chances to design a low complexity UFOFDM transmitter without decreasing the quality of any signal making the UF OFDM mainly appealing for adoption in upcoming wireless uses and standards. Acceptable framework of communication system is the key goal of current era, which can provide high data rate and high capacity services to the users with less error rate. This research work proposes the achievements of F-OFDM and UF-OFDM schemes based accurate transmission, including high capacity and less error rate. In the previous chapters the background and proposed models are studied for F-OFDM and UF-OFDM in detail with mathematical approaches. The performance assessments of F-OFDM and UF-OFDM related with current methodologies are analyzed in this chapter using simulation setups. Analyzing the UF-OFDM and F-OFDM parameters to boost up the wireless communication system are the goals of this research model. This simulation model is explored based on the mathematical background explored in this work. The simulation results are designed for the important parameters like PAPR, frequency, normalized signal to noise ratio using BER and PSD modern approaches. The results are compared among different already used approaches such as OFDM and UPMC. It is found that the proposed UF-OFDM and F-OFDM are out performed as compare to OFDM and UPMC models.

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Figures

Figure 1

OFDM: - orthogonal subcarriers and cardinal sin function spectrum.

Figure 2

Principle of the UF-OFDM transmitter.

Figure 3

Basic model of communication system.

Figure 4

Block Diagram of Digital communication system

Figure 5

Implementation of the CP-OFDM, transmitter and receiver.

Figure 6

Subcarrier indexes

Figure 7

Performance of comparison of the proposed F-OFDM, UF-OFDM with OFDM.

Figure 8

PAPR reduction comparison for UF-OFDM, F-OFDM, OFDM and UPMC formats.

Figure 9
Power spectral density results for UF-OFDM methodology.

Figure 10

Power spectral density results for F-OFDM methodology.

Figure 11

Power spectral density results for OFDM methodology.

Figure 12

Power spectral density results for UPMC technique.

Figure 13

Impulse response of F-OFDM.

Figure 14

Impulse response of UF-OFDM.

Figure 15

Impulse response of OFDM.

Figure 16

Impulse response of UPMC.