iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** VIII **Month of publication:** August 2019

DOI: http://doi.org/10.22214/ijraset.2019.8030

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue VIII, Aug 2019- Available at www.ijraset.com

Analysis of F-OFDM in 5G Wireless Communications

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Abstract: ***The aim of this paper is to present the Challenges in multi carrier transmission like orthogonal frequency division multiplexing (OFDM) implementations and Scope of OFDM techniques for research with advantages and disadvantages. As the research in Internet of things taking exponential growth which is connecting and operated by many of devices through wireless networks, 4G will not be sufficient to meet future requirements as it requires the high speed data transmission & very low end-to-end latency, In future mobile and wireless communication network traffic will increase rapidly, and adopts the 5G networks in coming years. This paper presents the introduction to 5G wireless communications and analysis OFDM techniques, and gives brief introduction about OFDM transceivers as it promises the high data rate in transmission with less complex and good precision, also summarizes the usage and applications of OFDM in 5G wireless communications.***
Keywords: Mobile Communications, Wireless Communications, 5G, OFDM, Wireless Networks, IOT.

I. INTRODUCTION TO 5G

As the research in IOT (Internet of things) increases Internet traffic is evolving into more dynamic changes, forecasts indicating that this will increase x1000 times in a decade, So the research will turn around for building the systems with 5G technology as 4G will not be sufficient for future needs, And 5G will become an evolution for Internet of things to connect everyone to everything and to operate / manage many devices over the internet, most of the internet traffic is video streaming / multimedia sharing applications so there will be a huge benefit if 5G converges with mobile networking systems and IOT devices to form hetero genius networks. 5G enables the self-organizing networks, and cloud computing networks Cellular networks will undergo the major shift and optimization.

The combination of embedded systems and emerging IOT devices will make possible for driverless automated vehicles, which requires machine to machine (M2M) or endpoint to endpoint (E2E) or device to device (D2D) or vehicle to vehicle (V2V) communication link with very low latency (Less than 1ms).

History of wireless Communications

1) *Before 1983:* At this time the most widely used modulation scheme was SSB (single side band), and most of the wireless communications were voice centric.
2) *During 1983 to 1989:* In 1983 US introduced AMPS (Advanced Mobile Phone Services), this was considered as 1G.
3) *During 1990 to 1995:* During this period migration from analogue systems to digital systems was happened, by introducing GSM using TDMA multiplexing , this was called as a 2G.
4) *During 1995 to 1999:* During this period US introduced CDMA (Code Division Multiple Access) system using 1.25Mhz, At the same time European countries enhanced GSM to GPRS and EDGE based systems. In this period wireless communications not only voice centric but also limited data service.
5) *During 1999 to 2013:* During this period 3G was first introduced by ITU, 3G uses WCDMA technology (Wideband Code Division Multiple Access) using 5Mhz bandwidth, It adopts both TDD(Time Division Duplexing) and FDD (Frequency Division Duplexing), These systems migrated as voice centric systems to data centric systems.
6) *During 2013 to 2019:* In 2013 US has introduces voice centric plus data centric systems using WiMAX, There are two 4G systems, They are 1)WiMAX 2)LTE , Both the systems technology was very similar and both uses the bandwidth of 20Mhz. most of the cellular operators started using licence for LTE systems. WiMAX uses OFDM technology and also LTE systems uses OFDM in downlink.

In LTE Physical channels will carry the data, there are several physical channels such as: Physical Broadcast channel (PBCH), Physical Multicast Channel (PMCH), Physical Downlink Shared Channel (PDSCH), Physical Control Format Indicate Channel (PCFICH), Physical Hybrid ARQ Indicator Channel (PHICH) [2].

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There are four types of downlink reference signals in the LTE systems, they are defined as follows:

a) Multimedia Broadcast over single frequency network signals.
b) Cell specific signals.
c) User equipment (UE) signals.
d) Positional Reference Signal (PRS).[2]

After LTE there are few advancements in the standard were released as LTE-A, LTE-B. According to predictions by industries / academia's ITU may release the 5G standard by 2021.

The present paper categorised into IV sections, Section I gives the brief Introduction and history to wireless communications, Section II explains the classification of OFDM, applications and scope of OFDM in 5G. Section III gives the block diagram for OFDM transmitter and receiver. Section IV give the conclusion.

II. OFDM INTRODUCTION AND CLASSIFICATION

The modulation scheme can be categorized into two ways they are 1) Base Band Modulation and 2) Band Pass Modulation, The 5G wireless communication deals with the radio frequency so in this paper we are concentrating on Band-Pass Modulation.the carrier wave used for Band-Pass modulation is given by: $s(t) = A(t) \cos(\omega ct + \varphi(t))$, Where A(t) is the amplitude parameter, ωc is the angular frequency which is $2\prod fc$, f is the frequency and $\varphi(t)$ is the phase , So according to the considered message signal waveform whichever the parameter changes among these three will be called as Amplitude modulation, Frequency modulation, Phase Modulation respectively.

In wireless communication the channel will have limited data rates, so to improve the overall data rate the best techniques is split data stream into multiple number of parallel channels and to use different carriers for individual channels. This concept brought the basic idea for OFDM. Orthogonal frequency division multiplexing (OFDM) is the extension of the frequency division multiplexing technique. The basic idea of the frequency division multiplexing is to divide the available bandwidth into many sub-bands and to use many subcarriers than a single wide-band carrier to transfer the information. In December 1966, Robert W. Chang1 outlined a theoretical way to transmit simultaneous data stream through linear band-limited channel without inter-symbol interference (ISI) and inter-carrier interference (ICI). Subsequently, he obtained the first US patent on OFDM in 1970[1]. The advantages of using OFDM are:

A. Frequency selective fading.
B. Narrow band interference.
C. Less inter symbol interference.

But the disadvantage is spectral efficiency is low due to guard intervals, It will be very beneficial to use orthogonal subcarriers in terms of eliminating the problem and recovery of subcarriers also easy, No need of guard intervals and also complexity of both transmitter and receiver will decrease. [3] OFDM uses the available spectrum very efficiently which is very useful for multimedia communications. Drastically simplifies equalization problem by converting frequency selective channels to flat channels, by considering all the above reasons OFDM is adopted in all the future generation systems.

1) *CP-OFDM:* Cyclic Prefix OFDM, In short it is known as CP-OFDM, It is the simplest multicarrier technique which provides complete orthogonality of subcarriers, basically it was designed for MBB applications in LTE-Advanced 4G cellular systems, as it employs the rectangular signal pulses which creates signal discontinuities in OFDM symbol, which leads to unwanted Slow of OFDM spectrum, CP- OFDM cannot support low latency applications which is undesirable for 5G applications.
2) *Windowed OFDM:* In order to overcome the discontinuities in CP-OFDM, Weighted Overlap and Add Modulation scheme is introduced for replacing the rectangular pulsed with smooth functions, In general windowing is done in time domain and filtering is done in frequency domain, WOLA replaces the rectangular window function by smooth window function which increases the tame gap between two symbols at the transmitter and receiver, Decreases the throughput. But the advantage is simple to implement. But it also not satisfies the requirements of 5G so the better solution is filtering.
3) *Filter Bank Multi Carrier:* Filter bank multicarrier is known as FBMC, It is also a multicarrier modulation technique in which the subcarriers are filtered to give a more efficient waveforms. The spectral efficiency of FBMC is greater than the spectral efficiency of OFDM since filter bank multicarrier techniques does not use cyclic prefix. In this technique the subcarriers are not orthogonal, and due to its long filter tails it is not suitable for 5G applications which requires very low latency.

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4) *Generalized OFDM:* Generalized OFDM is similar to the FBMC, this technique also filters the subcarriers individually, but tail biting technique is used to short the cyclic prefix and also to improve the spectral efficiency. GFDM subcarriers also not orthogonal and the demodulation of GFDM can be done using three methods 1) Matched Filter 2) Minimum Mean Square error and 3) Zero forcing, GFDM also suffers decoding latency due to its demodulation process starts after receiving the entire block.
5) *Universal Filtered Multicarrier Modulation:* Universal Filtered Multicarrier Modulation is also known as UFMC, Which is proposed for new 5G wireless communication waveforms by EU funded research project, which reduces the side lobe and improves the spectrum fragmentation compared with OFDM. Compared to FBMC there are two main advantages like shorter time impulse response and protection against the inter symbol interference.
6) *Filtered OFDM:* Filtered OFDM divides the complete bandwidth into different sub bands .All the sub bands are filtered by different filters .Each sub band can have different sub carrier spacing, different cyclic prefix length and different transmission time interval(TTI) depending upon the application. Filters can be designed to suppress the out of band emission. The main difference between UFMC and F-OFDM is the filter length [5].

III.F-OFDM TRANSMITTER AND RECEIVER

The F-OFDM transmitter block diagram is given by

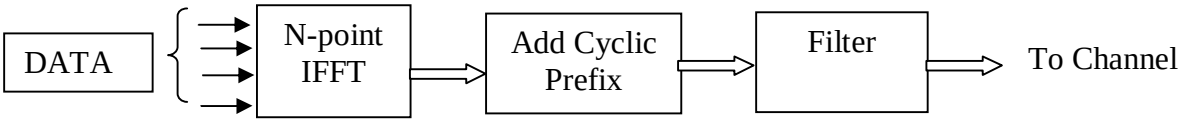

Fig. 1 Block Diagram of F-OFDM

The F-OFDM receiver diagram is given by

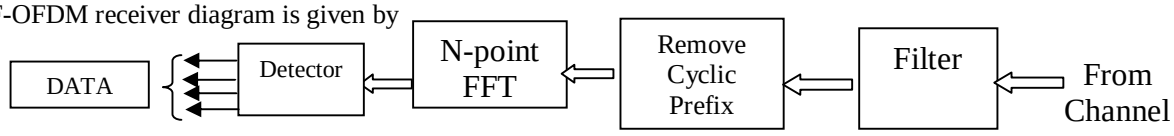

Fig. 2 Block Diagram of F-OFDM

Advantages of F-OFDM

1) Simple channel equalization.
2) Efficient spectrum utilization.
3) Longer filter length compared to UFMC.
4) Good trade-off between frequency band and time localization.
5) Less Complex than UFMC

IV. CONCLUSION AND FUTURE SCOPE

The multi carrier OFDM based systems offers higher spectral efficiency, energy efficient and lower complexity, In this paper we have presented the history of wireless communications and Basics of LTE networks and OFDM usage in LTE networks, classification and scope of OFDM in 5G wireless communications, we found that FMBC , GFDM , UFMC and F-OFDM are suitable for 5G waveforms and as per our literature survey we found that UFMC and F-OFDM performs better than other techniques and having good scope to be a part of 5G and suitable for Device to Device high speed communication latency applications. In our future presentations we will try to make an experiment by designing a simulation model for UFMC and F-OFDM to verify the requirements and specifications matching by 5G waveforms.

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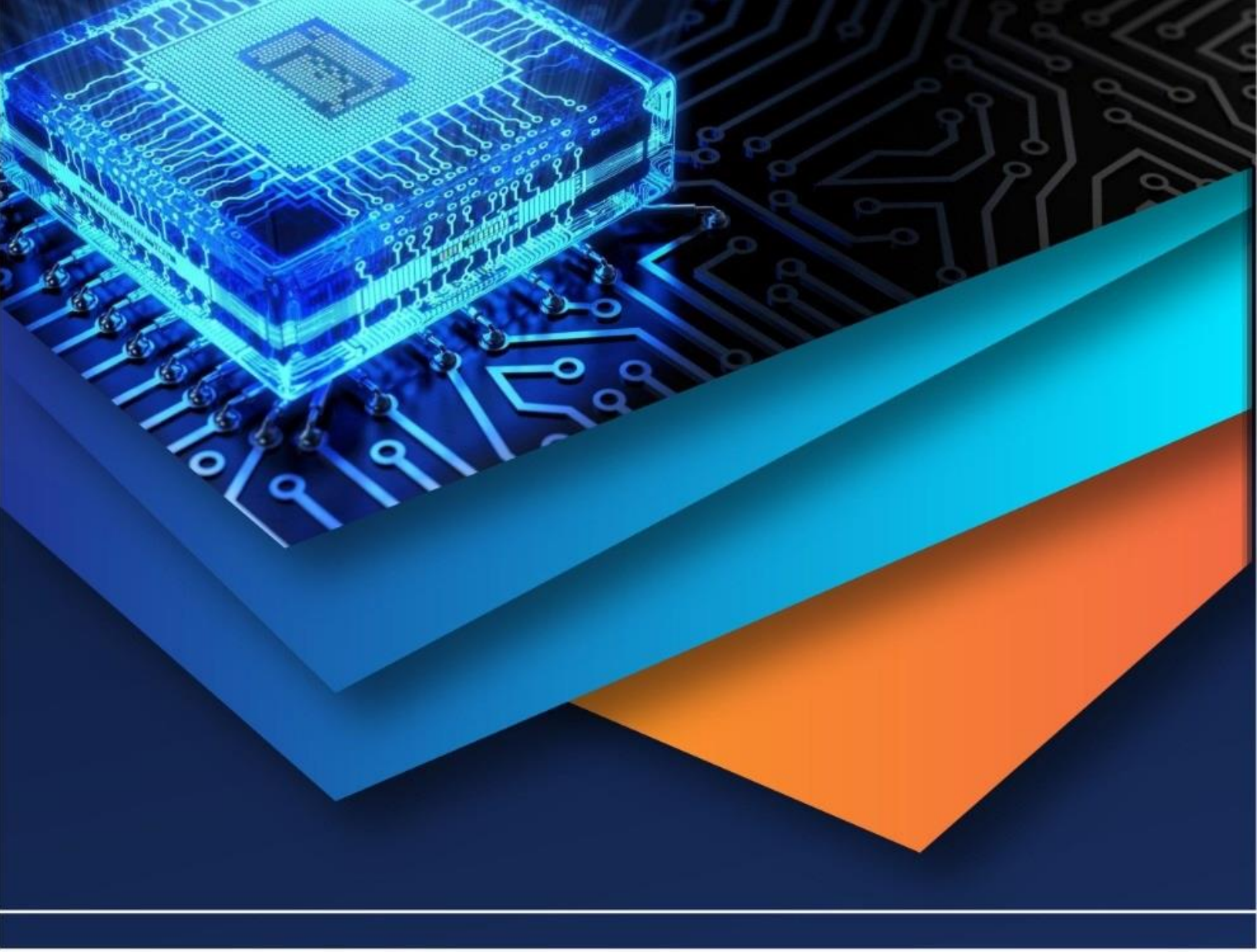

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