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Comparison of GFDM and OFDM with respect of SER, PSD and PAPR

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Abstract:As the technology grows up and the increase in the use of technology, it is a need of time to improve our communication systems, to face the diverse applications we people need to work on; the improved data rate, low battery consumption, robust systems and better response time. For all these we need to utilize the bandwidth as efficient as possible. Here our focus will be on the physical layer waveforms including the Power Spectral density, Bit error rate performance and peak to average power ration of Generalized Frequency Division Multiplexing (GFDM) and Orthogonal Frequency division multiplexing(OFDM). After introduction of both GFDM and OFDM this paper includes 1) why we need waveforms and what are the possible techniques for the next coming generation; 2) Complete analysis with bock diagram; 3) Bit error rate based performance and the effects of channels; 4) Power spectral density (PSD) comparison; 5) Peak to average power ration base comparison 6) Frame wise comparison 7) The summery of all, where GFDM lag and where this technique is helpful.

Keywords:5G, GFDM, OFDM etc.

I. Introduction

As communication system is growing up, there is increase in the demand of data drastically. 3G physical layer uses Coded Division Multiple Access (CDMA), this technique needs code for every sub carrier. To utilize the resource in better way the researcher introduces new technique for 4G technology. The original of cell frameworks gave fundamental, yet creative, voice transmission. Correspondence began to end up distinctly individual as opposed to being associated with settled areas. The second era has digitalized the voice so as to expand framework limit, battery life of gadgets and Quality of Service (QoS) [1]. It likewise presented the Short Message Service, which upset the way individuals convey. The third era empowered versatile Internet get to and information rates not very a long ways behind of wired arrangements of that time. The appearance of advanced cells with vast stockpiling and handling capacities furnished with top notch screen and cameras, in blend with informal communities that transformed clients from media purchasers into substance suppliers, has pushed the fourth era towards considerably higher throughput. Beginning with the second era, the advancement of the portable correspondence has concentrated on expanding the throughput. Cell frameworks of the fourth era (4G) have been streamlined to give high information rates and dependable scope to portable clients. In any case, the situations predicted for future fifth era (5G) systems have necessities that unmistakably go past higher information rates.

For example, the required pinnacle information rate for IMT-propelled, will achieve 100Mbit/s for high portability applications and 1Gbit/s for low versatility applications. Stringent necessity has been put on ghastly proficiency and the issue is further irritated by rare transfer speed. Then again, it is turning out to be increasingly important to give "ubiquitous" network to end clients with the goal that they can simply get associated by means of heterogeneous get to procedures. Consequently, it is alluring to create advancements with reasonable many-sided quality that encourages consistent handover among various models in different radio situations: indoor or open air, in urban-sub-urban or provincial ranges.

The blast of versatile applications and information utilization in the current years require the improvement of versatile, adaptable, and productive radio get to innovations. Subsequently, multicarrier procedures have been widely utilized in the course of the most recent decade for broadband remote interchanges. This wide intrigue is fundamentally because of their engaging attributes, for example, the support for multiuser differing qualities, less difficult adjustment, and versatile balance and coding systems [2].

Among numerous other multicarrier strategies, orthogonal recurrence division multiplexing (OFDM) commands the current broadband remote correspondence frameworks. As a key innovation, Orthogonal Frequency Division Multiplexing (OFDM) has appeared to be exceptionally effective in remote and wire line correspondence over broadband channels. At present, Orthogonal Frequency Division Multiplexing (OFDM) is a broadly received arrangement for the most part as a result of its heartiness against multipath channels and simple usage in view of Fast Fourier Transform (FFT) calculations [5]. In any case, the cell frameworks of the cutting edge will confront more assorted application necessities: the interest for higher information rates surpassing 4G abilities; battery-driven correspondence sensors require ultra-low power utilization; control applications require short reaction times. The fundamental situations for 5G systems are machine sort correspondence (MTC) [6], Tactile Internet and Wireless Regional Area Network (WRAN), while traditional piece pipe correspondence is still viewed as a vital application. These application situations anticipated for 5G systems show challenges which OFDM can just address limitedly. MTC and machine-to-machine (M2M) [6] correspondence require low power utilization, which makes the strict synchronization prepare required to keep the orthogonality between subcarriers excessively expensive. The low inertness required for Tactile Internet and vehicle-to-vehicle (V2V) applications requests for short blasts of information, implying that OFDM signals with one cyclic prefix (CP) per image would exhibit a restrictive low ghostly effectiveness. The low range productivity due to the CP addition is additionally an issue for WRAN application, where the run of the mill channel motivation reaction has the span of tenths of microseconds. Furthermore, the high out-of-band (OOB) emanation of OFDM [7] represents a test for astute and element range get to. Every one of these difficulties make OFDM not the most encouraging waveform for the cutting edge systems. In this specific situation, elective multicarrier plans are as of now being assessed as possibility for the Physical layer of up and coming era of versatile correspondence frameworks.

An adaptable multicarrier regulation plan, named Generalized Frequency Division Multiplexing GFDM) [8], has likewise been proposed for the air interface of 5G systems. The adaptability of GFDM permits it to cover CP-OFDM and single bearer recurrence space adjustment (SC-FDE) as uncommon cases [2]. GFDM depends on the regulation of autonomous pieces, where every square comprises of various subcarriers and sub-images. The subcarriers are separated with a model channel that is circularly moved in time and recurrence space. This procedure decreases the OOB emanations, making divided range and element range portion attainable without extreme obstruction.

Thus, the GFDM handset is wide band and addresses the accompanying requests:

- Low out of band radiation to stay away from unsafe obstruction
- Simple adjustment regardless of the wideband way of the transmit flag
- Flexible flag transmission capacity
- Digital execution to diminish the necessities of the simple front-end

GFDM goes for consolidating the adaptability and straightforwardness of OFDM with more grounded impedance diminishment systems.

The other segment of this paper incorporates: Section II: The frameworks show portrayal and procedure of tweak and demodulation. Segment III investigate the Bit mistake rate execution of both systems. Segment IV breaking down the waveforms for the Power ghostly proficiency execution Section V Frame base examination Section VI Conclusion of the paper.

II. System Model and Properties:

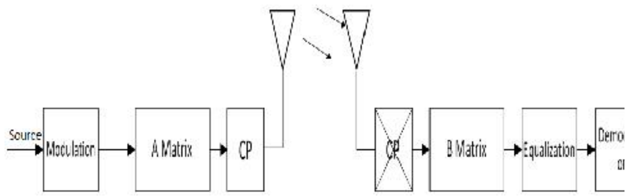

Figure 1: GFDM block diagram

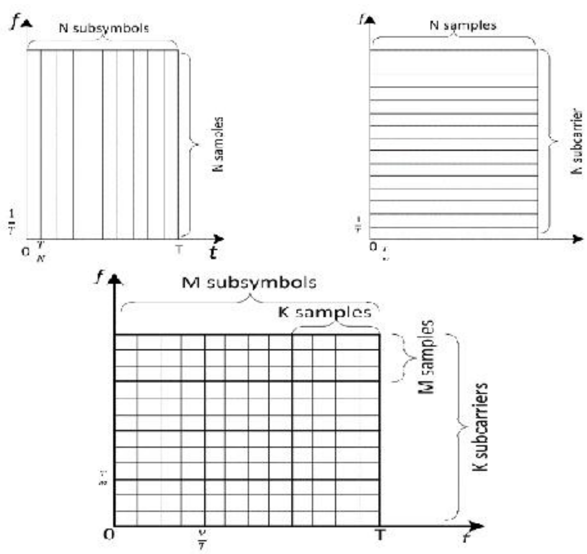

Figure 2: Time and Frequency based divisions of sub-carriers

These sub-carriers and sub-symbols makes the difference in the transmission process. The total number of symbols are N = MK. Here $d_{k,m}$ corresponds to data transmitted at kth sub-carrier and mth sub-symbol. These are transmitted with the pulse shaping filter.

$$g_{k,m}[n] = g[(n - mK) mod\ N].\exp\left[-j2\pi \frac{k}{K} n\right] \quad (1)$$

n denotes sampling index. $g_{k,m}[n]$is a circularly shifted version of $g_{k,0}[n]$. Thetransmit samples

Block diagram given in Figure 1 is a system model of GFDM.Binary bit generated from a data source.

These data bits have been mapped by using QAM modulator, map the bits to symbols from a2^{μ}valued complex constellation whereμ is the modulation order. Here the resulting vector contains N elements, which can be decomposed into K subcarriers with M sub symbols. These are shown in the Figure 2

$\vec{x} = (x[n])$ areobtained by superposition of all transmit symbols.

$$x[n] = \sum_{k=0}^{K-1} \sum_{m=0}^{M-1} g_{k,m}[n] d_{k,m}, \qquad n = 0, \dots, N-1$$

Collecting the filter samples in a vector. In the form of formula given below

$$\vec{x} = A\vec{d}$$

Here A is the transmit matrix having MK x MK [9] elements. The other way of writing A matrix is

$$A = (\vec{g}_{0,0} \dots \dots \vec{g}_{K-1,0} \vec{g}_{0,1} \dots \dots \vec{g}_{K-1,0M-1})$$

In Figure 3 the implementation of A matrix has been shown. We can see the implementation of circular convolution matrixTransmission is done through a channel using equation

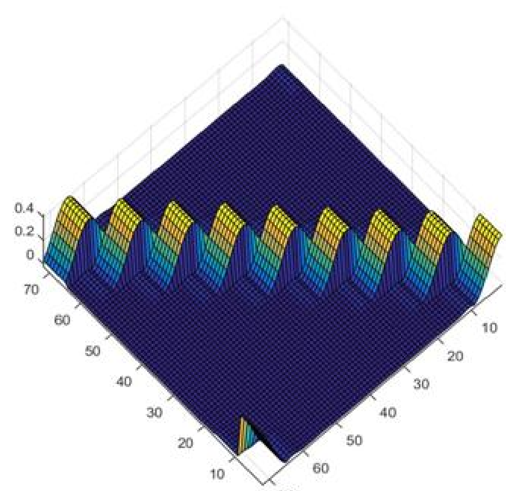

Figure 3: GFDM modulator/transmitter matrix with K = 8, M = 9 and N = MK = 72

$$\vec{y} = H\vec{x} + n$$

Here H is the channel, while $\vec{y}$ is the receive counterpart of $\vec{x}$.

At receiver end the cyclic prefix is removed firstthen comes the equalization process. There are several techniques for doing equalization. Zero-forcing channel equalization is efficiently used in OFDM, although other equalization procedures can be employed. The overall transceiver equation can be written as$\vec{y} = HA\vec{d} + n$. In GFDM the equalization technique can be used. The received signal after channel equalization, linear demodulationof the signal can be expressed as

$$\vec{d} = B\vec{z}$$

Here B is a KM ×KM receiver matrix. Several standard receiver options for the GFDM demodulator are readily available in literature:The*matched filter*(MF)receiver

$$B_{MF} = A^H$$

Maximizes the signal-to-noise ratio (SNR) per subcarrier,but with the effect of introducing self-interference whena non-orthogonal transmits pulse is applied. The*zero-forcing*(ZF) receiver [10]

$$B_{ZF} = A^{-1}$$

On the contrary completely removes any self-interference at the cost of enhancing the noise.
From the description of the transmitter and receiver, it can be concluded that GFDM falls into the category of filtered multicarrier systems. The name derives from the fact that the scheme offers more degrees of freedom than traditional OFDMor single carrier with SC-FDE. GFDM turns into OFDM when M = 1, A = F_H^N and B = F_N, where F_N is a N × N Fourier matrix. SC-FDE is obtained when K = 1 and SC-FDM, a frequency division multiplexing of several SC-FDE signals. However, the important property that distinguishes the proposed scheme from OFDM and SC-FDE is that, like SC-FDM, it allows dividing a given time-frequency resource into K subcarriers andM sub-symbols as depicted in Figure 4. Therefore, it is possible to engineer the spectrum according to given requirements and enables pulse shaping on a per subcarrier basis. As a consequence, without changing the sampling rate, GFDM can be onfigured to cover a portion of bandwidth either with a large number of narrow bandsubcarriers like in OFDM or with a small number of subcarriers of large individual bandwidth like in SC-FDM. Further it is important to note that although filters are introduced, GFDM is still a block based approach. These aspects are relevant for the scheduling of users in a multiple access scenario and also when targeting low latency transmission [11].

1. BER vs SNR performance

This section includes the analysis of GFDM performance in terms of symbol error rate (SER) vs Signal to Noise Ratio (SNR). Assuming that a ZF receiver is employed. This type of linear receiver is able to remove self-generated interference at the cost of introducing noise enhancement [12-28], depending on the pulse shape. This section introduces analytical expression to evaluate the GFDM SER performance under AWGN and static frequency-selective channels (FSC).

Sr. No	Parameters	GFDM	OFMD
1.	Modulation Technique	16-QAM	16-QAM
2.	Transmit Filter	RC	Rectangular
3.	Roll off factor	0.1 or 0.9	N/A
4.	Number of subcarriers	64	64
5.	Number of sub-symbols	9	-
6.	Cyclic Prefix	10	10

The parameters for simulation are given in table 1. Figure 5 compares the SER performance of GFDM and OFDMunder AWGN taking the energy spent for CP into account.
The Figure4 shows that the pulse shape and, consequently the Noise enhancement factor (NEF) i.e. α, plays an important role in the GFDM performance. At α = 0.1 SER vs SNR performance is better as compared to α = 0.9.

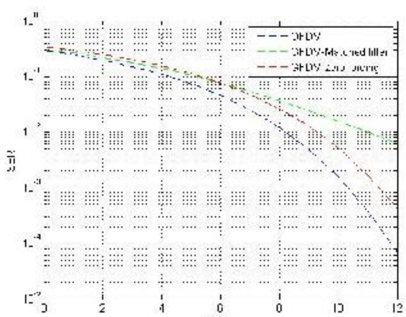

Figure 4: SER vs BER curve on AWGN channel

Now in Figure 5 we can see the performance on Frequency selective Rayleigh fading. Considering GFDM match filtering curve with OFDM curve at α = 0.1 and α = 0.9 for both the results are not good for the system because it is giving at every 10^{th} bit which shows lack of robustness. Now looking at the GFDM curve with zero forcing equalization this result is pretty closer to the result of OFDM.

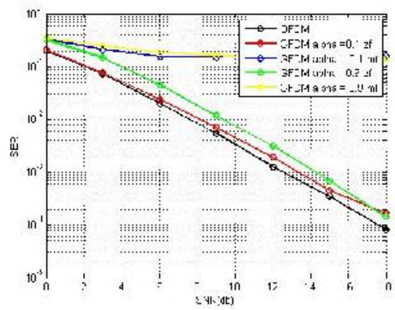

Figure 5: SER vs BER curve on Frequency selective Rayleigh fading

2. Waveforms of PSD:

GFDM flexibility gives advantage over out-of-band emission. In this section we will discuss about the power spectral density vs frequency graph.

We present the OOB emission performance of OFDM and GFDM, at the transmit side in Figure 6. For our setup, OFDM and GFDM exhibit identical OOB emission performance. GFDM has been reported to exhibit better OOB emission than OFDM, which is caused by the fact that the number of subcarriers for both waveforms was not set to be equal.

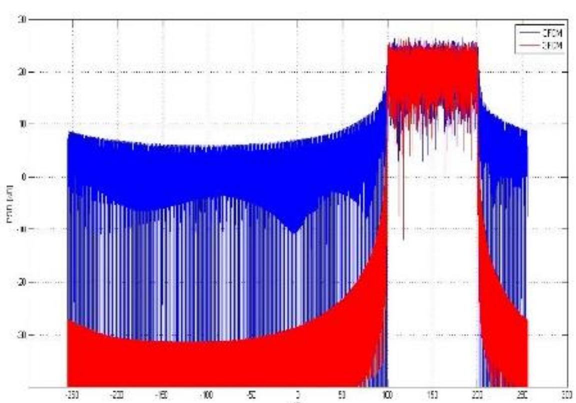

Figure 6: PSD vs f/F graph with K = 512 and M = 14 for GFDM and M = 1 for OFDM

It can be clearly scene that the power consumes on the side lobs is much high in case of OFDM while in case of GFDM more power is consumed on the main lobs.

When it comes to complexity comparison, GFDM require higher complexity than OFDM, the difference is more prominent in case of GFDM since we use a root-raised cosine filter while in case of OFDM we use rectangular pulse shaping filter. Since GFDM sub-carriers are semi-orthogonal so during equalization we cannot retrieve the original signal back by multiplying the transmit signal with its conjugate we need to multiply it with the inverse of the transmitted signal.

5. Frame base comparison:

Consider Figure 7 we can see that there is cyclic prefix after every timeslot which utilize too much bandwidth so while in case of GFDM there is CP after every frame this proves that utilization of bandwidth is increased.

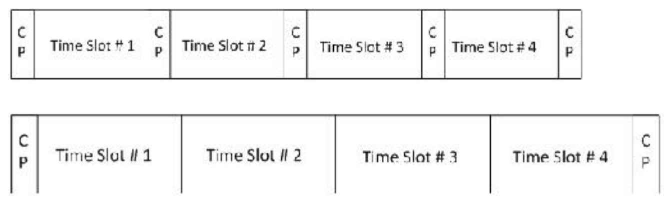

Figure 7: Comparison of frames of OFDM and GFDM

6. Conclusion:

In conclusion GFDM is better techniques for two reasons, First, it has low PAPR [12], which helps in low power consumption of mobile devices.

Second, the power spectral density (PSD) of GFDM is less this shows GFDM provides lesser leakage of energy on the side lobes which helps in reduction of OOB radiation.

But for one reason GFDM is not suitable for 5G technology i.e. its complexity. It is more complex as compared to OFDM. This makes the system cheaper.

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