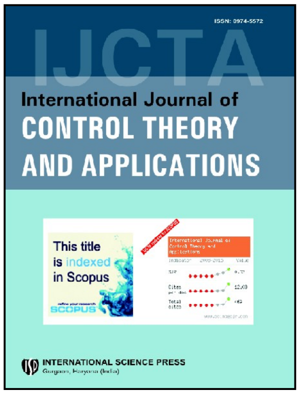

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SER Analysis of Generalized Frequency Division Multiplexing under Various Real Time Fading Conditions

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Abstract: As 4G LTE(Long Term Evolution), is getting deployed across the globe, research fraternity and industry is working on the 5G requirements and especially in improving spectral efficiency and the communication everywhere. As the existing OFDM, which is getting used in 4G LTE has limitations such as Inter Carrier Interference(ICI) and Inter Symbol Interference(ISI), due to Orthogonality. To avoid the ICI and ISI, cyclic prefix is added to each symbol andit needs more spectrum. In an effort to improve the spectrum efficiency, Generalized Frequency Division Multiplexing (GFDM) is proposed as an alternative to OFDM. In this paper GFDM transceiver and various channel conditions are simulated using Matlab Software andalso analyzed the SER performance of GFDM as a 5G candidate waveform with the existing LTE OFDM, under various 3GPP defined LTE fading profiles like EPA, EVA and ETUM. It is observed that GFDM performance is better than OFDM under fading conditions.

Keywords: OFDM, ISI, ICI, Orthogonality, Cyclic Prefix, GFDM, Rayleigh, 3GPP Profiles

I. INTRODUCTION

Mobile communication has turned into a key component of the current technology driven society. Analog voice services with mobility are provided by 1G and digital voice services with increased voice capacity in 2G;3G mobile broadband services enabled faster data rates and better connectivity. Now, 4G systems provide high speed data along with voice and multimedia services. 4G mobile communication system involves OFDM, Multiple Input Multiple Output (MIMO) and smart antenna technologies. OFDM is adopted solution for LTE mainly due to its easy implementation based on Fast Fourier Transform (FFT) algorithms and robustness against multipath channels. The OFDM systems cannot cope up with the challenges in realizing the applications and use cases for the 5G networks [1]. GFDM is proposed to overcome the deficiencies of OFDM system [2].

To bring out better energy efficiency and spectrum, GFDM goes for a dynamic adoption of pulse-shaping gain on frequency and time on the fading channel. Unlike the OFDM system, GFDM transmits multiple symbols in the multi-carrier for each two-dimensional (time and frequency) block structure [3]. By circularly convoluting each individual subcarrier, block structure can be attained by pulse shaping filter, thanks to the pulse-shaping filters, good placement of the transmitted signal shows sub-carrier frequency provides low radiation in stop band. In addition, the time windowing schemes better leakage control can be applied to block a GFDM stop band CPs in small values. Variable pulse shaping filters cut-out orthogonality among the subcarriers; ICI and ISI are attained at the end of this process. GFDM allows very simple design of transmitters and also reduce the signal processing load. In addition to these features of GFDM, if some of the processing shifted to base stations wherever possible, help in the reduction of the power consumption at terminals. This is not possible in OFDM; due to the requirement of accurate synchronization and sync pulse leakage. The second section describes GFDM system design, third section describes simulation of communication channel with 3gpp profiles, fourth section describes about results of PSD and 3GPP profiles.

II. GFDM SYSTEM DESIGN

The GFDM transceiver [4] block diagram is as shown in the fig.1. In the GFDM system, binary information is encoded, mapped with QAM symbols, given to GFDM modulator and the CP is added and transmitter on a wireless channel. At the receiver side information will be received, CP will be removed then demodulated, de-mapped, and decoded in to binary data.

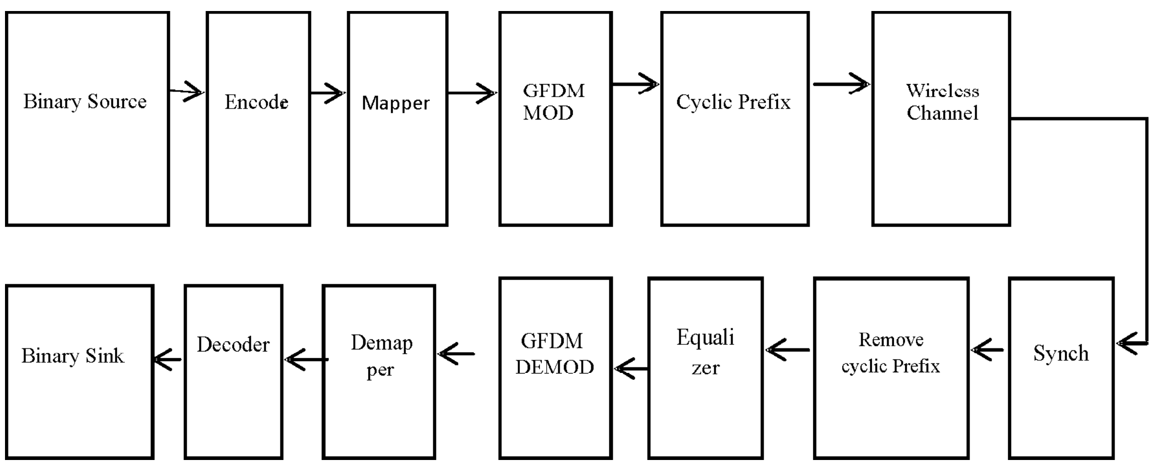

Figure 1: Block diagram of Communication transceiver using GFDM

A. Transmitter

Let us consider a base band system with K carriers and M symbols of complex information symbols $i\ (K, M)$. Atransmit pulse $g_{Tx(n)}$ is used to shape each sub-carrierand modulated with a center frequency $e^{j2\pi k.kn/N}$. Each symbol is sampled N times which results MN samples per sub-carrier, so that the Nyquist criteria is satisfied. The filter $g_{Tx}(n)$ was placed to have the $M \times N$ periodicity. After the information samples are placed in $i(k, m)$ matrix, I perform the up sampling, circular convolution upon pulse shaping filter results to up conversion and superposition equation as

$$x = Ai, \tag{1}$$

Where, x transmitted samples in time, A is $MN \times MN$ modulation matrix

Transmitted signal is written as

$$x[n] = \sum_{m=0}^{M-1} \sum_{k=0}^{K-1} i_k\,[m] \tilde{g} T_x [n - mN] e^{j2\pi \frac{kn}{n}} \tag{2}$$

Cyclic prefix should be added to $x[n]$ results as $\overline{x}[n]$.

Table 1
GFDM System Parameters

Parameters	*Description*
T_s	Sampling time
B	Bandwidth
N	FFT size
K	Active subcarriers
M	Block Size
Filter	RRC Filter
α	Roll-off factor[Filter]
L	Filter size in frequency domain

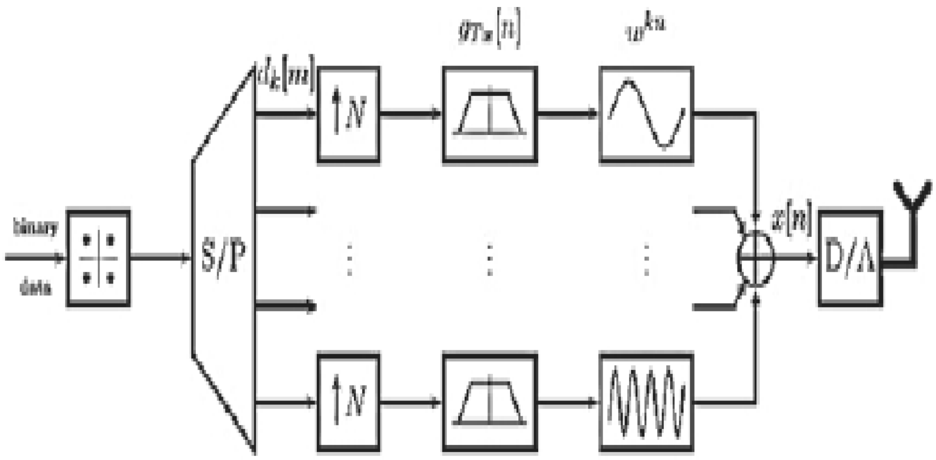

Figure 2: GFDM Transmitter block diagram

The information bits are mapped to QAM symbols and are up sampled. On those information symbols circular convolution with RRC pulse is performed. Circular convolution inphase indicates the real part and circular convolution Quadrature indicates the imaginary part. Real and imaginary signal is changed into the baseband signal when it was filtered with Low Pass Filter (LPF). Here we use RRC filter in this process to achieve unity gain at low frequencies.The root raised cosine pulse shape filter is also a well-known and often applied pulse shaping filter. The frequency response of RRC filter is given be

$$G_{RRC}(f) = \sqrt{G_{RC}[f]} \quad [2] \tag{3}$$

This way, applying a matched filter results in a raised cosine composite response and therefore no ISI is expected when receiving data. However, the filter is not ISI-free after the transmission and therefore a larger out of band radiation is expected. Applying an inverse Fourier transform to $G_{RRC}(f)$ results in the time domain response of the RRC pulse filter, given by

$$G_{RRC}(\mathrm{t})=A\,\frac{\sin\left(\pi\frac{t}{T_S}(1-\alpha)\right)+4\alpha\frac{t}{T_S}\cos\left(\pi\frac{t}{T_S}(1+\alpha)\right)}{\pi\frac{t}{T_S}\left(1-\left(4\alpha\frac{t}{T_S}\right)^2\right)} \tag{4}$$

Where, A is a normalized factor. When using this transmit filter, no ISI is expected, ICI will be higher than that of the raised cosine filter, this is because of RRC frequency response is greater than RC frequency response.

(B) Receiver

The received signal is a time invariant multi path channel with impulse response $h[n]$ and expression can be written as

$$\bar{y}=\bar{x} * h[n] + n[n] \tag{5}$$

Where $\bar{x}$ transmitted signal along with CP is, $n[n]$ are Gaussian noise samples with zero mean and variance $\sigma^2 n$.

When CP is removed, we get the equation as

$$y[n] = x[n] + n[n] \tag{6}$$

Suppose that is known at the receiver, M block of information symbols is equalized by

$$\bar{y}=IDFT\left[\frac{DFT(y(n))}{DFT(h(n))}\right] \tag{7}$$

From the transmitter, receiving the signal can happen in three ways[5]; one way is to find a matrix $A^{\#}$ so it becomes (Identity matrix), depending on the capacity of One, that can be seen as

$$A^{\#}=(A^{\#}A)^{-1}A^{H} \;\; or \;\; A^{\#} =A^{H}((AA^{H})^{-1}) \tag{8}$$

Where $\bar{\iota}_{ZF}=A^{\#}Y$ is a *zero forcing Receiver*.

Zero Forcing Receiver helps to lower the self-interference when no noise being present.

Matched filter can be used in the 2nd way of receiving the GFDM signal which helps to reduces the signal to noise ratio when additive stochastic noise is exists.

$$\bar{\iota}_{MF}=A^{H}Y. \tag{9}$$

MMSE (minimum mean-squareError) can be used as third way of receiving the GFDM signal

$$A^{\alpha} = \left(\frac{\sigma_n^2}{\sigma_n^2} I + A^{H}A\right)^{-1}A^{H}. \tag{10}$$

The input parameters used to simulate the GFDM system is described in the table 1

III. SIMULATION OF COMMUNICATION CHANNEL WITH 3GPP PROFILES

Simulation of the GFDM Transceiver along withchannels for various 3GPPfading profiles will be done by using Matlab simulation Software Package.

(C) Channel

Channel was the main concept need to consider while talking about digital communication, it's a medium to send and receive the information. While we talking about wireless channel modeling we need to consider Reflection, Refraction, and Scattering, these results in fading of signal .Over large distances, the signal quality degrades even without the presence of large quantities of AWGN.

Degradation is known as fading, and this is characterized by the channels are fading channels. In overall fading channels Rayleigh and Rician distributions are most commonly used. In this paper Rayleigh Distribution is used.

(D) Rayleigh Distribution

When are likely independent components, probability density function of the amplitude has Rayleigh pdf as-

$$f(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}} \quad (11)$$

Rayleigh fading represents the worst case fading condition because we do not consider Line-Of-Sight (LOS). The power is distributed quickly, the phase is evenly distributed and is independent of amplitude ,most commonly use in wireless communication signal model.

(E) Multipath Fading Propagation Conditions

Meanwhile when a signal propagates from transmitter to receiver it undergoes multipath. There might be Line Of Sight in between a transmitter and a receiver or it may reflect to ground and then it may reach to receiver, when this reflected copies of same signal reaches to receiver they may have delay and attenuation based upon path length. Three well known LTE channel models of multipath profiles are defined by 3GPP [6] and is given in the tables 2, 3, 4.

Table 2
Extended Pedestrian Models(EPM)

Tap	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Excess Tap Delay in Nano seconds	0	30	70	90	110	190	410
Relative Power in dB	0.0	-1.0	-2.0	-3.0	-8.0	-17.2	-20.8

Table 3
Extended Vehicular Models (EVM)

Tap	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Excess Tap Delay in Nano Seconds	0	30	150	310	370	710	1090	1730	2510
Relative Power in dB	0.0	-1.5	-1.4	-3.6	-0.6	-9.1	-7.0	-12.0	-16.9

Table 4
Extended Typical Urban Models (ETUM)

Tap	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Excess Tap Delay in Nano Seconds	0	50	120	200	230	500	1600	2300	5000
Relative Power [in dB]	-1.0	-1.0	-1.0	-0.0	-0.0	-0.0	-3.0	-5.0	-7.0

IV. SIMULATION RESULTS

The GFDM and OFDM systems along with the 3GPP fading profiles are simulated and the input parameters are used is as per table 5

Table 5
Input parameters with values

Parameter	*Value*
T_s	50
B	20000000
K	99
M	15
A	0.3
L	2
N	K*M

The power spectral density (PSD) diagram of simulated GFDM and OFDM signals are shown in figure 3.

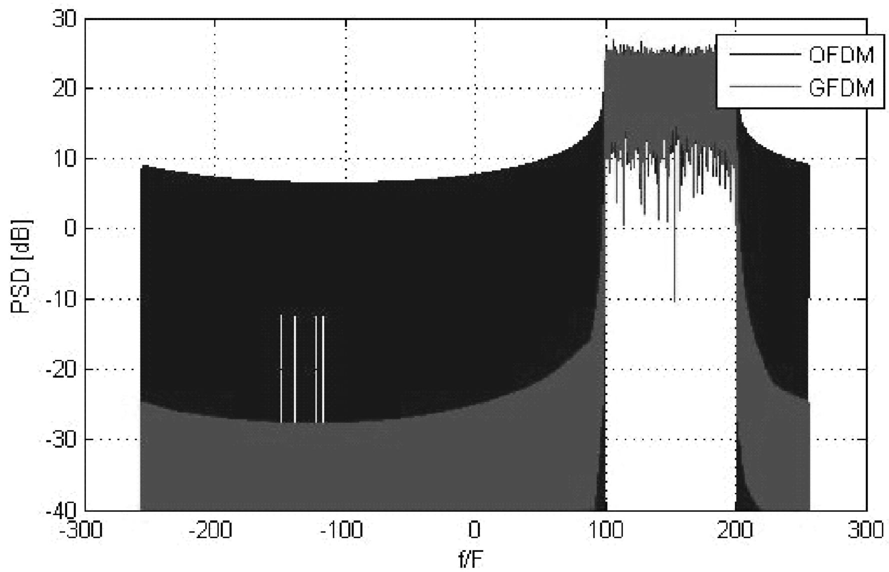

Figure 3: PSD of GFDM and OFDM

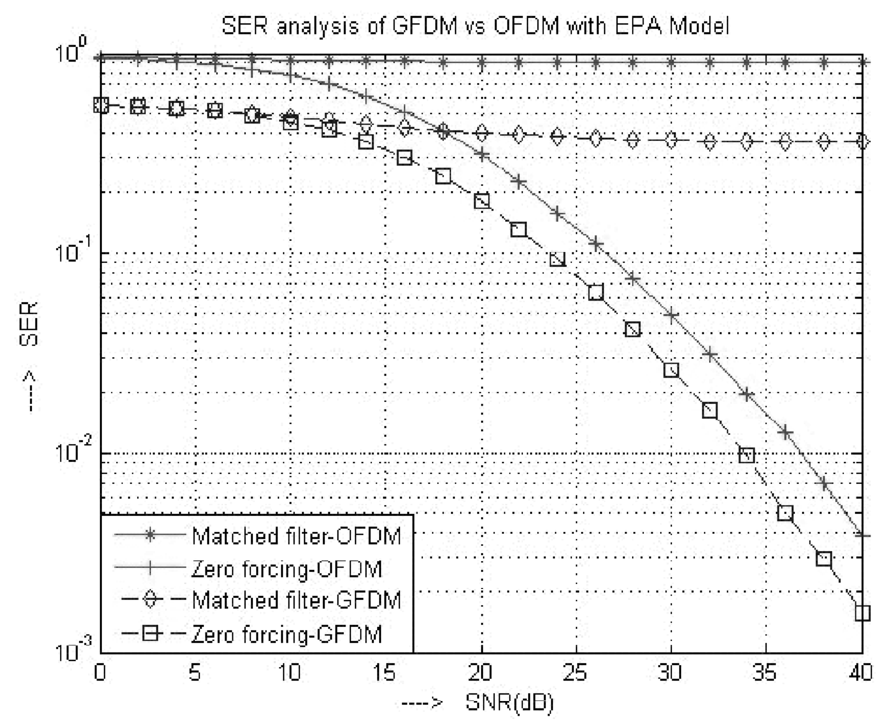

Figure 4: SER analyses under the EPA fading profile

From the fig.3, it is noticed that in the GFDM system, the side lobe suppression is more than 14 dB, when compared to the OFDM system.

In this paper the SER calculations are performed for both GFDM and OFDM under various 3GPP fading profiles –EPA, EVM, and ETUM and the diagrams are as shown in fig. 4, 5, 6 respectively.

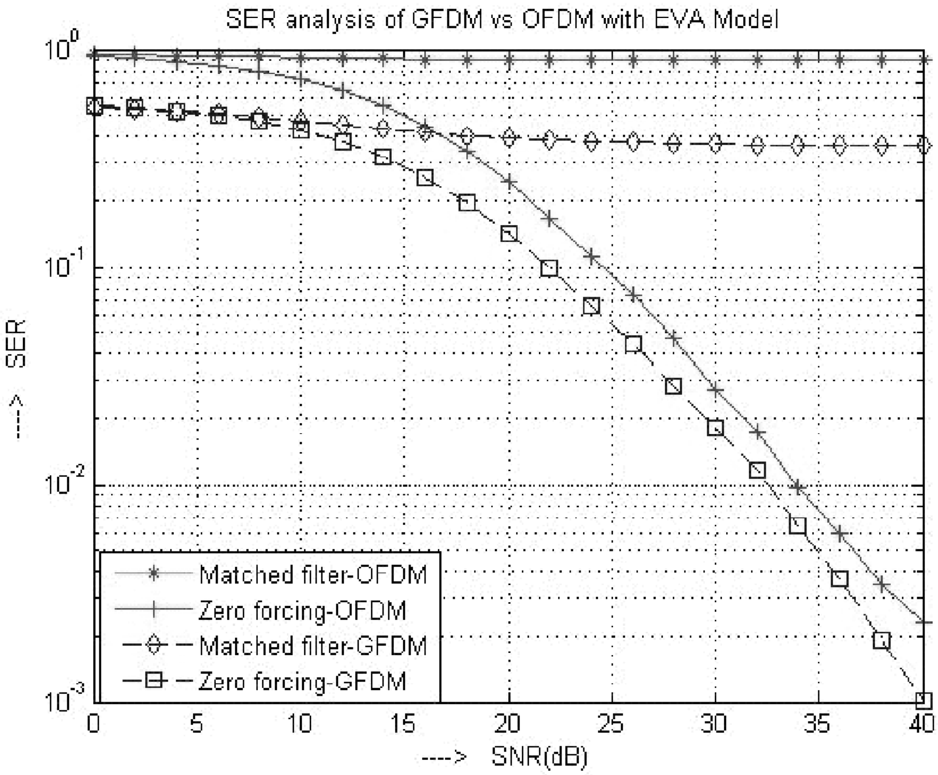

Figure 5: SER analyses under the EVM fading profile

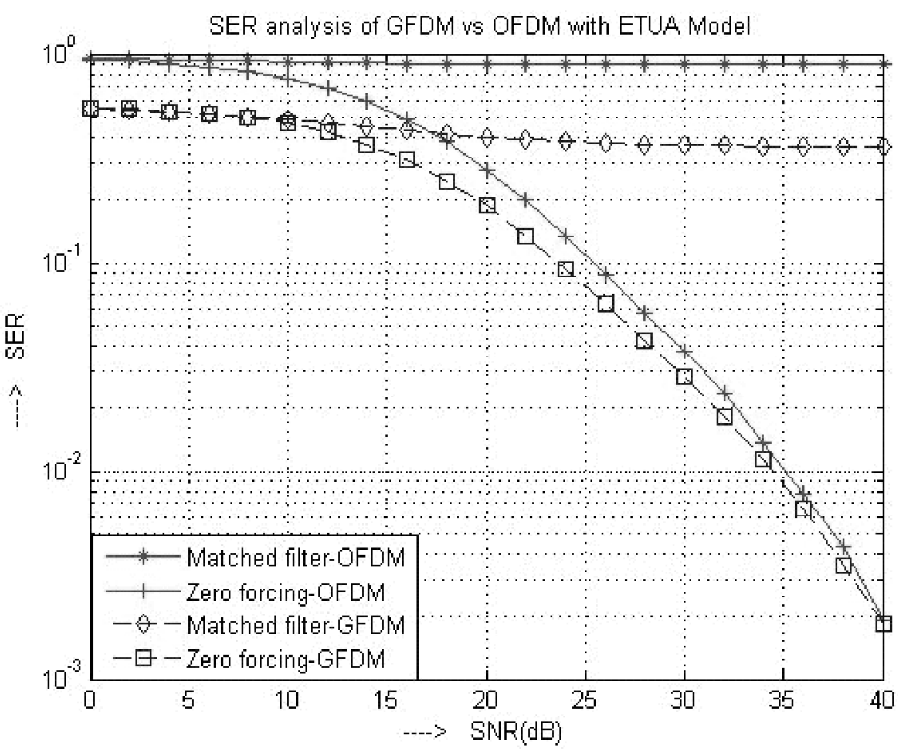

Figure 6: SER analysis under ETUM fading profile

From the fig.4, 5, 6 it is observed that, zero forcing filter at the receiver gives a better performance than the matched filters. It is also observed that the GFDM signals have fewer errors than OFDM signal at the receiver for all the 3GPP defined fading conditions. One more noticeable thing about GFDM is under noisy conditions (i.e., lower SNR), it outperforms the OFDM.

V. CONCLUSIONS

In this paper, it has been proved that GFDM outperforms, OFDM in terms of better PSD characteristics, immune to noisy and fading conditions, under various 3GPP defined conditions. The present work can be extended to high speed vehicles profile, since 5G communications includes high speed vehicle communications.

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