Performance Analysis of Generalized Frequency Division Multiplexing in Various Pulse-shaping Filter with raised cosine and root raised cosine filter

Megha Gupta (meghagupta4747@gmail.com)
Shri Govindram Seksaria Institute of Technology and Science https://orcid.org/0000-0001-5456-0300
R.S Gamad
Shri Govindram Seksaria Institute of Technology and Science

Research Article

Keywords: Generalized frequency division multiplexing (GFDM), signal to noise ratio, raised cosine filter, root raised cosine filter, additive white gaussian noise

Posted Date: June 6th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1630671/v1

Performance Analysis of Generalized Frequency Division Multiplexing in Various Pulse-shaping Filter with raised cosine and root raised cosine filter

Megha Gupta[1] and R.S. Gamad[2]

Phd scholar, Department of Electronics & Instrumentation Engg. Shri G.S Institute of Technology and Science, Indore, India[1], meghagupta4747@gmail.com

Professor, Department of Electronics & Instrumentation Engg. Shri G.S Institute of Technology and Science, Indore, India[2], rsgamad@gmail.com

ABSTRACT: Generalized frequency division multiplexing (GFDM) is non orthogonal multicarrier modulation scheme which is suitable for the fifth generation (5G) of wireless network. Pulse shaping filter design in GFDM system have effects on symbol error rate performance due to inter symbol interference (ISI). In this paper Contribute to symbol error rate (SER) performance in GFDM system with additive white Gaussian noise channel (AWGN), zero forcing channel (ZF) rayleigh fading has been analyzed for pulse shaping filter namely raised cosine (RC) and root raised cosine filter (RRC) and also Simulation is done and results are reported in terms of symbol error rate (SER), signal to noise ratio (SNR), different value of roll off factor and different modulation technique. Comparison of simulation results of this method with existing methods is done and improvements in result are obtained as compared to existing.

Keyword: Generalized frequency division multiplexing (GFDM), signal to noise ratio, raised cosine filter, root raised cosine filter, additive white gaussian noise.

1. INTRODUCTION:

GFDM is the multiplexing technique proposed for the 5G networks. It is the generalization of digital multi-carrier concept of trans receiver [1]. In GFDM, the blocks of data are independently modulated. Every block consists of various sub-carriers and every sub-carrier has various sub symbols. The pulse shaping of sub-carriers are done using circularly shifted filter which is shifted in both domains time as well as frequency. Out of band emissions (OOB) get reduced by this process. The inter symbol interference (ISI) and inter carrier interference (ICI) may arise due to subcarrier filtering [2]-[4]. Overhead is small in GFDM block as there is a single cyclic prefix (CP) for a block having various sub symbols . GFDM transreceiver encoded symbols belong to line of complicated constellation factors in which denotes the amount of bits in keeping with symbol, additionally referred to order of modulation [5]-[8].

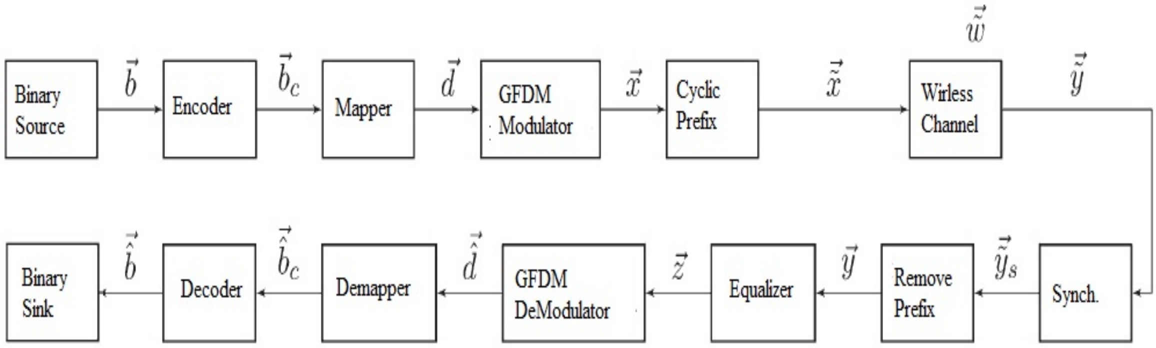

Figure 1: GFDM transreceiver

GFDM trasreceiver is given in figure 1. This is K= MN manufactured from two integers. The k factors are frequently visualized as disintegrated into N subcarrier and M subsymbol with the GFDM system overlapping factor. The NM X I coloumn vector d=[d(0)………d(M-1) denotes the transmitted data on the subcarrier. The baseband transmit signal in digital communication is achieved through the sum of all subcarrier and sub symbol signals according to

$$x[n] = \sum_{k=0}^{K-1} \sum_{m=0}^{M-1} g\,k,m[n]dk,m \quad n = 0,\ldots,N-1 \qquad (1)$$

where g(n) denotes the impulse response of prototype filter with N samples while k,m,n are subcarrier, subsymbol and time sample.This sequence can also be represented as a coloumn vector $g_{k,m}$ and d k,m being dk,m being the data symbol transmitted in the mth subsymbol of the kth subcarrier. Collecting the filter samples in a vector allows formulating as $\vec{x} = A\vec{d}$ whereas d represent data matrix and A represent transmit matrix[9]-[14].

2. PULSE SHAPING FILTER

In GFDM modulator various operation is performed serial-to-parallel conversion, pulse shaping operation is performed on each data symbol separately as represented by the equation (2)

$$p_{k,m}[n] = p[(n - mK) mod N]\; e^{j2\pi kn/K} \qquad (2)$$

where n is the sampling index, $p[n]$ is the pulse shaping used and $p_{k,m}[n]$ is the pulse shaping filter, p[n] after shifting in both time and frequency domain (2). In this shifted version of pulse shaping filter, complex exponential performs shifting in frequency domain and modulo operation performs shifting in time domain[15]-[17].

2.1 RAISED COSINE FILTER

Raised cosine filter (RC) is the pulse shaping filter and it is used to minimize the inter symbol interference (ISI). The impulse response of this filter as given (3)

$$p_{RC}(t) = sinc\left(\frac{t}{T}\right)\frac{\cos(2\pi\alpha t)}{1-(2\alpha\, t/T)^2}$$

…… (3)

In this pulse shaping filter, α is the roll off factor and T is the transmission symbol period.

2.2 ROOT RAISED COSINE FILTER

In digital communication, RRC is mostly used as transmit and receive filtering. The equivalent response of these two filters is equal to that of RC filter.

$$P_{rrc}(f) = \sqrt{|P_{rc}(f)|} \quad (4)$$

The impulse response of RRC is given as

$$p_{rrc}(t) = \sin[\pi t/(1-\alpha)] + 4\alpha t/T \cos[\pi tT(1+\alpha)]/\pi tT[1-(4\alpha tT)2] \quad (5)$$

where α is the roll off factor and T is the transmission symbol period[18]-[20].

2.3 SYMBOL ERROR RATE ANALYSIS

Symbol error rate (SER) is defined as the number of symbols in error when the symbols are transmitted through the channel. In the Generalized frequency division multiplexing model data symbols are transmitted through the additive white gaussian noise (awgn) and rayleigh channel using different pulse shaping filters at various values of roll off factor. The analysis of SER versus $Es/N0$ is done in case of zero forcing (ZF) receiver. The analytical expressions of SER in AWGN and Rayleigh channel are also calculated in this section[21]-[24]. The ZF receiver eliminates self-interference but introduces noise enhancement which depends on the choice of the pulse shaping[25,26]. The noise enhancement factor (NEF) denoted by ξ which causes reduction in signal-to-noise ratio (SNR) while using ZF receiver is given by the equation (6)

$$\xi = \sum_{n=0}^{MK-1} |[B_{ZF}]_{k,n}|^2 \quad (6)$$

3. RESULT AND DISCUSSION

Simulation results of the impulse response of the pulse shaping filters used in the GFDM model at various roll off factor values, PSD and SER of the GFDM using different pulse shaping filters. The simulation results symbol error rate (SER) are calculated using AWGN channel and rayleigh channel and at various values of roll off factor. The simulation results are obtained using software MATLAB 2017a. The parameters used for the computation of results are given in table

Table 1: Simulation parameter spectrum analysis of GFDM model

Sub-symbols (M)	4
Sub-carriers (K)	4
Mapping	QAM
Roll off factor (α)	0.1
Channel	AWGN
Pulse shape filter	Raised cosine filter(RC)

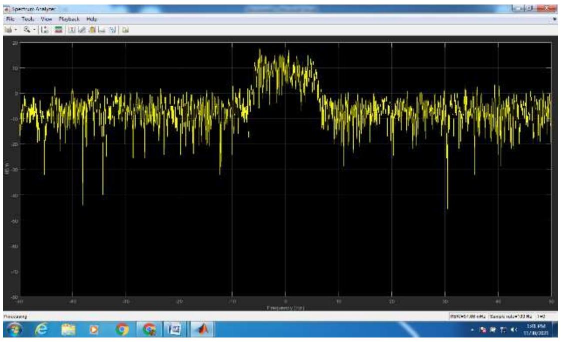

Figure 2 : **Spectrum analysis of GFDM transmit signal at α =0.1 in Quadrature amplitude modulation**

The figure 2 shows spectrum analysis of GFDM system. Number of symbol is 4,number of subcarrier is 4.roll of factor is 0.1,quadrature amplitude modulation are used . In this case signal passes through additive white Gaussian noise channel and zero forcing cannel .Raised cosine filter are used to improve the performance. Here obtained symbol error rate performance is zero and observed improvement in results.

Table 2: Simulation parameter spectrum analysis of GFDM with RC (α =0.1) in QPSK modulation

Sub-symbols (M)	2
Sub-carriers (K)	4
Mapping	QPSK
Roll off factor (α)	0.1
Channel	AWGN
Pulse shape filter	Raised cosine filter

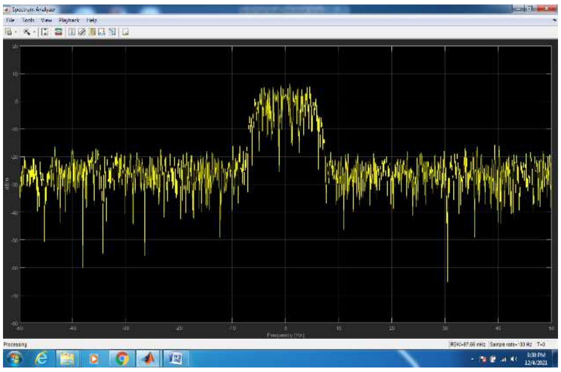

Figure 3: **Spectrum analysis of GFDM transmit signal at α =0.1 in QPSK modulation**

The figure 3 represent spectrum analyzer of GFDM system. number of symbol is 2, length is 50, number of subcarrier is 4 and roll off factor is 0.1. Quadrature phase shift keying are used This signal passes through additive white gaussian noise channel. Raised cosine filter are used to improve the performance and result shows performance improvement.

Table 3: Simulation parameter symbol error rate and snr performance with raised cosine filter in GFDM

Sub-symbols (M)	8
Sub-carriers (K)	4
Mapping	QAM
Roll off factor (α)	0.05, 0.1, 0.15, 0.2, 0.25 and 0.3
Channel	AWGN
Pulse shape filter	Raised cosine filter

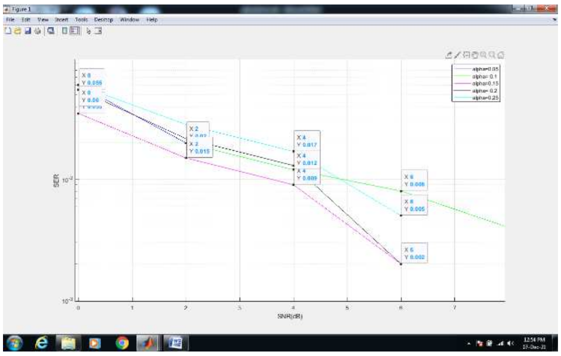

Figure 4: Simulation result of SER versus SNR at different roll off factor in AWGN channel

The figure 4 indicates signal to noise ratio at x axis and y axis represent symbol error rate. Quadrature Amplitude modulation is used at transmitter with different roll off factor 0.05, 0.1, 0.15, 0.2 and 0.25 such as shown in figure. Then signal is passed through additive white Gaussian channel. At the receiver end raised cosine filter are used to improve the performance. The result indicates improvement result at roll factor 0.2 and 0.15 with signal to noise ratio 6 and here obtained symbol error rate is 0.002.

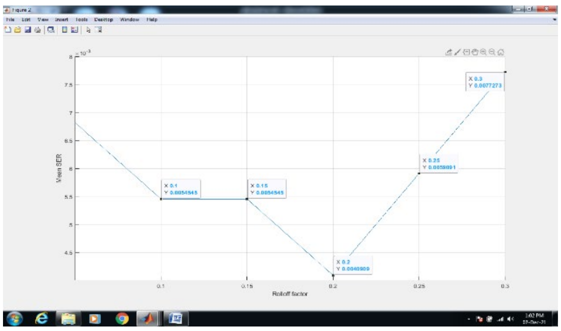

Figure 5: Simulation result of mean symbol error rate versus different roll off factor in additive white gaussian channel

This figure 5 shows x axis represent roll off factor and y axis represent mean symbol error rate when roll off factor is 0.2 and get the values 0.0004. It obtains improvement result.

Table 4: Simulation parameter of symbol error rate and SNR with root raised cosine filter in GFDM

Sub-symbols (M)	512
Sub-carriers (K)	4
Mapping	QAM
Roll off factor (α)	0.05, 0.1, 0.15, 0.2,0.25 and 0.3
Channel	AWGN
Pulse shape filter	Root Raised cosine filter

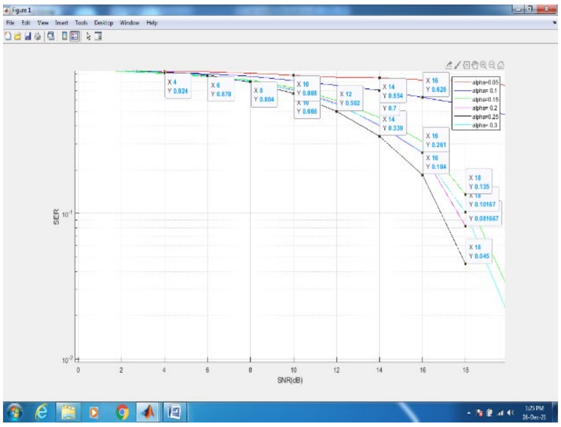

Figure 6: Simulation result of SER versus SNR with root raised cosine filter in GFDM

The figure 6 shows x axis represent signal to noise ratio (SNR) and y axis represent symbol error rate (SER) with different roll off factor 0.05, 0.1, 0.15, 0.2 ,0.25 and 0.3 such as shown in figure.In this case signal passes through awgn and zero forcing channel. Quadrature amplitude modulation and root raised cosine filter are used to improve the performance. It gives improvement result signal to noise ratio 18 get values symbol error rate obtained 0.045.

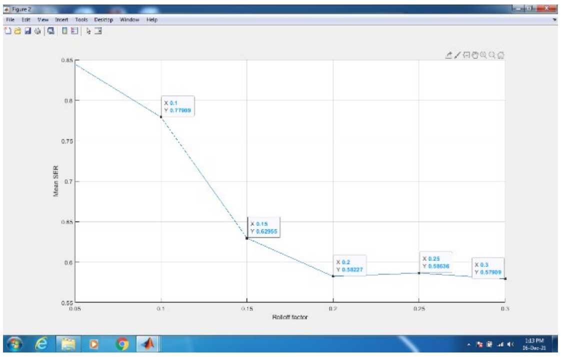

Figure 7: Simulation result of mean symbol error rate versus different roll off factor

This figure 7 shows x axis represent different roll off factor 0.1, 0.15, 0.2, 0.25, 0.3 and y axis represent mean symbol error rate. 0.1 roll off factor get the result 0.77, 0.15 roll off factor get the result 0.62, 0.2 roll off factor get the result 0.58, 0.25 get the result 0.58, 0.3 get the result 0.57.Here obtained improvement result.

Table 5: Simulation parameter of symbol error rate (SER) and signal to noise ratio (SNR) with Rayleigh fading channel filter in GFDM in root raised cosine filter

Sub-symbols (M)	128
Sub-carriers (K)	4
Mapping	QAM
Roll off factor (α)	0.05, 0.1, 0.15, 0.2, 0.25 and 0.3
Channel	Rayleigh fading channel

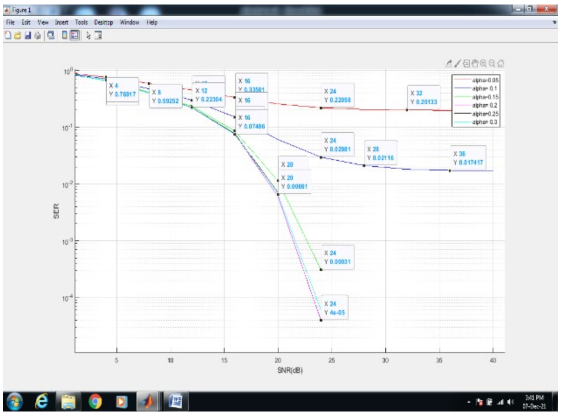

Figure 8: Simulation result of symbol error rate and snr with Rayleigh fading channel in GFDM with root raised cosine filter

The figure 8 shows x axis represent signal to noise and y axis represent symbol error rate with different roll of factor 0.05, 0.1, 0.15, 0.2,0.25,0.3 such as shown in figure. In this case signal passed through Rayleigh fading channel.Quadrature amplitude modulation and root raised cosine filter are used to improve the result performance and result shows performance improvement.

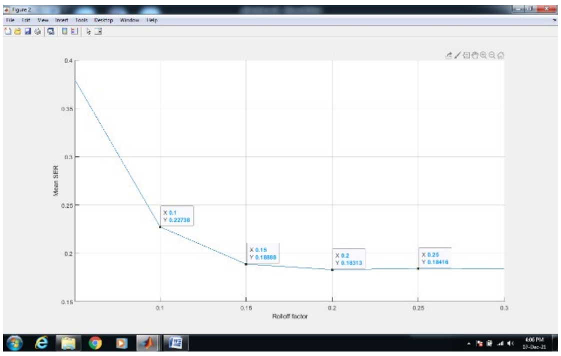

Figure 9: Simulation result of mean symbol error rate and roll off factor with Rayleigh fading channel

The figure 9 shows x axis represent roll off factor and y axis represent mean symbol error rate. 0.1 roll off factor get symbol error rate 0.22 and 0.15 roll off factor get symbol error rate 0.16,0.2 roll off factor get symbol error rate 0.5. Here obtained improvement result.

Table 6: Result comparison table between earlier method and present method

SNR	Result by earlier method (SER)	Reference	SNR	Result by present Method (SER)
8	0.7	[11]	8	0.5
5	0.3	[12]	5	0.2
24	0.001	[12]	24	0.0003

In this table shows that the result comparison table between Earlier method and present method. x axis represent signal to noise ratio and y axis represent symbol error rate.In case of signal to noise is 8 get the symbol error rate 0.7 in earlier method and present method get symbol error rate 0.5.Similarly Signal to noise is 5 get the symbol error rate 0.3 in earlier method and present method get symbol error rate 0.2. Signal to noise is 24 get the symbol error rate 0.001 in earlier method and present method get symbol error rate 0.0003 .it conclude that in present Method get improvement resuit

.

CONCLUSION : In this paper a detailed study of the spectrum analysis, roll off factor and symbol error rate,signal to noise ratio done using pulse shaping raised cosine and root raised cosine filters.Considering the number of subsymbol, subcarrier, roll off factor, modulation technique mapping , channel type like rayleigh chanel, AWGN channel, zero forcing receiver channel . Reported results are comparing present and existing methods. The standard pulse shaping filter raised cosine filter are compared with spectrum analysis and different roll of factor. Simulation results for spectum analysis and different roll of factor are reported. The overall research work carried out has given a significant contribution for raised cosine filter in spectrum analysis . paper result will be useful in quality improvement and error minimization of spectrum analysis and different roll off factor testing with symbol error rate. Raised cosine and Root raised cosine filter are used to improve the performance symbol error rate. Proposed technique reported this paper are very much useful in quality improvement and error minimization of GFDM.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by

Megha Gupta. The first draft of the manuscript was written by Megha Gupta and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Funding: Megha Gupta will applied for funding in UGC

Code Availability

The code of the algorithm has been run in MATLAB software.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

REFERENCES:

[1] G. Fettweis, M. Krondorf, and S. Bittner, "GFDM—Generalized frequency division multiplexing" in Proc. 69th IEEE VTC Spring, Barcelona, Spain, Apr. 2009, pp. 1–4.

[2] Rohit Datta "FBMC and GFDM Interference Cancellation Schemes for Flexible Digital Radio Phy Design" 2011 IEEE DOI 10.1109/DSD.2011.48.

[3] Nicola Michailow et.al "Generalized Frequency Division Multiplexing for 5th Generation Cellular Networks IEEE Trans On Comm, vol. 62, NO. 9, September 2014 .

[4] Nicola Michailow "Robust WHT-GFDM for the Next Generation of Wireless Networks"DOI10.1109/LCOMM.2014.23 74181, IEEE Communications Letters.

[5] Ivan S Gaspa, Luciano L Mendes Nicola Michailow, Gerhard Fettweis" A synchronization technique for generalized frequency division multiplexing "Journal on Advances in Signal Processing 2014, 2014:67http://asp.eurasipjournals.com/con tent/2014/1/67.

[6] Hsuan-Fu Wang et al "High Spectral Efficiency and Low Error Rate MIMO GFDM for Next - Generation Communication Systems" DOI : 10.1109 / TVT. 2021. 3127912 IEEE Transactions on Vehicular Technology .

[7]Jessica B.Sanson, Daniel Castanheira, Atilio Cameiro and Paulo P. Monteiro "Non Orthogonal Multicarrier Waveform for Radar With Communications Systems 24 GHz GFDM RadCom. date of publication September 11, 2019, date of current versio September 20, 2019 Digital Object Identifier.

[8] Mengyi Wang, Zhihui Chen, Zhenxing Chen "Energy-Efficient Index Modulation With In-Phase/Quadrature Format in the Generalized Fading Channel DOI: 10.1109/ACCESS.2021.3107955 IEEE access.

[9] G.Wunder et al., "5GNOW Non-orthogonal asynchronous waveforms for

future mobile applications," IEEE Commun. Mag., vol. 52, no. 2, pp. 97–105, Feb. 2014.

[10] Zhenduo Wang" BER Analysis of WFRFT Precoded OFDM and GFDM Waveforms with an Integer Time Offset" IEEE Trans on Vehicular Technology, Vol. XX, NO. XX, XXX 2018.

[11] Zhenyu na et. al "Pseudo-Noise Sequence Based Synchronization for Generalized Frequency Multiplexing in 5G Communication System" Digital Object Identifier 10.1109/ Access. 2018/ 2814682.

[12] Zhenyu Na,Mudi Xin Liu,Weidang Lu,Yongjian Wang and Lisheng Fan "Turbo Receiver Channel Estimation for GFDM-based Cognitive Radio Networks" DOI 10.1109/ ACCESS.2018.2803742, IEEE Access.

[13] Danilo Gaspar, Luciano Mendes, Tales Pimenta "GFDM BER under Synchronization Errors"DOI 10.1109/ LCOMM. 2017.2694837, IEEE Communications Letters.

[14] Khaled Tahkoubit et. al "Generalized Iterative Dichotomy PAPR Reduction Method for Multicarrier Waveforms"DOI 10.1109/ACCESS.2021.3102848

[15] Byungju Lim and Young-Chai Ko "Multiuser Interference Cancellation for GFDM with Timing and Frequency Offsets"DOI 10.1109/TCOMM. 2019. 2905202, IEEE Transactions on Com

[16] A. Kumar, M. Magarini, "Improving GFDM Symbol Error Rate Performance using Better than Nyquist Pulse Shaping Filters" IEEE latin America Trans, Vol.15, no. 7, Jul 2017.munications.

[17] Fei Li, Kan Zheng, and Yonghui Li "Design and Performance of a Novel Interference-Free GFDM Transceiver With Dual Filter" IEEE Trans. on vehicul Technolog, vol. 68, NO. 5, may 2019.

[18] Tewelgn Kebede et. al "Multi-Carrier Waveforms and Multiple Access Strategies in Wireless Networks: Performance, Applications, and Challenges" DOI: 10.1109/ACCESS.2022.3151360 IEEE access.

[19] Zhang D et al Widely Linear Estimation For Space-Time-Coded GFDM in Low-Latency Applications, IEEE Transactions On Communications, 63(11), 4501-4509.

[20] Kumar A et al. (2017). Impact of "Better than Nyquist Pulse Shaping in GFDM PHY with LTE Compatible Frame Structure, IEEE Latin-American Conference [9th: Guatemala City, Guatemala: 2017], pp. 1-6.

[21] Zhang D et al Frequency-Shift Offset-QAM for GFDM, IEEE Communications letters, 19(8), 1454-1457.

[22] Lentmaier M et al "'Bit Error Rate Performance of Generalized Frequency Division Multiplexing, IEEE Vehicular Technology Conference (VTC) [Quebec City, QC, Canada: 2012], pp. 1-5.

[23] Byungju Lim, Young-Chai Ko" SIR Analysis of OFDM and GFDM Waveforms with Timing Offset, CFO and Phase Noise"Doi.org/10.1109/TWC.2017.27369

98.IEEE Transactions on Wireless communication.
[24] Amirhossein Mohammadian, Mikko Valkama "Analysis of Self-Interference Cancellation under Phase Noise, CFO and IQ Imbalance in GFDM Full-Duplex Transceivers" DOI 10.1109/ TVT.2019. 2953623, IEEE Transactions on Vehicular Technology
[25]Vejandla Kishore et.al "Implementation of Linearly Pulse Shaped Generalised Frequency Division Multiplexing for Visible Light Communication Systems" DOI 10.1109/OJCOMS.2020.3030118 IEEE journal of communication society.
[26] M.Mirahmadi A.Al-Dweik and A.Shami"BER Reduction of OFDM Based Broadband Communication system over Multipath Channels with impulsive Noise" IEEE Transactions on communications vol 61,no 11.pp 4602-4615,Nov.2013.