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Performance of GFDM and OFDM over Fading Channels

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Abstract—*Flexibility feature is the main feature for generalized frequency division multiplexing (GFDM); digital transceiver can using any pulse shaping filter. While it was limited by rectangular pulse shape in Orthogonal frequency division multiplexing (OFDM). In this work Rayleigh and Nakagami- fading channel are depended with different Nakagami fading parameter, furthermore Additive White Gaussian noise (AWGN) to describe the GFDM performance in terms of symbol error rate. Also make performance comparison between the two multicarrier physical layer modulations OFDM and the new GFDM over above channels by simulation and theoretical expression.*

Keywords— *GFDM, AWGN, Nakagami-* $\boldsymbol{m}$ *, fading parameter, performance, symbol error rate.*

I. INTRODUCTION

Mobile network has been an essential tool in our modern wireless communication. It is developed from 1st generation until present 4G series, each generation has it is specifications, advantages, and disadvantages. 4G series generation depends on orthogonal frequency-division multiplexing (OFDM) instead of time division multiple access (TDMA) that uses in GSM second generation "2nd G", or code division multiple access (CDMA) that employed in 3rd G series. OFDM it is adopted solution against multipath fading channels [1]. OFDM uses fast Fourier transform "FFT", so it is easily for implementation [2]. OFDM bases on rectangular pulse shaping for modulation. This gives disadvantages compared with GFDM. GFDM can cover the new communication requirements like internet of things "IOT", machine type communication "MTC", Machine-to-Machine communication "M2M" etc… These applications need flexibility, relaxed synchronization, low-out-of band "OOB" signal emission, high spectral efficiency. OFDM it is not supportive enough for these specifications [3]. In OFDM the cyclic prefix "CP" is mandatory; it is inserted between symbols to keep orthogonality property. CP makes OFDM work with low spectral efficiency, high latency and high OOB radiation [4]. In GFDM it is not necessary for CP insertion and if it is needed, the CP adds to GFDM block (number of sub-symbols) this leads the GFDM has higher spectral efficiency and lower latency. In GFDM each subcarrier filtered separately by filter bank multicarrier "FBMC" to provide lower OOB emission [5]. All above reasons make GFDM outperform OFDM.

GFDM is a type of multicarrier modulation [6]. Each carrier in GFDM divided into subcarriers in frequency domain like OFDM modulation. And also divided into time slots in time domain likes signal carrier Frequency Domain Equalization "SC-FDE". So it will be the well-known OFDM when choosing 1 time slot in time domain with different subcarriers and be SC-FDE when it is divided into 1 subcarrier in frequency domain with many time slots in time domain [7]. In this work a transmitter based GFDM modulation and GFDM block with it is basic principles under system model are explained in section II. In section III analyze the performance for both GFDM and OFDM bases SER. While in section IV discusses the theoretically results and compared with the results that obtained from simulation. In last section V lists the conclusions.

II. SYSTEM MODEL DESCRIPTION

A transmitter based on GFDM modulation is explained. Rather than a comprehensive explanation for GFDM modulation with mathematical model.

A. Transmitter

The general block for transmitter with GFDM modulation is described in Fig. (1). A binary data vector $\boldsymbol{d}$ is mapped

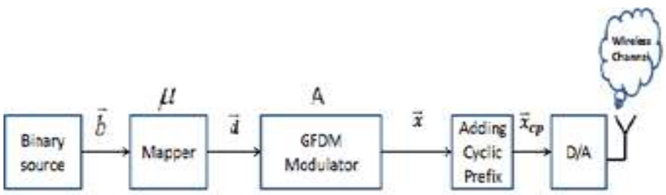

Fig. 1. General GFDM transmitter

by QAM in complex format symbols with 2^{μ}, where μ is the modulation order, the resultant vector with N elements consist of K subcarriers and M sub-symbols as $\boldsymbol{d} = [d_0^T, d_1^T, \ldots\ldots d_{K-1}^T]^T$, each d_k can be represented by $\boldsymbol{d_k} = [\, d_{k,0}\,, d_{k,1}\,, \ldots., d_{k,M-1}]^T$, where $(.)^T$ refers to transpose description. The data vector $\boldsymbol{d}$ is modulated by GFDM modulation that represented by Fig. 2 [8]. The transmitted signal after modulation will be as in the bellow equation [9]

$$x[n] = \sum_{k=0}^{K-1}\sum_{k=0}^{M-1} g_{k,m}[n]\, d_{k,m}, \quad n = 0,\ldots,N-1. \tag{1}$$

Where

$$g_{k,m}[n] = g[(n-mk) \bmod N\,] \exp[-j\,2\pi \frac{k}{K} n] \tag{2}$$

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is the pulse shaping filter , $N = MK$. The transmitted signal can be represented by matrix form [9]

$$\vec{x} = \mathbf{A}\vec{d} \tag{3}$$

where $\mathbf{A}$ is the GFDM modulation matrix refers to prototype filter pulses for each element to be matrix with $MK \times MK$ [8].

B. Receiver side with channel

The received signal can be represented with matrix form included the channel affection by

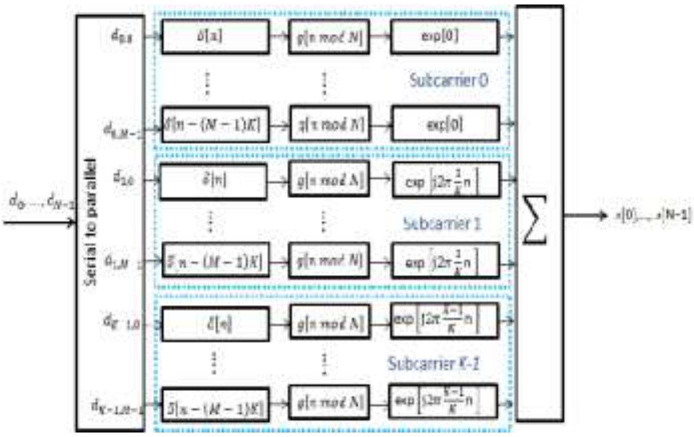

Fig. 2. GFDM modulation block

$$\boldsymbol{r} = \boldsymbol{H}\bar{\boldsymbol{x}} + \boldsymbol{n} \tag{4}$$

Where $\boldsymbol{H}$ is a circular convolution matrix of channel coefficients for Rayleigh and Nakagami-*m* for this work, $\boldsymbol{n}$ denotes the noise vector containing AWGN samples with variance σ_n^2 .

The signal will fallow the probability density function (PDF) for Nakagami-$\boldsymbol{m}$, so the gamma distribution "γ" can be expressed by [10]

$$p_\gamma(\gamma) = \left(\frac{\boldsymbol{m}}{\bar{\gamma}}\right)^m \frac{\gamma^{m-1}}{\Gamma(\boldsymbol{m})} e^{\frac{-m\gamma}{\bar{\gamma}}} \tag{5}$$

$\boldsymbol{m}$ is the Nakagami-$\boldsymbol{m}$ parameter fading channel, when $\boldsymbol{m}$ =1 the channel will be Rayleigh, $\bar{\gamma}$ is the average signal to noise ratio "SNR" per symbol.

In this work, perfect channel and perfect time and frequency synchronization as well as perfect channel knowledge are assumed. In frequency domain the channel equalization can be gotten by [11]

$$\boldsymbol{y} = \boldsymbol{IFFT}\left\{\frac{\boldsymbol{FFT}(\boldsymbol{r})}{\boldsymbol{FFT}(\boldsymbol{h})}\right\} \tag{6}$$

The data symbols can be extracted from the received signal by [8]

$$\vec{\hat{\boldsymbol{d}}} = \boldsymbol{C}\vec{\boldsymbol{r}} \tag{7}$$

Where $\boldsymbol{C}$ is the demodulation matrix, here a zero forcing "ZF" receiver is employed to extract the original data, thus $\boldsymbol{C}_{ZF} = \boldsymbol{A}^{-1}$, this type of receiver help to remove all the inter carrier interference "ICI" but with increasing noise by factor called noise enhancement factor ϑ [12].

$$\vartheta = \sum_{i=0}^{MK-1} \left| [\boldsymbol{C}_{ZF}]_{k,i} \right|^2 \tag{8}$$

This ϑ in our study equal to 1, since root-raised-cosine filter "RRC" and square RRC filter with roll-off factor ROF α = 0.1 are implemented [8].

III. Performance Analysis

In this study, SER performance is considered for GFDM transceiver with Additive White Gaussian noise (AGWN), Rayleigh and Nakagami-m fading channel, ZF receiver is employed.

A. Signal to Noise Ratio

The SNR under fading channel is equivalent to

$$\bar{\gamma}_n = \frac{3\boldsymbol{R}_T \delta_n^2}{\left(2^\mu - 1\right)} \frac{\boldsymbol{E}_s}{\vartheta \boldsymbol{N}_o} \tag{9}$$

Where $\boldsymbol{R}_T = \dfrac{\boldsymbol{MK}}{\boldsymbol{MK} + \boldsymbol{N}_{cs} + \boldsymbol{N}_{cp}}$

$\boldsymbol{E}_s$ is the average energy per symbol, $\boldsymbol{N}_{cs}$, $\boldsymbol{N}_{cp}$ are the cyclic suffix and cyclic prefix lengths respectively, $\boldsymbol{N}_o$ is noise power density.

B. Symbol Error rate

The probability of symbol error rate for any fading channel normally fallows the it is probability density function "PDF" as [13]

$$\boldsymbol{P}_{Nak}(\boldsymbol{e}) = \int_0^\infty \boldsymbol{P}_{AWGN}(\boldsymbol{e}) \boldsymbol{P}_\gamma(\gamma) \boldsymbol{d}\gamma \tag{10}$$

$\boldsymbol{p}_\gamma(\gamma)$ is the PDF of Nakagami- $\boldsymbol{m}$ fading as in eq. (5), and

$$\boldsymbol{P}_{AWGN}(\boldsymbol{e}) = 2\boldsymbol{B}_1 \boldsymbol{erfc}(\sqrt{\gamma}) - \boldsymbol{B}_1^2 \boldsymbol{erfc}^2(\sqrt{\gamma}) \tag{11}$$

Where $\boldsymbol{B}_1 = \dfrac{\sqrt{2^\mu - 1}}{\sqrt{2^\mu}}$

If we substituted Eq. (5) and (11) in Eq. (10) the resultant will be as

$$\boldsymbol{P}_{Nak} = 2\boldsymbol{B}_1 \boldsymbol{B}_2^{\boldsymbol{m}} \frac{\Gamma(\boldsymbol{m} + \frac{1}{2})}{\sqrt{\pi}\,\Gamma(\boldsymbol{m} + 1)} \tag{12}$$

$\boldsymbol{m}$ is the Nakagami-$\boldsymbol{m}$ factor, when $\boldsymbol{m}$ =1 gets Rayleigh fading channel case. $\boldsymbol{B}_2 = \dfrac{\boldsymbol{m}}{\bar{\gamma}_n}$

IV. Discussion and Conculsion

The simulation parameters that used in our system model as in table (I) with employing the Zero forcing receiver.

By Matlab simulation a SER performance comparison between OFDM and GFDM over AWGN and Nakagami-$\boldsymbol{m}$ is produced in this study, furthermore the ROF of the bank filter " α = 0.1 " is considered. From the figure we can notice that when we increase the value of $\boldsymbol{m}$ from 1 to 3, the SER decreases. For example at 25 dB the error values for m = 1, 2, 3 are respectively 0.077, 0.008 and 0.00087, i.e. approximately there is a 95% decrease in error from m = 1 to $\boldsymbol{m}$ = 3,and the simulation values exactly same the theoretical result. Also it is clear from these results the behavior of GFDM and OFDM is the same. Last the SER for GFDM and OFDM approximately same under this conditions.

TABLE I. Simulation parameters

S. No.	description	Parameters	Value
1	Number of subcarriers	K	64
2	Number of time slots	M	5
3	Filter pulse shaping	g	RRC
4	Modulation order	μ	16-QAM
5	Roll- off factor	α	0.1
6	length of cyclic prefix	N_{cp}	8

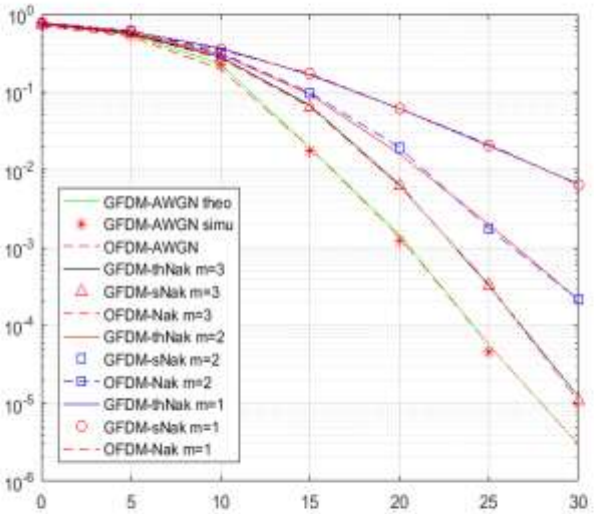

Fig. 3. Example of a figure caption.

V. CONCLUTIONS

In this work we investigated GFDM performance under Nakagami- $\boldsymbol{m}$ fading channel. In summary, for a certain ROF for pulse shaping filter, we observed a significant SER decrease as the Nakagami fading parameter $\boldsymbol{m}$ increased from the value 1 to 3. This implies that GFDM has better error performance for higher fading parameter. In addition, we can conclude that the new GFDM can gives similar performance of OFDM, and similar behavior over fading channels Rayleigh and Nakagami- $\boldsymbol{m}$ and AWGN.

REFERENCES

[1] M. Mirahmadi, A. Al-Dweik, and A. Shami, "BER reduction of OFDM based broadband communication systems over multipath channels with impulsive noise," *IEEE Trans. Commun*., vol. 61, no. 11, pp. 4602–4615, Nov. 2013.

[2] S. Fechtel and A. Blaickner, "Efficient FFT and equalizer implementation for OFDM receivers," *IEEE Trans. Consum. Electron.*, vol. 45, no. 4, pp. 1104–1107, Nov. 1999.

[3] J. Kim, J. Lee, J. Kim, and J. Yun, "M2M service platforms: Survey, issues, and enabling technologies," *IEEE Commun. Surveys Tuts.*, vol. 16, no. 1, pp. 61–76, 2014.

[4] J. Van De Beek and F. Berggren, "Out-of-band power suppression in OFDM," *IEEE Commun. Lett.*, vol. 12, no. 9, pp. 609–611, Sep. 2008.

[5] B. Farhang-Boroujeny, "OFDM versus filter bank multicarrier," *IEEE Signal Process. Mag.*, vol. 28, no. 3, pp. 92–112, May 2011.

[6] 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.

[7] D. Falconer, S. Ariyavisitakul, A. Benyamin-Seeyar, and B. Eidson, "Frequency domain equalization for single-carrier broadband wireless system," *IEEE Commun. Mag.*, vol. 40, no. 4, pp. 58–66, Apr. 2002.

[8] N. Michailow, M. Matthe, I. Gaspar, A. Caldevilla, L. Mendes, A Festag and G. Fettweis, "Generalized Frequency Division Multiplexing for 5th generation cellular networks," *Communications, IEEE Transactions on*, vol. 62, no. 9, pp. 3045–3061, Sept 2014.

[9] N. Michailow, S. Krone, M. Lentmaier, and G. Fettweis, "Bit error rate performance of Generalized Frequency Division Multiplexing," in *Vehicular Technology Conference (VTC Fall), 2012 IEEE*, Sept 2012, pp. 1–5.

[10] M. Simon and M. Alouini, *Digital Communication over Fading Cha*nnels, 2nd ed. Hoboken, NJ: Wiley Interscience, John Wiley & Sons, 2015.

[11] I. Gaspar, L. Mendes, N. Michailow, and G. Fettweis, "A synchronization technique for generalized frequency division multiplexing," *EURASIP Journal on Advances in Signal Processing*, vol. 2014, no. 1, 2014. [Online]. Available: http://dx.doi.org/10.1186/1687-6180-2014-67

[12] Yenilmez, A. Gucluoglu, T. and Remlein, "Performance Maximal Ratio Transmission over Nakagami-m fading Channels", International Symposium on wireless Communications Systems ISWCS 20-23, September 2016, Poland, 523-527.

[13] M.K. Simon and, M.S. Alouini, Digital Communications over Fading Channels: A Unified Approach to Performance Analysis, 6th ed., New York: John Wiley & Sons Inc., 2000.

Nidaa A. AL Hasaani and Aya Algamluoli, "Performance of GFDM and OFDM over Fading Channels," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 1, Issue 7, pp. 10-12, 2018.