ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 7, July 2017

Performance of GFDM for e-Call MSD Service in Vehicular Ad-hoc Network

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***Abstract* - Automobile is highly required various service technology for user convenience compared to the past. The number of vehicles and drivers are increased constantly so reliable communication technology between vehicles is getting important. Vehicular Ad-hoc network is one of existing mobile network and communication technology to apply fast moving vehicles. Research of emergency call service is typical communication technology business which is applied Ad-hoc network. Efficient and fast communication are required in data communication caused by these environmental factor of nowadays. In this paper, GFDM (General Frequency Division Multiplexing) is suggested which is one of new technology that for 5G as a manner of new automobile. In the discussion, suggested GFDM system will be designed and its superiority will be verified. To do the task, difference between GFDM and OFDM and advantage of GFDM are suggested with result from several simulations of GFDM and OFDM.**

Index Terms: e-Call, GFDM, OFDM, Ad-hoc network

I. INTRODUCTION

A variety of communication methods shall be required to prepare for IoT generation connecting all users and things. Typically, automobiles have been increasingly demanding the need for a variety of service technologies for drivers than in the past. The number of drivers and vehicles are increased constantly and reliable communication technology between vehicles is highly required. Research regarding emergency call service based in MSD data of vehicle is representative vehicular communication technology business [1]. There are variety researches as to 5G of multiple access method to adopt communication environment and requirement. This paper suggests application GFDM (General Frequency Division Multiplexing) to vehicular Ad-hoc network rather than OFDM as new communication method of physical layer. To construct optimal communication environment where a number of vehicles are moving, adoption and optimization of new technology is demanded. Hence, the paper suggests that GFDM; asynchronous transfer mode, is more appropriate for data communication than OFDM; conventional way in physical layer.

II. SYSTEM DESIGN

A. GFDM (General Frequency Division Multiplexing)

GFDM is able to design flexibly to adjust various channels and frequency environment and reduce transmission time. Orthogonality with sub channel is unnecessary to GFDM as well. Due to those characteristics, using GFDM is feasible to reduce few second rather than existing method. In addition, it is possible to transmit in various ways in accordance with each situation by flexibly regulating the number of sub-symbol and sub-carrier. In the paper, difference between GFDM and OFDM and advantage of GFDM is demonstrated through research and simulation.

B. GFDM Transmitter Diagram

OFDM transmit N data symbol in a block in response to N sub carrier but GFDM transmits N data in response to M sub symbol time and K sub carrier. Figure 1 shows GFDM transmitter diagram to design tactile internet. Complexity is increased because it uses filter bank rather than FFT used in existing OFDM.

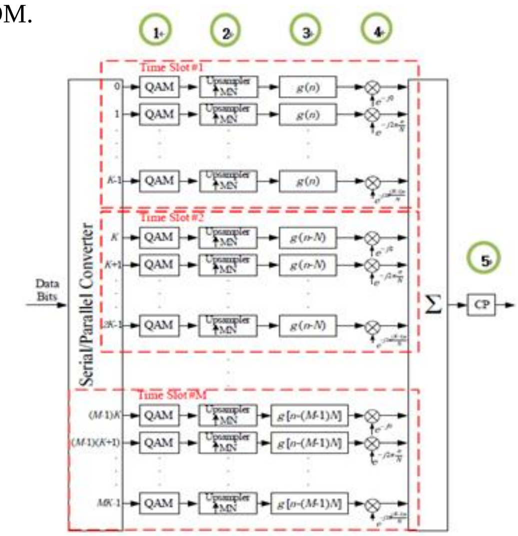

Figure 1. GFDM Transmitter Diagram

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1. After convolution coding, symbols mapped at 16-QAM. Symbols are normalized and transmitted by EsN0 = 0:20 of electric power.
2. Symbols mapped at 16-QAM are proceeded up-sampling as up-sampling rate = K.
3. GFDM proceeds pulse-shaping N of symbols with raise cosine filter. At the moment, N of symbols is stored in each M of timeslots shifting K by time axis.
4. Modulate N of symbols for each M of timeslots by using formula; exp(-1j*2*pi*n*(K-1)/K) is like carrying N of symbols on K of frequency for each timeslot.
5. Transmit modulated signal with CP.

C. Modulated Matrix

Step 2, 3 and 4 in transmitter diagram could be computed by below modulated matrix at once.

- **Modulated matrix**

$$\mathbf{A}=\begin{bmatrix} g(0) & g(0) & \cdots & g(0) & g(N-K) & \cdots & g(K)\\ g(1) & g(1)e^{-j2\pi\frac{1}{K}} & & g(1)e^{-j2\pi\frac{K-1}{K}} & g(N-K+1) & \cdots & g(K+1)e^{-j2\pi\frac{K-1}{K}}\\ g(2) & g(2)e^{-j2\pi\frac{1}{K}2} & & g(2)e^{-j2\pi\frac{K-1}{K}2} & g(N-K+2) & \cdots & g(K+2)e^{-j2\pi\frac{K-1}{K}2}\\ \vdots & & \ddots & & & & \vdots\\ g(N-1) & g(N-1)e^{-j2\pi\frac{1}{K}(N-1)} & & g(N-1)e^{-j2\pi\frac{K-1}{K}(N-1)} & g(N-K-1) & \cdots & g(K-1)e^{-j2\pi\frac{K-1}{K}(N-1)} \end{bmatrix}$$

$$\mathbf{g}_{0,0} \quad \mathbf{g}_{1,0} \quad \mathbf{g}_{K-1,0} \quad \mathbf{g}_{0,1} \quad \mathbf{g}_{K-1,M-1}$$

Figure 2. GFDM Modulated matrix

From first column to (K-1)th column are elements being relevant to first timeslots. There are N columns and M timeslots from K column. Therefore, N by N matrix is formatted.

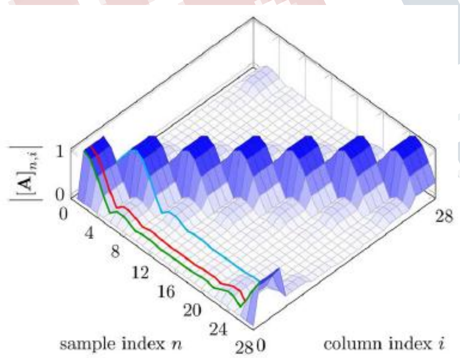

Figure 3. N=28, K=4, M=7 GFDM modulated matrix

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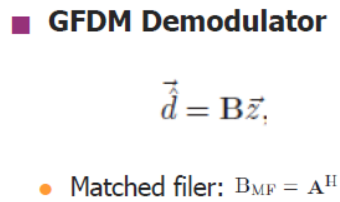
D. Receiver Structure



$$\hat{\vec{d}} = \mathbf{B}\vec{z},$$

$$\mathbf{B}_{\mathrm{MF}} = \mathbf{A}^{\mathrm{H}}$$

Figure 4. GFDM Demodulator

In receiver, demodulation and detection of signal is possible to implement by taking inverse matrix of A designed previously.

III. DETAILED DESIGN STANDARD

A.A Matrix Design

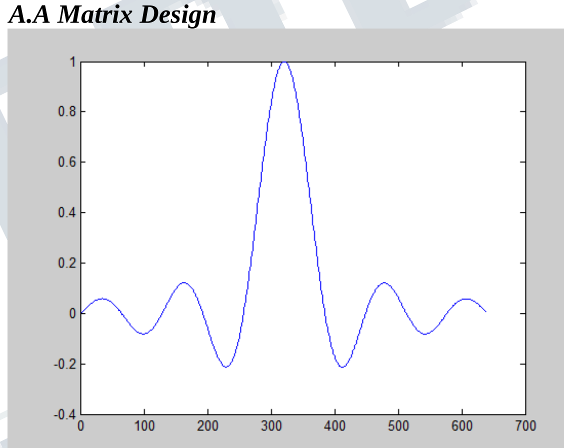


Figure 5. Raised Cosine Filter design

RCF is designed that it has peak point at 320 by setting 640 as N.

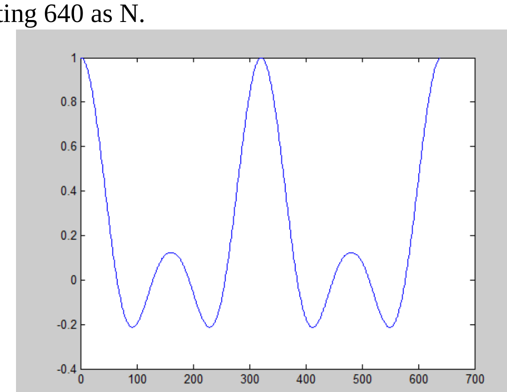


Figure 6. Copy the Raised Cosine Filter

Copy the values from 0 to 160 and from 480 to 640 as the values from 320 to 480 and from 160 to 320. Then, cut those as a half.

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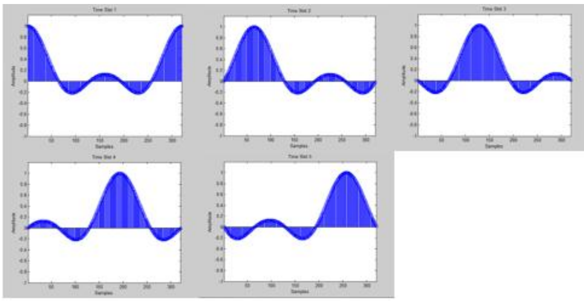

Figure 7. Shift copied filter

Graph is shifted as the value of symbol is 5. A matrix is designed by using 5 shifted graphs.

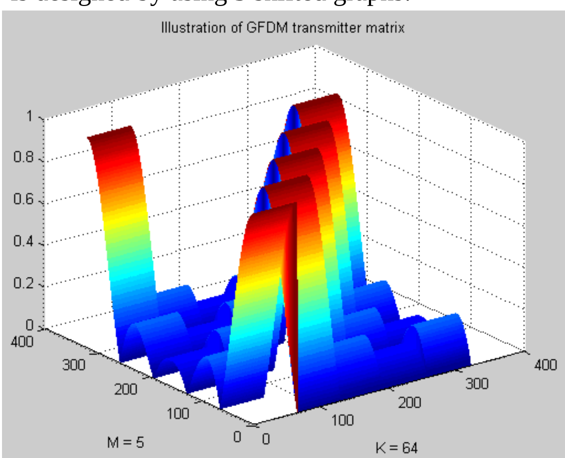

Figure 8. A matrix

Subcarrier = 64, Sub symbol = 5 GFDM Matrix is as figure 8.

IV. PERFORMANCE OF SYSTEM

A. Peak-to-Average Power Ratio

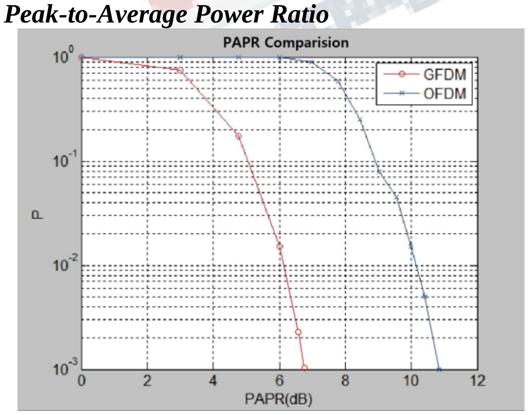

Figure 9. Comparison PAPR performance of OFDM and GFDM

Figure 9 shows that PAPR performance of GFDM is much higher than that of OFDM [2]. High PARP means that a signal strength having peak value is higher than average electric power of signal. In this case, expensive device should be used since high power consumption to receive all signals in receiver. Otherwise, error could occur due to loss of signals. Therefore, reducing deficit of signal caused by PAPR with adjusting M value is one of advantage of GFDM.

B. Bit error rate

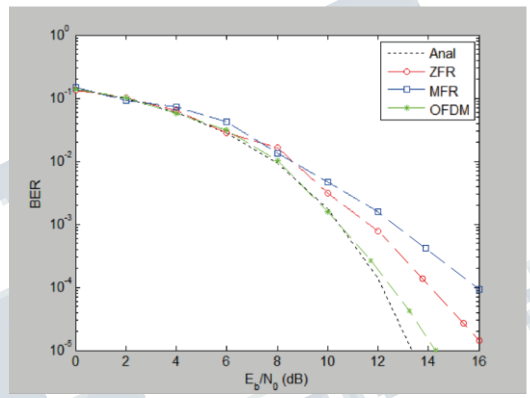

Figure 10. In AWGN, bit error performance of GFDM and OFDM at K=64, M=5, N=320

There are ZF(Zero-forcing), MF(Matched-filter) and MF-DSIC in detector ways of receiver structure of GFDM. In the study, ZF and MF detector are applied to measure BER performance. ZF has strength that it could eliminate ICI between non orthogonal subcarriers. MF could be used for evaluation affect in receiver such as ISI and ICI. With these basis, the study proceeded evaluating BER performance. Figure 10 demonstrates that BER performance is high OFDM, ZPR and MFR in order. That of ZFR is higher than MFR because it has ability to eliminate ICI [2]. OFDM has orthogonality so that it has higher performance than ZFR influenced ISI.

C. Out of band

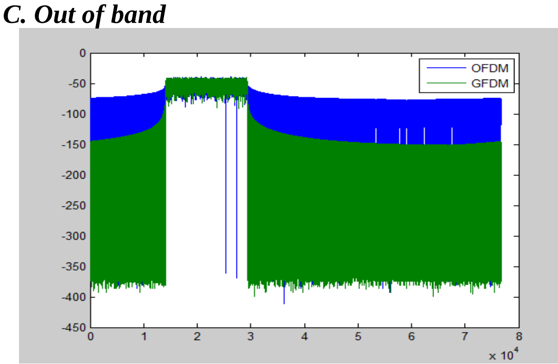

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Figure 11. Out of band comparison

Out of Band means frequency domain other than BW. If signaling rates of out of band and in band are similar, it means invasion of frequency domain and causes high error rate since signal from out of band is rarely transmitted to receiver. With above graph, it is possible to grasp that GFDM is much better than OFDM in terms of out of band [3].

V. CONCLUSION

	GFDM	OFDM
PAPR	Having high performance if value of subcarrier is appointer as low.	Performance is not good.
BER	In case of ZF, having relatively high performance due to its ICI elimination capacity.	Having higher performance than GFDM due to less influence from ICI and ISI.
OOB	Having high performance due to relatively large difference compared to In band.	Having less difference compared to In band.

Table 1. Comparison OFDM and GFDM

In the paper, GFDM is suggested as new wireless access technology for 5G and new physical layer communication method being adopted vehicular Ad-hoc network. In order to verify the superiority of GFDM, the paper designs suggested GFDM and compares the differences and performance of existing OFDM and GFDM. As a result, the performance of bit error rate of OFDM is higher than that of GFDM since OFDM has orthogonality so that it is less affected by ISI. PAPR performance shall be high when subcarrier value is designated as low. Therefore, performance of GFDM is much better than that of OFDM because GFDM could regulate value of subcarrier flexibly. GFDM shows less BER performance than OFDM but shows higher performance in terms of PAPR and OOB.

Thus, it is expected that if improved BER performance is adopted by using proper channel coding, GFDM shall show better performance than OFDM. Moreover, it likely applied to communication environment between vehicles demanded new generation mobile communication by flexibly adjusting value of K and M and designing customized to environment.

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