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ON VARIOUS TECHNIQUES IN OFDM AND GFDM: A SURVEY

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation that divides the available spectrum into a finite number of carriers and applied into a digital transmission system. But it has some drawbacks such as sensitivity in inter-carrier interference, high peak to average power ratio and insufficient cyclic prefix in spectrum. These drawbacks may be reduced by a technique known as Generalized Frequency Division Multiplexing (GFDM). In the present scenario, it is a high speed multi-carrier multiplexing data transfer scheme for the cellular network. This paper deals with a comparison between OFDM and GFDM and focuses on various techniques in OFDM and GFDM.

Keyword. Orthogonal Frequency Division Multiplexing; Generalized Frequency Division Multiplexing; Soft Computing; Fuzzy Logic; Artificial Neural Network

INTRODUCTION

During last four decades the wireless communication system has been rapidly increases in the area of Wireless Ad-hoc Network (WANET), Wireless Sensor Network (WSN) and cellular network. WANET [1], [2], [3], [4] is a collection of dynamic mobile node which are moving randomly to achieve specific goal. It is infra-structure less and each node of this network behave as router. WSN [5], [6] is a collection of low cost sensor node. Each node consists of low cost battery and has the capacity for operation, perception and transmission [7], [8]. Sensor nodes are distributed to obtained information about its environment.

Apart from these, wireless network play vital role in several ways such as Wireless Fidelity (WiFi), Worldwide Interoperability for Microwave Access (WiMax), 1G, 2G, 3G communication, High bit-rate Digital Subscriber Line (HDSL), Asymmetric Digital Subscriber Line (ADSL), Very-high-bit-rate Digital Subscriber Line (VDSL), etc. Data rates of each these technologies increases in chronological order and each technology has its own advantages.

It's very interesting to know that 3G is just roll out in the developed and developing countries and the whole engineering community is started to think about the 4G. Engineers from the world started to work on 4G. These next generation wireless systems are intended for Intelligent Transportation Systems (ITS). Intended ITS applications are broadband communications to high-speed trains, including real-time video security, video advertising and broadband wireless Internet. OFDM is one of those techniques which are proposed for this next generation wireless communication systems.

The benefits of OFDM are high spectral efficiency, resiliency to RF interference, and lower multi-path distortion. This is useful because in a typical terrestrial broadcasting scenario there are multi path-channels. Since multiple versions of the signal interfere with each other, it becomes very hard to extract the original information. OFDM is sometimes called multi-carrier or discrete multi-tone modulation. In OFDM, a rectangular pulse is used as sub carrier for transmission. It facilitates the process of pulse forming and modulation by implementing efficiently with simple Inverse Discrete Fourier Transform (DFT) along with Inverse Fast Fourier Transform (IFFT). To reverse this operation at receiver Fast Fourier Transform (FFT) is needed. The information transmitted over the carriers can still be separated because of the 'orthogonally relation'. By using an IFFT for modulation the spacing of the sub carriers is chosen in such a way that at the frequency where the received signal is to be evaluated, all other signals are zero.

Wireless network helps in every step of life in two ways: single-hop transmission and multi-hop transmission. The pictorial representation of wireless network is shown in Fig. 1. In recent years, dynamic nature of wireless network, has pervaded into world-wide applications such as Industry sector for E-commerce [9], Environmental monitoring, Vehicular networks, Bluetooth, Personal area network, Military usages, Disaster Management and others [10], [11].

Wireless system based on Multi Carrier Modulation (MCM) which is a method of transmitting data packet by splitting into more than one pieces. Each pieces send over separate carrier signals. Single carrier has narrow bandwidth but the combination of all signals have broad bandwidth. OFDM is the most well-known and widely deployed technique. It has several features as given below.

- It has simple signal generation technique based on Fast Fourier Transform (FFT) algorithm.

- Robustness against multi-path fading.
- Easy in Multiple Input Multiple Output (MIMO) application.
- New transmission concepts for instance Cognitive Radio (CR).
- Low Out-of-Band (OOB) radiation.

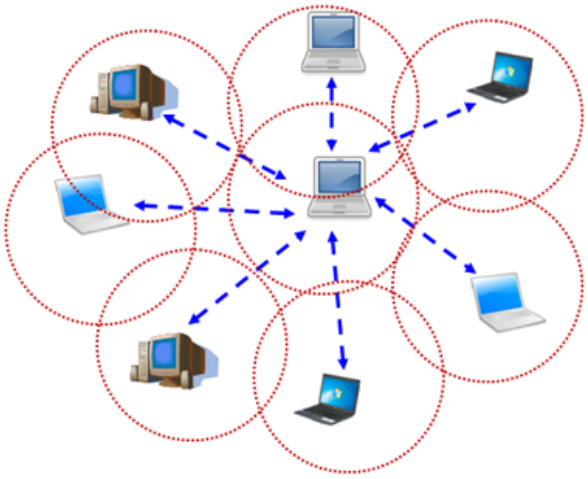

Figure 1. Wireless network.

MOTIVATION

Several surveys have been illustrated in last few decade. Each survey deal with either OFDM technique or GFDM technique, no survey deal with combination of both techniques. This paper discuss survey of both OFDM as well as GFDM technique.

CONTRIBUTIONS

In this survey paper, we illustrates the significance of OFDM as well as GFDM. The key contributions of this paper are as follows:

- It illustrates evolution of OFDM technique.
- It highlight design issues in OFDM.
- It defined derivation of GFDM based on OFDM principles.
- It defined evolution of GFDM technique.
- It illustrates comparison between OFDM and GFDM.

ORGANIZATION OF THE PAPER

The remainder of this paper is organized as follows. In Section 2, illustrates evolution of OFDM and GFDM techniques. Section 3 provides design issues in OFDM. Derivation of GFDM based on OFDM principle described in Section 4. Section 5 highlights comparison between OFDM and GFDM. Finally, conclusion and directions for future scope are outlined in Section 6.

EVOLUTION OF OFDM AND GFDM TECHNIQUES

Evolution of different techniques of OFDM and its related techniques are given below.

Ch. N. Kumari and M. R. Reddy [12] proposed a joint receiver for Low Density Parity Check coded (LDPC) for Multiple Input Multiple Output- Orthogonal Frequency Division Multiplexing signals (MIMO-OFDM) based on linear programming. In this approach, turbo receivers employed in MIMO-OFDM either utilizing disjoint serial detector and decoder or requires turbo message passing between the two functional blocks of detection and decoding.

Neha and C. Singh [13] surveyed on Inter Carrier Interference (ICI) for self-cancellation techniques in OFDM. It highlight, ICI causes several degradation of the Bit Error Rate (BER) performance of the OFDM receiver. It also indicates, numerous techniques for reducing ICI by combining ICI self-cancellation, time domain windowing and frequency domain equalization.

Anuj Singal and Deepak Kedia [14] reviewed a design issues and challenges in MIMO-OFDM. In the present scenario, spectrum is limited and demand for high speed data degrades the quality of service. So, OFDM system was proposed in the literature to overcome the problem of limited spectrum. It also coupling with MIMO for further improvement the performance of next-generation 4G wireless system.

K. Seshadri Sastry and M. S. Prasad Babu [15] proposed an adaptive modulation for OFDM system based on fuzzy logic system. Fuzzy logic is a soft computing [16] based technique. It deals with uncertainty and approximation. It is used in various areas [17], [18] to reduce uncertainty of information. It is based on 4G which is Adaptive OFDM (AOFDM). In this approach, adaptive transmission scheme is employed according to channel fading condition to improve the performance to fixed modulation system.

A. Mishra and K. K. Sarma [19] proposed a Trellis Coded Modulation (TCM) based OFDM which assisted by Artificial Neural Network (ANN) [20] for wireless channel. It decode the signal at the receiver side, over conventional TCM decoding scheme. It achieved higher throughput and performance improvement in multipath fading channel.

K. K. Nagar and K. Sharma [21] proposed an AOFDM implementation based on inference system. This scheme is an adapted modulation technique based fuzzy rule base system [22]. It enhance the achievable data rate in an OFDM system. The performance of this approach is outperform the fixed modulation scheme.

Matth'e et al. [23] proposed a Space Time Coding (STC) scheme for GFDM. It this scheme, it has been shown that GFDM and the STC scheme easily integrated and a full diversity gain is achieved with a very small computational overhead. However, the space-time combiner does not fully mitigate the ISI between the data sent in each GFDM sub symbol. Hence, the STC-GFDM suffers a performance loss for higher values of SNR.

Matth'e et al. [24] proposed an investigation that influence of misalignment in time and frequency of several users on the system performance which was measured as the MSE of the detected constellation symbols. It was shown that GFDM significantly outperforms. OFDM in terms of IUI because of its dramatically reduced OOB radiation. With GFDM, users on adjacent sub channels virtually do not interfere with each other, when only timing misalignments occur. This finding allows a CSMA-like random access structure of several nodes using different sub channels. When frequency misalignment occurs, GFDM again significantly outperforms OFDM, but a slight performance degradation is visible.

Choi et al. [25] demonstrated timing and frequency errors on GFDM systems in terms of linear matrix expression briefly and verified the effect of timing and frequency offset from the simulation results for GFDM and OFDM systems. Based on simulation results, GFDM systems were more sensitive to timing offset than conventional OFDM systems. But GFDM systems were robust to CFO when the frequency error was large. These results can be a good guide to decide the candidate waveform modulation scheme for 5G networks for alternating conventional OFDM systems.

Sharifian et al. [26] proposed a polynomial based companding method with iterative expansion that is called Polynomial-based Companding Technique (PCT). The proposed technique is based on application of a polynomial compressor at the transmitter and an iterative expander at the receiver side. This method is called PCT and it was previously proposed for PAPR reduction in OFDM [27]. However, application of PCT to other multicarrier systems is not straightforward. Therefore, the authors have introduced a generalized version of PCT which makes it applicable to any multicarrier system. Summarized details for evolution of OFDM and GFDM techniques described in Table 1 and Table 2 respectively.

Table 1: Evolution of OFDM technique.

Sl. no.	Techniques	Ref.
1	Equalization algorithm to suppress both ISI and ICI. Apply pilot tone, trellis coding and QAM modulation techniques in high speed OFDM system.	[28]
2	Cyclic Prefix (CP) or cyclic extension for fully-loaded OFDM modulation.	[29]
3	Introduced a pilot-based method to reduce the interference emanating from the multi-path and co-channels.	[30]
4	OFDM is used in digital broadcasting systems.	[31]
5	Suggested a sub-carrier selective allocating scheme.	[32]
6	Reviewed potential advantages, drawbacks of OFDM and introduced SCT-FDE as an alternative technique.	[33]
7	Algorithm for PAPR reduction.	[34]

Table 2: Evolution of GFDM technique.

Sl. no.	Techniques	Ref.
1	Performance of GFDM system undergoing non-linear amplification.	[35]
2	Performance evaluation of GFDM by using exact SER.	[36]
3	Influence of pulse shaping on bit error rate performance of GFDM.	[37]
4	Presentation of multi-carrier system architecture based on digitally implemented filter banks.	[38]
5	An iterative receiver scheme to reduce the error probability of GFDM signals undergoing non-linear amplification.	[39]
6	Analysis of C-FBMC receiver.	[40]

DESIGN ISSUES IN OFDM

In modern era, wireless communication like 3G become most popular technique. But it has some limitation such as small dynamic range of data rates as well as circuit switched voice transmission. The purpose of 4G communication is provides services anytime and anywhere, but it suffer scarcity of bandwidth. Hence, more advance technique need to be design to meet the objective of 4G communication. Some advantages and disadvantages of several issues are given in Table 3.

Table 3: Advantages and disadvantages of various issues.

Issues/ Disadvantages	Type	Advantages	Disadvantages
PAPR	Clipping	Simple and effective	Generates self-interference, BER increase and reduces spectral efficiency.
	Peak reduction carrier	BER degradation	Excessive side information required.
	Envelop scaling	Excessive side information not required.	Only suitable to PSK schemes.
	Peak windowing	Better spectral properties.	Increase BER and out-of-band radiation.
Antenna selection	Interleaving	Less complex than PTS	BER increases and loss in data rate at the receiver.
Channel estimation	DDCE (Non-Blind)	High spectrum efficiency	Error propagation

DERIVATION OF GFDM BASED ON OFDM PRINCIPLE

GFDM is derive based on OFDM signals. It is less complex than OFDM. It design based on same principle of OFDM such as data is transmitted with the help of modulating a number of original sine wave or tones. It is candidate waveforms which is extensively used in 5G communication. The derivation of GFDM points a number of resultant topics such as finding for less complex GFDM transmitter and every GFDM is designed with the help of tones. Data packet construction in GFDM is that data symbols over subcarrier are filtered by the help of well-localized pass band filter that limits the ICI.

COMPARISON BETWEEN OFDM AND GFDM

OFDM and GFDM both are used in wireless communication. OFDM is an efficient orthogonal subcarriers technique used in numerous modern communication techniques. But, it has several disadvantages such as a high Peak-to-Average Power Ratio (PAPR), sensitivity in ICI. In this technique, CP is not efficient in the spectrum and it fails to achieve its goal. To overcome these problems GFDM is designed. It is non-orthogonal subcarriers and flexible for multicarrier approach.

CONCLUSION AND FUTURE SCOPE

OFDM is foremost important technique for wireless communication system. Because of its spectrum efficiency and channel robustness. The MIMO technology has given the improvement in the capacity and performance in wireless system. Combination of both provides high access data rate in communication system and provide evolution 4G. Due to small data range and switched voice transmission, derived a new technique (i.e. GFDM). It has less complex due to break up long transmission into several slice and achieve the goal. Future scope include, to select any real life-world problem based on GFDM and solve it with the help of soft computing technique.

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