A Comparison Between 5G Waveforms – GFDM and FBMC

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Abstract - *With the evolution and introduction of the fifth generation (5G) of communication services, we come across the shift in the techniques used in the transmission signal. In this research, we have focused primarily on two new multicarrier schemes, Generalized Frequency Division Multiplexing (GFDM) and Filter Bank Multi Carrier (FBMC). The two techniques use the multicarrier transfer phenomena to transmit data signals, however, we measure the outcomes of their usage with respect to different communication parameters.*

Keywords — *GFDM, FBMC, 5G, PAPR, BER*

I. INTRODUCTION

With the evolution of wireless technology and communication services, the world has begun to heavily rely on these technical resources. This results in the requirement of technical advances in the communication industry. Some of these requirements include higher data rates, stable connections between users and the server, and increased capacity to hold the traffic which is always increasing in numbers, and thereby increases the difficulty with which the servers can handle this traffic keeping up with other parameters in check.

After the initial release of the Fourth Generation (4G) of communication services which became globally popular with the boon in the smartphone industry, developers began to work on the next step in the revolution. 4G uses the Orthogonal Frequency Division Multiplexing (OFDM) for data transmission. OFDM technique with a cyclic pre-fix (commonly denoted as CP-OFDM) which uses an orthogonal set of subcarriers is one of the most common multicarrier systems developed. But for the Fifth Generation (5G) services, the developers have reserved to different multicarrier systems, primarily two, Generalized Frequency Division Multiplexing (GFDM) and Filter Bank Multi Carrier (FBMC) technique.

Although, as we can easily presume, there are a lot of differences in the two techniques and any 5G system would behave differently with the use of each of the two. In the following sections, we will study both GFDM and FBMC and endeavor to comprehend the baselines on which they are based and used in 5G systems in different scenarios created which would thereby enable us to differentiate and compare the each of the two

The basic principle that FBMC works on is that it divides frequency spectrum into many narrow subchannels. This phenomenon is used as per the need in multiple technologies including WLAN and LTE.

II. FBMC

FBMC or Filter Bank Multi Carrier is a multicarrier scheme based on the filter bank developed by Chang in the year 1960. FBMC was first introduced by Saltzberg and was introduced to overcome the difficulties and drawbacks faced by the OFDM systems. With an overview comparison, FBMC delivers better spectral shaping of subcarriers than the OFDM systems commonly relied upon.

As discussed previously, FBMC has been designed to overcome the drawbacks posed by OFDM as the cyclic prefix OFDM technique provides with a loss of spectral efficiency due to the insertion of the cyclic prefix itself. It also has a high out-of-bound radiation, and a high narrowband interferer sensitivity. The FBMC modulation can simply be presented as the evolved version of OFDM modulation.

To understand FBMC in detail, let us have a look from the baseline and begin with the general system model overview of FBMC consisting of a Filter Bank as shown in the figure.

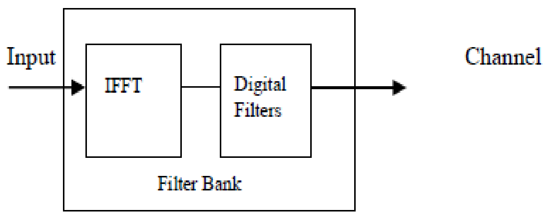

Fig. 1: Basic Diagram of Filter Bank

As denoted in the figure above, FBMC uses Inverse Fast Fourier Transform (IFFT) as the input for modulation and at the receiving end, Fast Fourier Transform (FFT) is used as a demodulator. The filter bank used in FBMC address the primary setbacks encountered with OFDM. FBMC has channels designed optimally in the frequency domain to have desired spectrum use. In addition, FBMC systems will be more spectral efficient as it would not require cyclic prefix.

In context with the multiple user systems, where a large number of users are to be balanced on the network, FBMC spectrally separates groups or subchannels that are allocated to the users as soon as empty subchannels are present. Thus, the users in the system do not need to be synchronized before access to the transmission system is provided.

This phenomenon helps further the scope of FBMC as a multicarrier scheme and opens up for the use of multi-antenna systems. However, the use of Multiple Inputs Multiple Outputs (MIMO) techniques can also be considered. Although FBMC is being heftily involved in the development of 5G projects across the world, further research in the matter is still necessary to make the technique usable on a mass scale.

III .GFDM

Generalized Frequency Division Multiplexing or GFDM is another multicarrier scheme which is based on the traditional multi-carrier filter bank concept. GFDM is another technique which is being used digitally in the implementation of 5G. Particularly, it is a transceiver concept contained with varying features which hold significant importance in scenarios which show high degree of spectrum fragmentation.

As we have studied earlier, the use of Orthogonal Frequency Division Multiplexing (OFDM) poses multiple challenges in its multicarrier scheme. To avoid this, a generalized version of OFDM was devised which came to be known as GFDM. GFDM primarily characterizes to show a low out of band emission which is achieved by flexible time-domain pulse shaping of individual subcarriers. Unlike its counterpart OFDM, GFDM is able to transmit a group of symbols at a particular instant of time.

In the context of using spectrum white spaces in TV UHF bands, GFDM poses to be an efficient alternative for white space aggregation even when heavy fragmentation is in place. Further, unlike OFDM, GFDM outputs a non-orthogonal, flexible waveform as it is based upon the time filtering of data blocks. We shall study GFDM further in detail and further in our research, we shall compare it with FBMC with reference to pre-decided parameters. Let us now look at the block diagram of a GFDM transceiver to understand the GFDM system model in detail.

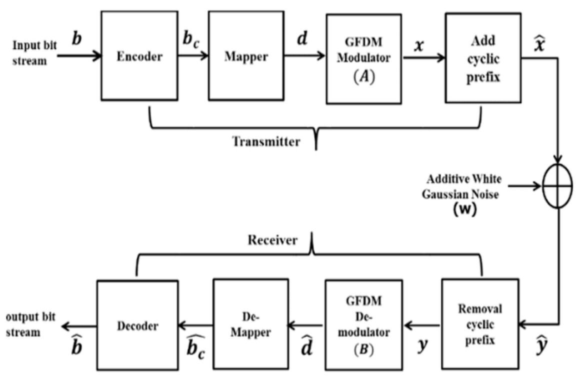

Fig. 2: Block Diagram of a GFDM transceiver

As denoted in the figure above, we can see a GFDM transceiver divided among two major sections, consisting of several blocks which carry out the GFDM signal transmission process.

The design of an ideal transceiver poses a big challenge as it should comply with the following constraints in its function. In context of TV UHF signals as mentioned above, they should avoid harmful interference by legacy TV signals and thus show ultra-low out of band radiation. But at the same instant, they should ensure high sensitivity in order to explore white spaces in the spectrum to interact with weaker signals as well. Therefore, it becomes further more necessary to design a system that can cop with strong spectrum fragmentation.

To tackle these constraints, the GFDM transceiver is wide band and complies with a range of necessities. As mentioned, it emits low out of band radiation to avoid interference. It has a flexible signal bandwidth and a more versatile white space allocation, which furthers it agility and efficiency as a multi carrier scheme.

GFDM is implemented digitally which also reduces the analogue front-end complexity and deepens the measures with increased accuracy.

As mentioned previously, GFDM provides with reduced demand of large subcarriers as the data transmission in GFDM is carried out with a time-frequency block manner, with which we are able to measure the performance of a GFDM system using the Peak to Average Power Ratio (PAPR).

PAPR in GFDM is less as compared to OFDM when it is measured with the equal spectral efficiency condition due to the reduced requirement of large subcarriers. It is also known, that the pulse shaping property of GFDM is responsible for controlling the out of band radiation. However, due to this, a self-induced interference is brought about in the system. And thus, a **Cyclic Prefix** is added to the entire block as shown in the figure to make GFDM relatively more spectrally efficient in comparison with OFDM.

However, another parameter that comes into place while studying GFDM is the Bit Error Rate (BER). A GFDM system model is compared with an OFDM model to observe their behavior while measuring the BER for both of them. We know that GFDM possess non-orthogonal characteristics, as a result of which, the BER performance of GFDM is slightly worse than that of OFDM, yet almost similar. And the orthogonality loss can eventually be tackled by the use of different filter designs.

Further studies in 5G by global organizations have also come to observe that OFDM causes significant spectrum leakage, even if preventive measures like pulse shaping and guard carriers are used. GFDM, on the other hand, combines flexibility and simplicity by reducing interference in the medium with the use of effective prevention techniques. Furthermore, we have looked how GFDM exhibits low PAPR, which allows low hardware costing and power consumption, which will make it a more attractive purchase for the customers when it shall enter the markets

IV. PARAMETER COMPARISON

Till now, we have studied FBMC and GFDM individually and have tried to comprehend the behavior of both with respect to OFDM. On assessment, we observed that both FBMC and GFDM, being multicarrier schemes proved to be a better alternative in comparison with their counterpart, OFDM for the Fifth generation of telecommunication services.

However, both multicarrier techniques behave differently under varying conditions. And although both have proved to perform better than OFDM, both have their own setbacks and positives. In this section, we shall study their behavior with respect to each other, and bring out a conclusive result as to which is an optimal multicarrier technique and can be equipped for better results in 5G services.

As we've learnt, FBMC provides optimal frequency-domain localization by using pulse shaping filters and stretching the pulse duration in time domain. Furthermore, there are multiple ways to implement FBMC like Staggered Modulated Multitone (SMT), Cosine Modulated Multitone (CMT), and Filtered Multitone (FMT). However, when we discuss 5G waveforms, we consider FBMC as SMT which is also known as Offset Quadrature Amplitude Modulation (OQAM-FBMC) due to its ability to deal with interference while allowing dense symbol placement in the time-frequency domain.

FBMC utilizes prototype filters for subcarrier localization. Also, due to the use of OQAM, orthogonality is ensured between the neighboring subcarriers.

A similar method is employed by GFDM for subcarrier filtering with the use of prototype filters. But as we have studied, circular convolution is carried out over a certain number of symbols in GFDM and a cyclic prefix is added. And in context with orthogonality, there is no constraint on GFDM prototype filters to satisfy the orthogonality condition, unlike FBMC. Therefore, we observe that GFDM is a non-orthogonal transmission technique with the use of non-orthogonal filters.

Apart from this, the good frequency-domain localization trait of FBMC is shared by GFDM. This makes it more suited for high mobile scenario in addition to being immune to synchronization errors. However, despite the waveform flexibility provided by GFDM, the nonorthogonal scheme requires complex algorithms at the receiver block. Therefore, the complexity constraint in pilot design and MIMO transmission is shared by the two schemes.

FBMC, GFDM, and OFDM with respect to various parameters to get a better understanding of each of their behavior.

PARAMETERS	OFDM	GFDM	FBMC
Spectral Efficiency	Low	High	High
Power Spectral Density	Low	Medium	High
PAPR Ratio	High	Medium	Low
Complexity	Low	High	Medium
ACLR (Adjacent Channel Leakage ratio)	Low	-	High

Table 1. Parametric Comparison between OFDM, GFDM, and FBMC

In the table shown above, we can see how each of the multicarrier schemes show varying characteristics. This gives us a better insight to figure out which one of them is a better scheme to choose from and which is better suited for 5G services.

V. CONCLUSION

In this paper, we have researched the carious techniques that are employed and tested for the use of the next generation of telecom services – 5G. We have seen how multicarrier schemes like FBMC and GFDM work and tried to study their characteristics in brief.

We have compared the two on several grounds with their counterpart OFDM which was used in the previous generation – 4G LTE, and observed how they prove to be a better alternative as they yield a more sound and optimal output for the use in 5G.

Then, we compared the two with respect to their localization ability with the use of prototype filters. In addition to this, when a linear filter is used in a GFDM system model, the GFDM system beings to show dynamic properties and starts behaving like an FBMC model, showing the latter's characteristics.

This comes to us as a huge advantage as it allows to incorporate the individually separate properties of both systems in a single GFDM model, which enhances flexibility of the system. This observation is key to our research and comparison between two system models and gives us a passive justification to how and why a GFDM system is better among the two models. It also gives us an insight to how filtering methods prove to be an external stimulus to the models and how the use of different filtering methods affects the final output of a model.

Keeping in mind the key observations made during this research, we were able to reach a diction over which system is better. Conclusively, we were able to figure that GFDM is better suited for the use in 5G.

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