A Review on Filter bank Multicarrier

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***Abstract*-Multicarrier modulations attract a lot of attention among engineers and researchers working in the field of, particularly in wireless applications. One specific form of multicarrier modulation referred to as OFDM has been the dominant technology for broadband multicarrier communications. Despite their many advantages, OFDM systems have a few, but important drawbacks like not able to maintain orthogonality due to ISI among consecutive multicarrier symbols. Filter bank multicarrier (FBMC) is an evolution with many advantages over the wide spread OFDM multicarrier scheme. Filter banks are an evolved form of sub band processing based on Fast Fourier Transforms and addressing some of its short comings, at the price of a somewhat increased implementation complexity. This paper is a review of FBMC.**

Keywords: FBMC-Filter Bank Multicarrier; FFT-Fast Fourier Transforms; OFDM- Orthogonal Frequency Division Multiplexing; GFDM-Generalized Frequency Division Multiplexing; BFDM-bi-orthogonal Frequency Division multiplexing; UFMC -Universal Filtered Multicarrier; TFP-Time-Frequency Packing.

I. INTRODUCTION

Multicarrier modulation (MCM) techniques enable transmission of a set of data over multiple narrow band subcarriers simultaneously. With an advanced wideband modulation and coding scheme (MCS), a system with MCM can achieve much higher spectral efficiency in frequency selective channels compared to those using single carrier modulation techniques. The filter bank is an array of filters, which are applied to synthesize multicarrier signals at the transmitter and analyze received signals at the receiver[1].

OFDM is widely applied in current broad band wireless network due to its advantages of low complexity in multicarrier modulation and channel equalization accessible frequency diversity gain multiusers scheduling gain in frequency OFDM signal suffers from large side lobes that can potentially lead to high inter-carrier interference (ICI) and severe adjacent-channel interference (ACI). Also we can see some disadvantage mainly large spread of subcarrier spectrum high sensitive to time and frequency synchronization error. Major alternative modulation formats beyond OFDM, including filter-bank multicarrier (FBMC), generalized frequency division multiplexing (GFDM), bi-orthogonal frequency division multiplexing (BFDM), universal filtered multicarrier (UFMC) and time-frequency packing (TFP) ,in the path channels, plain orthogonal multicarrier modulation formats are not able to maintain orthogonality due to ISI among consecutive multicarrier symbols. The traditional approach in OFDM to counter this issue is to introduce a CP longer than the time spread introduced by the channel. This enables the preservation of traditional transceiver implementations by IFTT and FFT operations, but introduces a time overhead in the communication, resulting into a loss of spectral efficiency. The approach used by FBMC to overcome this issue is to keep the symbol duration unaltered, thereby avoiding the introduction of any time overhead, and to cope with the overlap among adjacent multicarrier symbols in the time domain by adding an additional filtering at the transmit and receive side, besides the IFFT/FFT blocks. This is done by filtering each output of the FFT by a frequency-shifted version of a low pass filter termed a “prototype” filter. This additional filtering, together with the IFFT/FFT operation, forms a synthesis-analysis filter-bank structure, where the prototype filter is designed to significantly suppress ISI[2].

Filter bank multicarrier (FBMC) modulation is a family of MCM techniques in which a prototype filter is designed to achieve a certain goal, such as minimizing inter-symbol interference (ISI), inter-carrier interference (ICI) and/or stop band energy. the FBMC scheme is a potential successor of the dominant OFDM scheme and it is definitely a promising modulation technique for use in forthcoming 5G systems[1].

II. METHEDOLOGY

A. The Filter Bank

The filter bank is an array of filters, which are applied to synthesize multicarrier signals at the transmitter and analyze received signals at the receiver. A filter bank transceiver consists of two filter banks, one at the transmitting end (also called synthesis filter) and the other at the receiving end (also called analysis filter). A filter bank contains M digital filters arranged in a parallel configuration. These filters are employed with K-fold digital upsamplers at the transmitter denoted by $\uparrow K$ and with K-fold decimators at the receiver, denoted by $\downarrow K$. To emphasis the multi rate nature of the system, two time indices, n and m are used to denote the time samples corresponding to the low sampling rate(symbol rate) and the high sampling rate (channel rate), respectively. There exist many types of filter banks depending on how the filters are designed [3].

In figure, the input bit stream is assumed to have already partitioned appropriately and mapped to constellation symbols x0(n)……x_{N-1}(n).

When a signal x(n) goes through a filter with an impulse response of f(n), its output signal can be expressed as

$$u(m)=\sum_{k=0}^{N-1} x(n) * f(n) \quad \ldots\ldots.1$$

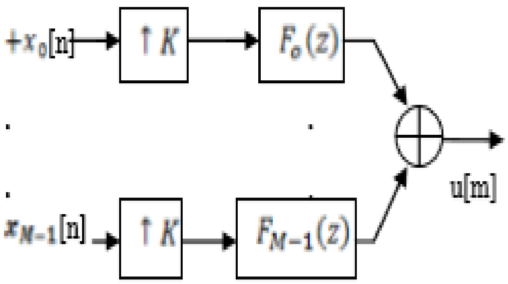

Figure 1: Synthesis filter

In practical implementations, to combat inter symbol interference (ISI) due to the presence of a frequency selective channel, the symbols at the output of the receiving filter bank, $y_0(n)\ldots\ldots y_{N-1}(n)$ needs to be equalized [5].

When a signal u(m) goes through a filter with an impulse response of h(n), its output signal can be expressed as

$$y(n)=v(m)*h(n) \quad \ldots\ldots2$$

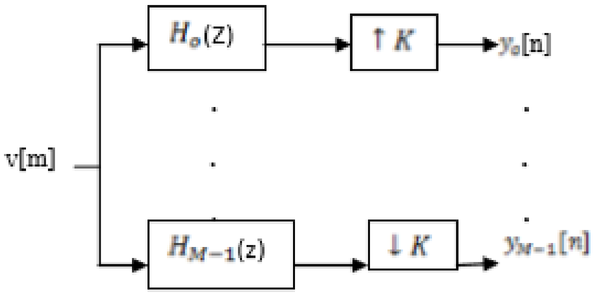

Figure 2:Analysis filter

To properly demodulate the transmit signal at each subcarrier, two conditions need to be satisfied that is No ICI in the frequency domain, No ISI in the time domain[4].

B.Filter Bank Multicarrier

Principle is to design a prototype filter to achieve a side lobe as small as possible by means of the filter bank. In the frequency domain, the frequency response of the FBMC subcarrier is very compact. The ripples can be neglected, and there is no ICI between the non-neighboring subcarriers. A number of N FIR filters constitute the PPN to generate the FBMC signals. Based on the DFT modulator and PPN, the digital implementation of FBMC is illustrated in Figure 3. PPN constitutes a series of subsequences. The ISI of the FBMC symbol can be reduced with a properly-designed polyphase filter and the FMBC symbol does not need a guard interval, boosting spectral efficiency [6]. As a result robustness to ISI, the immunity to ICI and ACI, and the high spectral efficiency of FBMC are achieved at the cost of reasonable implementation complexity [7].

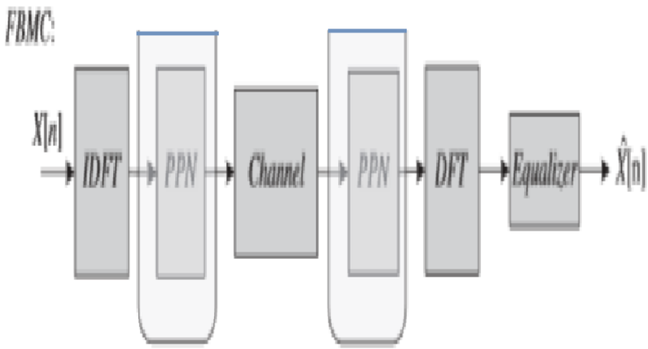

Figure 3: The digital implementation of FDMC

In the conventional (single-input single-output) FBMC systems, in order to reduce channel equalization to single tap per subcarrier, it is often assumed that the number of subcarriers is very large. Hence, each subcarrier band may be approximated by a flat gain. This, clearly, has the undesirable effect of reducing the symbol rate (per subcarrier) which along with it brings (i) the need for longer pilot preambles (equivalently, reduces the bandwidth efficiency); (ii) increases latency in the channel, (iii) higher sensitivity to carrier frequency offset (CFO), and (iv) higher peak-to-average power ratio (PAPR) due to the large number of subcarriers which increases the dynamic range of the FBMC signal[8].

III. FBMC ADVANTAGES AND CHALLENGES

A. ADVANTAGES

- Efficient usage of the allocated spectrum: FBMC technique, cyclic prefix is not required and also exploits the totality of the symbol period.
- The same filter bank can be used for receiver data signal processing and flexible, high resolution spectrum sensing with high dynamic range.
- High performance spectrum sensing and transmission: Due to the spectral sub channel separation, the functions of spectrum analysis and data transmission can be mixed and performed simultaneously. This serves as a remarkable facility for efficient opportunistic communications.
- Robustness to narrowband jammers and impulse noise.
- Spectral protection of neighboring users: The out of band attenuation curve of the prototype filter sets the level of spectral protection to the users[9].

B. CHALLENGES

- High computational complexity is associated with FBMC implementation when compared to OFDM. The time domain overlap of subcarrier symbols in filter bank introduces overhead in tightly time multiplexed operation.

- Analog RF performance is critical for implementing generic spectrum sensing with wide bandwidth and high dynamic range.
- The development of MIMO-FBMC system is nontrivial and may be very limited [10].

IV. APPLICATIONS

1. Cognitive radio communications:

   Compared to OFDM, FBMC offers higher spectral efficiency and is more applicable for the CR network with small size of spectrum holes and also the performance of FBMC is close to that of the perfectly synchronized case because of its frequency localization.
2. Multiple access networks:

   In the multiuser context, the uplink of an OFDM network employs a method called multiple access interference (MAI) cancellation in order to meet its basic operational requirements that is tight time and carrier synchronization which increases implementation complexity of the system. On the other hand FBMC avoids MAI without any need to perform synchronization.
3. Access to Television White Space(TVWS):

   For opportunistic access to the TVWS, flexibility, low adjacent leakage power ratio (ACLR), frequency agility and sharp spectrum roll off are important factors. In OFDM, implementing filter for avoiding non agile RF filters dramatically increases system complexity. Moreover, OFDM does not have the flexibility to address TVWS fragmented spectrum while FBMC can met the ACLR co-existence requirements and its performance is significantly better than OFDM [11].
4. Power Line Communication:

   The intrinsic properties of FBMC makes it well suited for broadband power line communication .In addition to its capability of fully exploiting the time and the channel bandwidth, they also offer high level of protection for the tones and are robust to jammers. Due to the absence of cyclic prefix, the streaming of data is regular in case of FBMC.
5. MIMO Communications:

   Multicarrier transmissions particularly OFDM combine easily with MIMO techniques. Whereas in MIMO-FBMC systems, for moderate and highly frequency selective channels, received signals are corrupted by ISI, ICI and IAI (inter antenna interference) and equalization techniques adopted to mitigate the above is not an easy task. Also with imperfect channel state information (CSI), additional significant ICI/ISI terms appear in FBMC and not in OFDM. So far, in adopting the various MIMO techniques, only FMT-based FBMC can offer the same flexibility as OFDM [12].

V. CONCLUSION

In this paper, a multicarrier modulation technique, FBMC evolved from OFDM, the most widely deployed technique for multicarrier communication is presented. Qualities of FBMC make it an ideal choice for CR communications, multiple access networks, TVWS and PLC. Whereas FMT is the only FBMC system that can be efficiently extended for transmission over MIMO channels so far.

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