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A Paradigm Shift from OFDM to WPMCM as the Preferred Multi-Carrier Modulation Technique

Ambika Omana Menon, Sakuntala S. Pillai

Abstract: ***As of now, Multi-Carrier modulation (MCM) is considered an effective technique for both wired and wireless communications. Studies have been done by different researchers in this area and analysis of the comparative advantages and disadvantages of the different options for multi-carrier modulation have been extensively done. The place of OFDM, which was once considered as a very strong candidate for multi-carrier modulation technique, has almost been taken over by its successor, WPMCM. This paper reviews the paradigm shift from OFDM to WPMCM as the preferred multi-carrier modulation technique.***

Index Terms: Multicarrier modulation, WPMCM, OFDM, Discrete Wavelet Packet Transform.

I. INTRODUCTION

In the field of digital communications, information in the form of input bit stream is transmitted from the source to the destination. Because of the uncompromising outburst of information to be transmitted, there is no limit to the desired bit rate of a communication system. Ways to enhance the bit rate of the system is always welcomed by the technical community. This resulted in a shift from single to multi-carrier communications. Recently, the attempt at multi-carrier communications has been successful because of the advent of digital signal processors and the introduction of FFT [1]. With efficient Fast Fourier Transform techniques, incorporating a multicarrier modulation technique using OFDM has become feasible. Research in this field, brought the drawbacks as well as the areas of possible performance enhancements for the OFDM scheme into limelight. In this paper, observations made independently by different researchers are brought together. This should provide material for analysing the paradigm shift from OFDM to WPMCM as the preferred multi-carrier modulation technique. The rest of the paper is organized as follows:

The basic OFDM transmission techniques as well as an assortment of drawbacks as pointed out from different areas of the technical community are discussed in section 2. This is followed by section 3, with a discussion on wavelet packet based techniques and the observations made by different researchers in this topic. In section 4, conclusions are drawn from the observations in the preceding sections which guide one to the scope of further work in this area.

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***** Correspondence Author (s)
Ambika Omana Menon, Department of Electronics and Communication, St. Thomas Institute for Science and Technology, Thiruvananthapuram, India.
Sakuntala S Pillai, Department of Electronics and Communication, Mar Baselios College of Engineering and Technology, Thiruvananthapuram, India.

II. OFDM MULTICARRIER MODULATION

Multi-carrier modulation subdivides the total bandwidth into N narrow channels, which are transmitted in parallel. The original data stream at rate Rs is divided into N streams each having data rate of Rs/N and therefore N times longer symbol duration, i.e. TMC = NT [2]. Each bit stream with a much lower bit rate modulates several carriers.

In OFDM, these subcarriers are allowed to have overlapping spectra owing to the orthogonal nature of the subcarriers [2,3]. In dispersive channels, guard intervals between OFDM symbols reduce inter symbol interference. Also OFDM systems can be efficiently implemented using IFFT-FFT combination [4] as shown in the following figure.

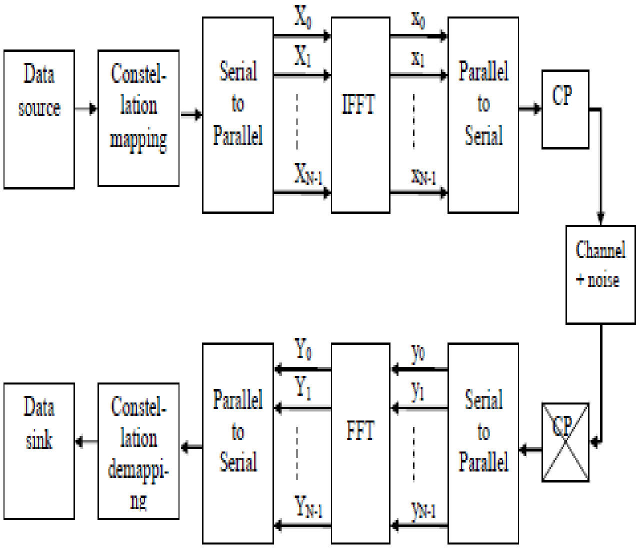

Figure 1: OFDM Transmitter and receiver.

2.1. OFDM - Issues

As the wireless services face increasing popularity among the technical community, there has also been a tremendous increase in the demands on resources like battery power and radio spectrum. The addition of cyclic prefix to OFDM symbols is an effective method to cope up with dispersive channels and time offset. But this also means that a compromise has been made in the effective utilization of the available radio spectrum.

Studies in the area of effective spectrum allocation show that spectrum congestions can be attributed more to the sub-optimal use of spectrum than to the lack of free spectrum[5][6]. The suggested solution to this problem is to operate in licensed spectrum without harmless interference with legitimate users [7].

This requires that the subcarrier allocation should be done in real time. But dynamic allocation of subcarriers is not feasible with OFDM technique since it uses static carriers.

Also each subcarrier in an OFDM system has large side-lobes resulting in a high degree of spectral leakage [8]. This necessitates thorough filtering and sufficient guard bands.

III. THE WPMCM MULTICARRIER MODULATION

In Wavelet Packet based Multi Carrier Modulation (WPMCM), orthogonal wavelet packets waveforms combine a collection of parallel signals into a single composite signal.

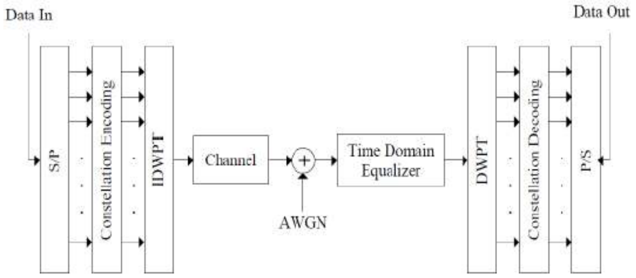

Figure 2: WPMCM Transmitter and receiver

The input data stream is divided into parallel lower data sub streams. The subcarrier waveforms are obtained by the wavelet packet transform (WPT). An IDWPT-DWPT combination can be used to efficiently implement the system.

Both OFDM and WPMCM use orthogonal waveforms as subcarriers and they achieve high spectral efficiency by allowing subcarriers 'spectra to overlap one another. The adjacent subcarriers do not interfere with each other as long as the or thogonality between subcarriers is preserved.

But the two schemes differ in the shape of the subcarriers and in the manner in which they are created. OFDM makes use of Fourier bases which are static sines/cosines while WPMCM uses wavelets which offer much more flexibility. By utilization of different wavelets in WPMCM we can get different subcarriers which lead to different transmission system characteristics [9].

3.1 A proposal for improvement

One issue of the OFDM scheme was the wastage of the precious radio spectrum due to the introduction of cyclic prefix to the OFDM symbols. Cyclic prefix is not needed in WPMCM systems, which means there is no associated spectral wastage. WPMCM employs subcarriers with overlapping frequency spectra, excellent frequency selectivity and flexibility. It is efficiently implemented by an iterative method where the number of subcarriers and their bandwidth can be easily changed. This allows for the real time allocation of subcarriers which was impossible in the case of the OFDM scheme. The filter coefficients can be tailored according to the specifications posed by the engineering requirement. Also by using frequency selective filters subcarriers with much lower side-lobes than those of OFDM can be obtained. This reduces the spectral leakage problem inherent to OFDM systems.

3.2 Performance comparison of OFDM and WPMCM

A vast amount of investigations have been done on the performance comparison between OFDM and WPMCM systems. Comparisons on the effects of carrier frequency offset, phase noise, time synchronization errors etc. have been extensively made, the results of which are documented below.

Frequency Offset

Performance comparisons show that WPMCM and OFDM are both very sensitive to frequency offset and that small variations of frequency offset degrade the system performance significantly. Also, majority of the wavelets show very similar performance as that of OFDM. The biorthogonal wavelet consistently gives a poor performance whereas the Haar wavelet outperforms other wavelets and OFDM [2,5]. In an OFDM scheme, the interference due to frequency offset is limited to inside the multicarrier symbol where ICI occurs. This means that the other OFDM symbols are not affected. In WPMCM systems, overlapping symbols results in both ICI and ISI [2][5].

Phase Noise

The effect of phase noise on the communication system is to scatter the constellation points around the reference positions. The results are comparable for the two schemes except for the biorthogonal wavelet which has an inferior performance. The presence of phase noise results in loss of orthogonality and subcarriers begin to interfere with each other. In the case of OFDM, interference due to phase noise is limited to the multicarrier symbol where ICI occurs whereas for a WPMCM system, this results in both ISI and ICI [2,5]

Time Offset

In the presence of time offset, OFDM systems perform much better than WPMCM systems due to the exploitation of cyclic prefix. WPMCM cannot profit from this revision and shows poor performance in presence of timing error [2][5].

Side lobe suppression

Compared to the OFDM Scheme, there is better side lobe suppression in the case of WPMCM which facilitates the coexistence of primary and secondary users which is of utmost importance in the case of cognitive radio [10].

IV. CONCLUSION

The survey shows that WPMCM Scheme is vulnerable to time synchronization errors, cannot use guard intervals and hence only moderate timing errors are acceptable. This suggests that a robust frame synchronization algorithm to detect and correct large time offsets should ease the situation. Also, an indication from the survey is that the implementation of dynamic spectrum allocation in WPMCM schemes increases the system capacity, by allocating spectrum resources according to the actual demand.

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