PERFORMANCE ANALYSIS OF OFDM AND WAVELET PACKET MODULATION

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ABSTRACT

Success of OFDM has proved that Multi carrier modulation is an efficient solution for wireless communications. Wavelet Packet Modulation (WPM) is a new type of modulation for transmission of multicarrier signal on wireless channel that uses orthogonal wavelet bases other than sine functions. Though this modulation is over all similar to that of OFDM, it provides interesting additional features. In this thesis, a detailed study is given on Wavelets and WPM and the BER performance comparison between the OFDM systems and WPM systems and equalization techniques are analysed. The analysis is done for different types of wavelet generating families, various number of modulations QAM constellation points (16 to64), and simulated over AWGN channel, and other Multipath fading channels.

Keywords*: *Wavelet packet modulation, Multicarrier Modulation, Orthogonal Frequency Division Multiplexing (OFDM), Bit error Rate (BER)

I. INTRODUCTION

In recent years, OFDM (orthogonal frequency division multiplexing) has attracted much attention as one of the multicarrier transmission methods according to the demands for high-speed mobile communications. Wavelet packet modulation (WPM) has been proposed as one of the multicarrier transmission methods using discrete wavelet transform (DWT) The wavelet transform can analyze a signal not only in the frequency domain but also in the time domain, enabling a wide use in the field of signal analysis. The FDE can be applied to WPM with a guard interval like OFDM, and it was shown that a high-quality mobile communication is expected using WPM because the performance of equalization was better than OFDM. A wavelet is a wave-like oscillation with amplitude that starts out at zero, increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one might see recorded by a seismograph or heart monitor. Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing. Wavelets can be combined, using a "shift, multiply and sum" technique called convolution, with portions of an unknown signal to extract information from the unknown signal.

II. HAAR WAVELETS

The first DWT was invented by the Hungarian mathematician Alfréd Haar. For an input represented by a list of 2^n numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale: finally resulting in $2^n - 1$ differences and one final sum. The Haar DWT illustrates the desirable properties of wavelets in general. First, it can be performed in $O(n)$ operations; second, it captures not only a notion of the frequency content of the input, by examining it at different scales, but also temporal content, i.e. the times at which these frequencies occur. Combined, these two properties make the Fast wavelet transform (FWT) an alternative to the conventional Fast Fourier Transform (FFT).

2.1. WPM System Compared to OFDM

From the system architecture point of view WPM provides interesting advantages-

The dependence of wavelet packet transform on the generating wavelet is major asset as it achieves improved transmission integrity be exploiting the most common physical diversities- space, frequency and time diversities. This modulation provides signal diversity similar to spread spectrum systems. In practice, two different generating wavelets can modulate two signals that can be transmitted on same frequency band and also the interference suffered is reduced. The amount of interference between the two signals transmitted on same frequency band directly depends on the wavelets chosen. This characteristic can be used in cellular communications where different wavelets are used in adjacent cells so that they use same frequency bands in those cells and therefore reduce the inter-cell interference. There is no limitation in number of subcarriers in WPM unlike OFDM, where they are usually fixed at the time of design and is difficult to implement a FFT transform of a programmable size. In WPT the transform size is exponentially dependent on the number of iteration of the algorithm. So it is easy to configure them without increasing the overall complexity in implementation point of view. So this allows the change of transform on the fly. Semi-arbitrary division is another useful feature of WPT. OFDM only allows all the subcarriers of same bandwidth. But WPM gives the flexibility to choose subcarriers of different bandwidth. But as explained the previous chapter, increase in subcarrier bandwidth is bounded to decrease the corresponding symbol length as each subcarrier has the time-frequency plane area. This feature allows the WPM to be referred as multi-rate system as its transmission over the channel is effectively done at different symbol rates the throughput of the corresponding subcarrier remains constant due to constant bandwidth-duration of the subcarrier. This feature can be used of the systems that should support multiple data streams with different transport delay. A channel that requires low transport delay can use subcarrier of greater bandwidth. The signalling information that could be carried within narrower bandwidth employs narrow subcarriers, and could be used for the purpose of synchronization to take advantage of the longer symbols. In OFDM, the set of waveforms is by nature defined in the complex domain. WPM, on the other hand, is generally defined in the real domain but can be also defined in the complex domain, solely depending of the scaling and dilatation filter coefficients. Altogether, WPM presents a much higher level of flexibility than current multicarrier modulation schemes and this makes it a candidate of choice for reconfigurable and adaptive systems for the next generation of wireless communication devices. In OFDM, a transmission signal is combined by the use of FFT (fast Fourier transform), while in WPM, the transmission signal is combined by the use of DWT. The wavelet transform is originally a technique for time frequency domain analysis. Therefore, WPM has time and frequency resolution.

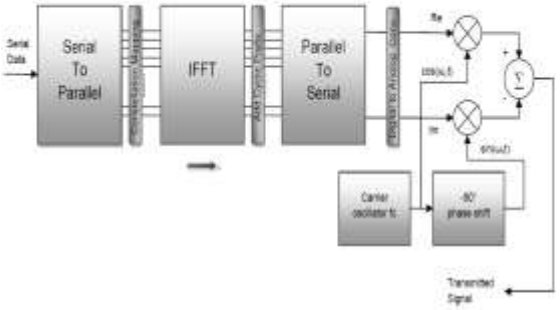

Figure 1: OFDM Transmitter

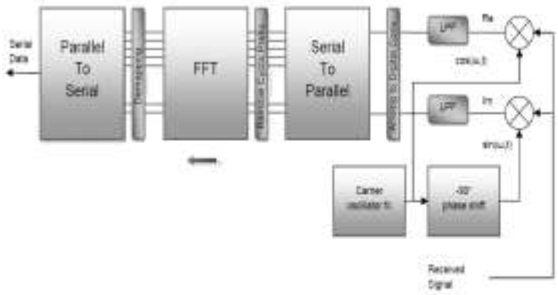

Figure 2: OFDM Receiver

Wavelet Packet Modulation is a novel multicarrier modulation technique. WPM is an alternate to OFDM.WPM overlaps in both frequency and time domain. The characteristics of a multicarrier modulated signal are directly dependent on the set of waveforms. Hence, the sensitivity to multipath channel distortion, synchronization error or non-linear amplifiers might present better values than a corresponding OFDM signal. The major advantage of WPM is its flexibility. This feature makes it eminently suitable for future generation of communication systems. A tremendous amount of work has been done recently to fulfill this requirement at the physical layer of communication systems: complex equalization schemes, dynamic bit-loading and power control that can be used to dynamically improve system performance. WPM can take advantage of all those advanced functionalities designed for multicarrier systems. This feature together with a modular implementation complexity make WPM potential candidate for building highly flexible modulation schemes.

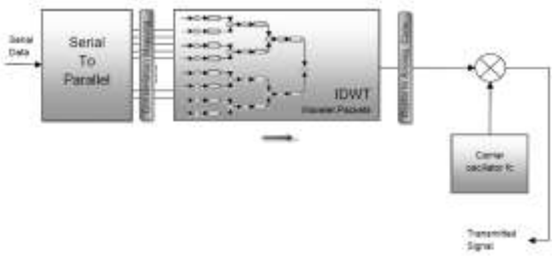

Figure 3: WPM Transmitter

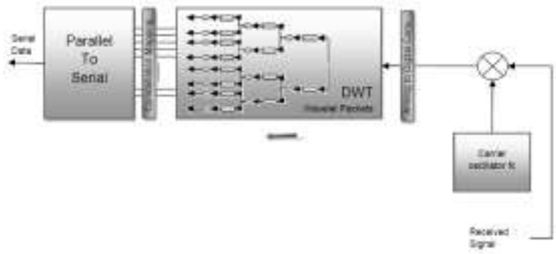

Figure 4: WPM Receiver

III. PERFORMANCE OF WPM SETUP WITHOUT TIME OFFSET

To gauge the system operation we first check its performance under optimal conditions. Fig. shows the DQPSK constellation points for WPM setup using various wavelets in ideal channel conditions with no time offset. From the plot we may note that perfect estimates of the transmitted data can be obtained at the receiver when the transmitter and receiver ends are in time-unison. A timing error results in a loss of time synchronization which causes a loss of orientation of incoming data at the receiver. As a result the time domain data entering the IDFT/IDWT block is incorrectly aligned whereby the samples of previous or next OFDM/WPMC symbol are selected while The 19th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'08) valid samples at the beginning or at the end of the symbol in consideration are discarded. We present the impact of time synchronization error in the sections *B* and *C*.

3.1. Performance when Time offset is Modelled as Discrete Uniform Distribution

DQPSK modulation scheme is used and where timing offset is modelled as discrete uniform distribution. WPM this corresponds to $0 \leq \tau os \leq 2/5$. In accordance with theoretical derivations carried out for OFDM, the ICI and

ISI parts have disappeared and only the phase shift has remained. The right half of Fig. illustrates received constellation points for time offset of $0 \leq \tau \leq 3$ samples in the opposite direction, towards the next symbol. In case of WPM this corresponds to $0 \leq \tau os \leq 0.15$. The OFDM system performs much better when the timing offset is towards CP in comparison to the case when it is away from it. On the other hand the performance of wavelets is equally bad for both cases because of the fact that WPM cannot profit from a CP due to the time-overlap of its symbols. Therefore direction of time offset is not important but only the size of timing error matters. For even small timing errors WPM suffers from ICI corresponding BER performance over AWGN channel for and ISI contributions.

3.2. Performance with Time offset modelled as Gaussian distribution

DQPSK modulation and with timing offset modelled as zero-mean Gaussian distribution with variance $\sigma 2$=3, which correspond to $\sigma s\ 2=2/5$ for WPM. The channel conditions are assumed to be ideal with no additional noise. From the constellation points we may note that wavelets are severely affected by ICI and ISI due to timing error while OFDM has relatively better performance. The BER curves plotted in Fig. 14 further The 19th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'08) corroborate this effect.

3.3. Effect of Frequency and Phase Offset on System Performance

Frequency offset can be caused by misalignment between receiver and transmitter oscillator frequencies and/or due to Doppler shift. It destroys orthogonality of subcarriers and therefore prevents perfect alignment of FFT bins with peaks of sinc pulses. As a result the energy of each subcarrier is spread to other subcarriers leading to ICI. Similarly, the phase offset also has a deleterious effect on the system functioning. After examining the BER performance under frequency offset and phase noise imperfections of OFDM and WPM with some standard wavelets. It is clear from that BER increases very rapidly with increase in frequency offset. Although, unlike the effect of time offset, there is no perceivable differences in the performances of WPM and OFDM systems.

IV. RESULT

The performance of wavelet packet modulation and OFDM has been investigated by means of computer simulations. We designed a communication system with DQPSK modulation.and 128 orthogonal subcarriers, corresponding to 7 stages wavelet packet tree. In case of WPM an oversampling is applied at rate *tos*. OFDM makes use of cyclic prefix of length 16 while WPM does not utilize any kind of CP or GIs. Further there are no additional error estimation or correction capabilities implemented. Several known wavelets such as Daubechies, Symlets, Coiflets, discrete Meyer and biorthogonal wavelets are applied and studied. To simplify the analysis the channel is taken to be additive white Gaussian noise (AWGN) and perfect frequency synchronization is assumed.

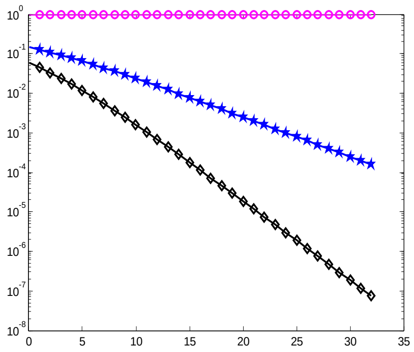

Fig 5: Bit Error Rate

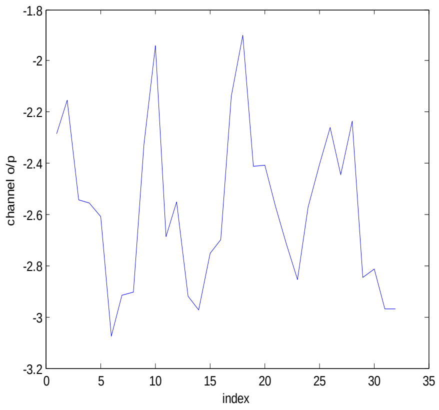

Fig 6: Mean Value of Channel Output

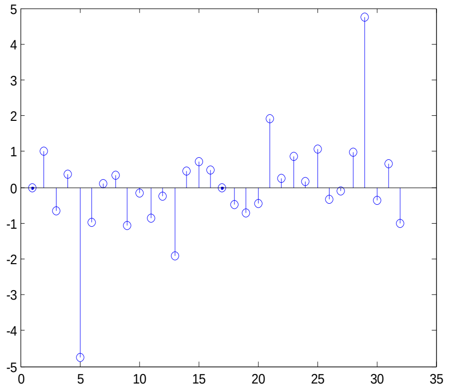

Fig 7: Implementation of FFT

DQPSK constellation points for WPM setup using various wavelets in ideal channel conditions with no time offset.

V. CONCLUSION

In this project the advantages of using WPM for multicarrier communication systems and comparison between this new scheme and OFDM has been evaluated. Overall, the performance results of WPM lead us to conclude that this new modulation scheme is a viable alternative to OFDM to be considered for today's communication systems. OFDM remains nevertheless a strong competitor because of its capability to cope with multipath effects efficiently. WPM is slightly more sensitive than OFDM to commonly encountered types of distortion due to non-ideal elements of the system. The major interest of WPM nevertheless resides in its ability to fulfil the wide range of requirements of tomorrow's ubiquitous wireless communications. The overlapping of wpm symbols causes a significant amount of interference that requires an dedicated equalization scheme to be studied. A study on synchronization of the WPM signals in both time and frequency domains would most probably lead to efficient algorithms, due to the multi resolution nature of the multiplexed signal. WPM is relatively a young and promising communication concept. It shares most of the characteristics of an orthogonal multi carrier system and in addition offers the advantage of flexibility and adaptation. These properties can make it suitable for the design and development of communication systems for the future (Cognitive Radio and 4G). However, to realize this vision there are potential pitfalls that have to be ironed out. In this paper we presented one of the major drawbacks of WPM in comparison with classical OFDM. OFDM can exploit simple CP to greatly reduce performance decrease due to timing error and/or dispersive channel. WPM as a consequence of the time overlap nature of its symbols cannot use CP or GI. Furthermore, the ISI in OFDM is normally generated due to overlap of two consecutive symbols. However in the case of WPM the ISI is generated due to a number of adjacent symbols overlapping over-one another. Because of this, WPM is very sensitive to even small timing discrepancies between transmitter and receiver, as can be seen from simulation results. During simulations several known wavelets including the popular Daubechies family and its variants Symlets, Coiflets as well as the discrete Meyer and biorthogonal wavelets were applied and studied. All of these families were found to be highly sensitive to time offset. It is worth mentioning here that when the characteristics, such as length of filter, amongst the members of the same family (e.g.db2, db10, db20) were altered, there were no perceivable differences in the system performance. The wavelets used in this article are standard wavelets that were developed for applications such as image processing or encryption, and hence not suitable for MCM.

Future work should consider design of wavelet and scaling filters that would minimize the interference energy which arises as a result of timing error Another possible solution is to use complex wavelets to reduce WPM time shift sensitivity . Furthermore, a robust synchronization scheme that can tackle relatively large timing offsets can be developed and applied .

REFERENCES

[1] S.Manikandan, “Speech enhancement based on wavelet de noising” Academic Open Internet Journal www.acadjournal.com, Volume 17, 2006.

[2] Hamid Sheikhzadeh, Hamid Reza Abutalbi, “An improved wavelet based speech enhancement system”, Proceedings of 7th European Conference on Speech Communication and technology, Alborg, Denmark, 3-7, Sept 2001, pp 1855-1857.

[3] Lallouani, M. Gabrea and C.S. Gargour, “Wavelet based Speech enhancement using different threshold based denoising algorithms”, Canadian conference, Electrical and Computer Engg., May2004.

[4] Amara Graps, “An introduction to Wavelets”, IEEE Computation Science and Engineering, Volume 2, Issue 2,June 1995, page 50-61.

[5] Soon Ing Yann, “Transform based Speech Enhancement Techniques”, PhD Thesis Nanyang Technological University 2003.

[6] Chris Perkins, Tobin Fricke, “Wavelets”, University of California at Berkely,1St December2000,pp 1-18.

[7] Nikhil Rao, “Speech Compression using Wavelets”, B.E Thesis, School of Information Technology and Electrical Engineering University of Queensland Oct 8th, 2001.

[8] Yan Long, Lin Gang and Guo Jun, “ Selection Of The best Wavelet Base For Speech Signal”, Proceedings of International Symposium on Intelligent Multimedia, Video and Speech Processing, October 20-22, 2004