

bradscholars

Improvements in Multicarrier Modulation Systems using a Wavelet OFDM Scheme

Item Type	Conference paper
Authors	Karkhaneh, H.;Ghazaany, Tahereh S.;Abd-Alhameed, Raed;Child, Mark B.;Ghorbani, A.;Rasheed, W.;Elkhazmi, Elmahdi A.
Citation	Karkhaneh H, Sadeghpour T, Abd-Alhameed R et al (2010) Improvements in Multicarrier Modulation Systems using a Wavelet OFDM Scheme. In: 6th International ICST Conference on Mobile Multimedia Communications, (MobiMedia 2010), Lisbon, Portugal, 6-8 September, 2010. ICST. No. 1. Pp. 1-8.
DOI	https://doi.org/10.1007/978-3-642-35155-6
Rights	© ICST 2010. This is the author's version of the work. It is posted here by permission of ICST for personal use. Not for redistribution. The definitive version was published in 6th International ICST Conference on Mobile Multimedia Communications, (MobiMedia 2010), Lisbon, Portugal, 6-8 September, 2010. ICST. ISBN: 978-963-9799-98-1
Download date	2026-03-15 01:42:03
Link to Item	http://hdl.handle.net/10454/4802

The University of Bradford Institutional Repository

<http://bradscholars.brad.ac.uk>

This work is made available online in accordance with publisher policies. Please refer to the repository record for this item and our Policy Document available from the repository home page for further information.

To see the final version of this work please visit the publisher's website. Where available access to the published online version may require a subscription.

Author(s): Karkhaneh, Haleh, Sadeghpour, Tahereh, Abd-Alhameed, Raed A., Child, Mark B., Ghorbani, Ayaz, Rasheed, W. and Elkhazmi, E. A.

Title: Improvements in Multicarrier Modulation Systems using a Wavelet OFDM Scheme.

Publication year: 2010

Conference title: 6th International ICST Conference on Mobile Multimedia Communications, (MobiMedia 2010), Lisbon, Portugal, 6-8 September, 2010.

Publisher: ICST

Link to conference site: <http://www.mobimedia.org/2010/index.html>

Citation: Karkhaneh, H., Sadeghpour, T., Abd-Alhameed, R., Child, M. B., Ghorbani, A., Rasheed, W. and Elkhazmi, E. A. (2010). Improvements in Multicarrier Modulation Systems using a Wavelet OFDM Scheme. In: 6th International ICST Conference on Mobile Multimedia Communications, (MobiMedia 2010), Lisbon, Portugal, 6-8 September, 2010. ICST. ISBN: 978-963-9799-98-1. Paper No. 1, pp. 1-8.

Copyright statement: © ICST 2010. This is the author's version of the work. It is posted here by permission of ICST for personal use. Not for redistribution. The definitive version was published in 6th International ICST Conference on Mobile Multimedia Communications, (MobiMedia 2010), Lisbon, Portugal, 6-8 September, 2010. ICST. ISBN: 978-963-9799-98-1

Improvements in Multicarrier Modulation Systems using a Wavelet OFDM Scheme.

Haleh Karkhaneh², Tahereh Sadeghpour¹, Raed Abd-Alhameed¹, Mark
B.Child¹, Ayaz Ghorbani², W.Rasheed³, E .A. Elkhazmi⁴

¹Mobile & Satellite Communications Research Centre, University of Bradford, Bradford,
United Kingdom, BD7 1DP.

²Department of Electrical Engineering, Amirkabir University of Technology, Tehran, Iran.
{tsadeghp,r.a.a.abd,m.b.child}@bradford.ac.uk
{karkhane,ghorbani}@aut.ac.ir

³Collage of Information Technology, Asra University, Aman, Jordan.
Wali20012001@yahoo.com

⁴The Higher Institute of Electronics, Bani Walid, Libya
Eaelkhazmi@hotmail.com

Abstract. This paper investigates the performance of wavelet OFDM signals over a wireless communications link. The scheme is shown to be generally similar to Fourier based OFDM, but with some additional features, and improved characteristics. The sensitivity of both schemes to the nonlinear amplification in the transmitter is compared by monitoring the time domain output data and the adjacent channel power ratio (ACPR) performance.

Keywords: wavelet transform, OFDM, ACPR.

Introduction:

OFDM is often seen as an efficient means of delivering high speed wireless data links over a multipath fading environment, but suffers a major disadvantage in its peak-to-average power ratio (PAPR) [1]. High peaks in the OFDM transmit signals drive the power amplifiers (PA) operating near their nonlinear saturation region, reducing their power efficiency, and causing an overall degradation in the link performance. It is therefore necessary to transmit signals with a lower PAPR because of the operating range of the PA [1]. Existing research suggests a performance gain in wavelet based OFDM compared with Fourier based OFDM, owing to the superior spectral containment properties of wavelet filters. The characteristics of an OFDM modulated signal depend directly on the set of waveforms from which it has been constructed.

Thus, any sensitivity to multipath channel distortion, synchronization error, and PA nonlinearities may be improved at this signal construction stage [2].

Wavelet based multi-carrier modulation, also known as wavelet (or filter bank) based OFDM has been studied in [3] and [4]. These wavelet OFDM systems possess all the broad advantages and disadvantages of Fourier based OFDM systems. However, in wavelet OFDM, the orthogonality is satisfied by orthogonal filter banks, and no guard band interval (cyclic prefix) is needed, thus enhancing the bandwidth efficiency (20%) compared vs. Fourier OFDM systems. In addition, there is an additional bandwidth efficiency (8%) in wavelet OFDM, as pilot tones are no longer required [5] [6].

In this paper we focus on the sensitivity of Fourier and wavelet based OFDM to the nonlinear amplification in the transmitter by comparison with time domain data and ACPR performance. A resume of the wavelet packet transform is given in section II, whilst in section III compares wavelet and Fourier OFDM for a representative system.

The wavelet packet transform:

The wavelet packet transform is a tool for analysing signals defined in the joint time-frequency domain, and is capable of providing simultaneous time and frequency domain data, as well as the combined time-frequency representation. The wavelets, or filter banks, under consideration possess better orthogonality compared with the more familiar orthogonal signal sets used [7]. In analytical terms they have compact support in both the time and frequency domain [8] [9]. Multi-resolution analysis allows wavelet and scaling functions to be represented by low pass (LP) and high pass (HP) conjugate mirror filters, respectively. These filter coefficients are denoted as $h[n]$ and $g[n]$, and satisfy the following conditions:

$$|\hat{h}(\omega)|^2 + |\hat{h}(\omega + \pi)|^2 = 2$$

$$|\hat{g}(\omega)|^2 + |\hat{g}(\omega + \pi)|^2 = 2$$

$$\hat{g}(\omega)\hat{h}^*(\omega) + \hat{g}(\omega + \pi)\hat{h}^*(\omega + \pi) = 0$$

The two orthogonal wavelet packet bases are defined as:

$$\Psi_{j+1}^{2p}(t) = \sum_{n=-\infty}^{\infty} h[n]\Psi_j^p(t - 2^j n)$$

$$\Psi_{j+1}^{2p+1}(t) = \sum_{n=-\infty}^{\infty} g[n]\Psi_j^p(t - 2^j n)$$

The wavelet basis set $\{\Psi_j^p(t - 2^j n)\}_{n \in \mathbb{Z}}$ is orthogonal, and represents the p^{th} wavelet (packet function) at the j^{th} level. This is an iterative decomposition, and the output coefficient vectors are reduced in size at each step by 2, eventually leading to a scalar output. This process is reversible, and the inverse discrete wavelet transform (IDWT) can be used to reconstruct the original input vector from the coefficient vectors. The action of the IDWT can be represented a series of up-sampling filters defined by $h[n]$ and $g[n]$. In Fig. 1 the decomposition and reconstruction trees are shown for 3-level wavelet packet, which may be used to illustrate demodulation and modulation, respectively.

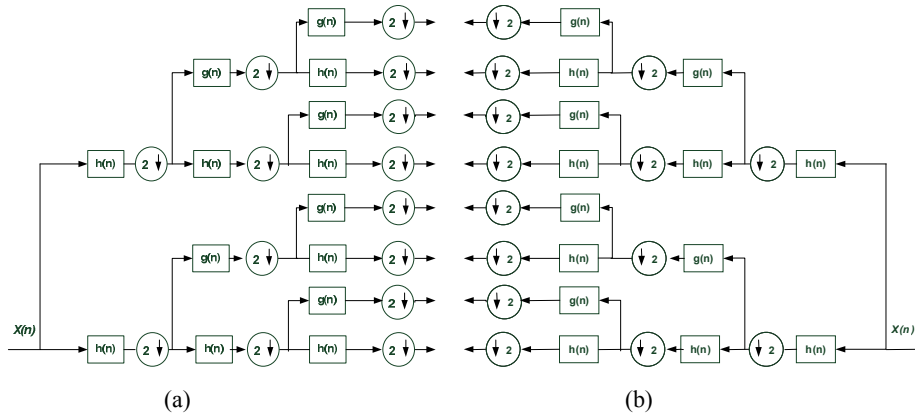


Fig. 1 Wavelet packet trees: (a) analysis/DWPT (b) synthesis/IDWPT

Wavelet packet based OFDM:

The OFDM transmitter is implemented by the IFFT and the output OFDM frame is given by,

$$s_{\text{OFDM}}(m) = \sum_{k=0}^{N-1} a_k \exp\left(2\pi j \frac{k}{N} m\right)$$

where a_k denotes the data symbols, k is the sub-carrier index, and N is the number of subcarriers with inter-carrier spacing fixed as $\Delta f = T^{-1}$ (T being the symbol period). The OFDM system is illustrated in Fig. 2. One drawback of this scheme is the high PAPR associated with the OFDM signal, for which wavelet OFDM offers an

alternative solution (Fig. 3). The modulated signal is initially converted from serial to parallel, as in the unmodified OFDM transceiver, but the IDWT is used in place of the IFFT. The transmitted signal takes the form,

$$s(m) = \sum_{p=0}^{N-1} \sum_{l=0}^{\infty} a_p(l) \Psi_{j,p}(m - lN)$$

where $a_p(l)$ are the modulated data symbols, and $\Psi_{j,p}$ is the reconstructed wavelet (packet) function. The action of the IDWT on a 64-QAM signal is given in Fig. 4. Our focus is on low frequency signals, so the modulated signals (a_p) perform a circular convolution with the LP filter, whereas the HP filter also performs the convolution with zeros padding the signal. The HP filter contains the wavelet coefficients. Different families of wavelet have different filter lengths, and hence approximated and detailed coefficients. Both filters must satisfy orthogonality to act as a wavelet transform. The up-converted analogue signal is sent to the power amplifier (PA), and the complex output of the memoryless PA envelope is given by,

$$w(s) = g(s) \exp\{j(\phi(s) + \theta)\}$$

where $s \mapsto s(t)$ is the amplitude of the complex input envelope, $\theta \mapsto \theta(t)$ is the arbitrary phase; the $g(\cdot)$ and $\phi(\cdot)$ are the AM-AM and AM-PM transfer functions, respectively [10]. The wavelet packet modulated (WPM) receiver signal is affected by the AWGN channel; in the receiver, the DWPT returns the signals to their original domain. Fig. 5 shows the signal at the input and output of the DWT, the estimation error is due the nonlinearity of the PA, and the AWGN.

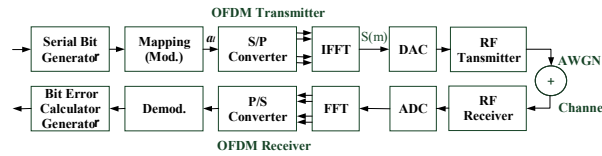


Fig. 2 OFDM Transceiver

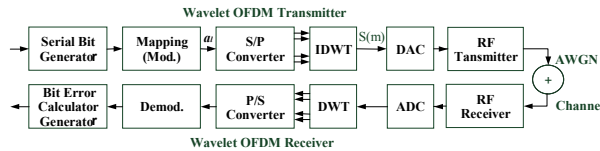


Fig. 3 Wavelet OFDM Transceiver

The received signal is illustrated in Fig. 6, comparing with Fig. 5, it can be inferred that the wavelet based OFDM has optimal performance over the conventional OFDM, and that wavelet bases may offer a more logical choice for constructing orthogonal waveform sets. Referring to the power spectral density (PSD) of the wavelet vs. conventional OFDM, it can be seen that the wavelet OFDM has the greater spectral efficiency.

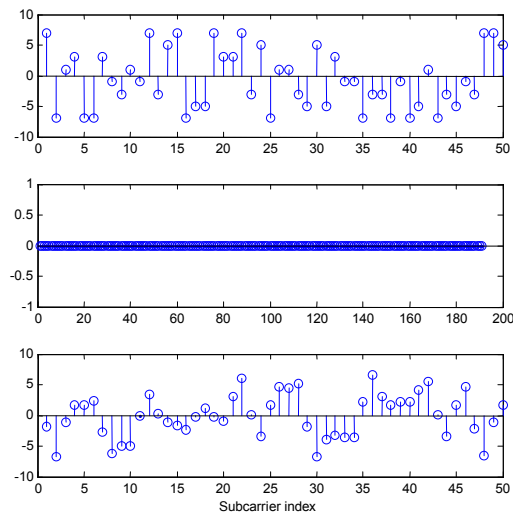


Fig.4 64-QAM modulated signal (a) before IDWT (b) Coefficients of detail (c) signal after IDWT.

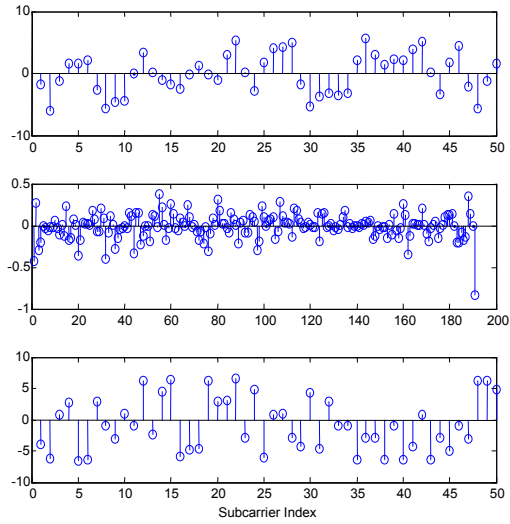


Fig.5 (a) Received signal before DWT (b) estimated Coefficients of detail (c) Received signal after IDWT.

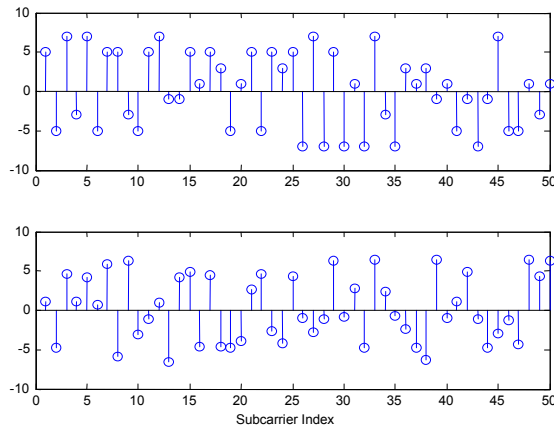


Fig. 6 Time domain OFDM signal

Conclusion.

In general, the wavelet based OFDM provides an efficient performance owing to the superior spectral containment property of the wavelet filters. This paper suggests a new design approach for OFDM signals which display superior spectral efficiency,

and the wavelet packet transform is employed to deliver a generalized OFDM modulation scheme.

Acknowledgement

Authors would like to thank (The National Organization for Scientific Research) www.nasr.ly. Tripoli. Libya

References.

1. Hara, S., and Prasad,R., Multicarrier Techniques for 4G Mobile Communications, Artech House, 2003.
2. Koga, H., Kodama, N., and Konishi, T., High speed power line communication system based on wavelet OFDM, in Proc. ISPLC, 2003.
3. Negash, B.G. and Nikookar, H., Wavelet based multicarrier transmission over multipath wireless channels, Electron. Lett. 36, 1787-8, 2000.
4. Zhang, Y. and Chen, S., A novel multicarrier signal transmission system over multipath channel of low voltage power lines, IEEE Trans. Power Deliv., 19 (4), 1668-72, 2004.
5. Rainmaker Technologies Inc., RM wavelet based (WOFDM) PHY proposal for 802.16.3c-01/12, 2001. <http://iee802.16.3>
6. Laksmanan and Nikookar, Review of wavelets for digital wireless communications, Wireless Pers. Comm., 37, 387-420, 2006.
7. Starnig, G, Nguyen, T, Wavelet and filter banks, Cambridge-Wellesley Press, 1996.
8. Strang, G, Computational Science and Engineering, Cambridge-Wellesley Press, 2007, pp. 388 – 400.
9. Jamin and Mahonen, Wavelet packet modulation for Wireless Communications, Wireless Communications and Networking Journal, 5 (2), 123-37, March 2005.
10. Karkhaneh, H, Sadeghpour, T., Ghorbani, A., and Alhameed, R.A., Modelling of Nonlinear Power Amplifier with Memory Effect for Wideband Application, IEEE International Conference on Signal Processing and Communications, ICSPC Dubai, United Arab Emirate, November 2007.