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The Optimization of HiperLAN/2 Baseband Transceiver Based Wavelet Signals with Multiple Antennas

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Abstract

The present trends in the improvement of high-data-rate wireless systems focus on the integration of multiple input, multiple-output (MIMO) orthogonal frequency-division multiplexing (OFDM), this paper investigates a new approach to the adaptation of the HiperLAN/2 Baseband Transceiver based on Haar orthonormal wavelets signals and the physical layer performance of wireless communications systems, as well as multi-antenna techniques, such as multiple-input, multiple-output (MIMO) systems. The use Alamouti-based orthogonal space-time block coding technique. In MATLAB/ Simulink modeling simulation proved that the performance of HiperLAN/2 Baseband Transceiver Based wavelet Signals has a significant degradation in the packet (PDU or PSDU) error rate (PER) compared to conventional HiperLAN/2 Baseband Transceiver due to the considerable channel models.

Keywords: HiperLAN/2, OFDM, DWT, IDWT, MIMO, PER, C/N.

1. Introduction

Multiple antennas technologies proposed for communications systems have gained much attention in the last few years because of the huge gain they can introduce in the communication reliability and the channel capacity levels. Furthermore, multiple antenna systems can have a big contribution to reduce the interference both in the uplink and the downlink by employing smart antenna technology. The use of multiple antennas at the receiver and transmitter has revolutionized wireless communications over the past decade. It has long been known that multiple receive antennas can improve reception through the selection of the stronger signal or combination of individual signals at a receiver. In the mid 1990s, however, seminal research by Foschini, Gans (G.J. FOSCHINI and M.J. GANS, 1998) and Telatar (Emre Telatar, 1999) predicted large performance gains from using multiple antennas at both transmitter and receiver. This kind of system is called a MIMO (Multiple-Input Multiple-Output) system in contrast with a SISO (Single-Input Single-Output) system that uses one transmit antenna and one receive antenna. SIMO and MISO systems also exist, as we will see shortly. To introduce Space Time Block Codes, we present The Alamouti code, (S. M. Alamouti, 1998) an early space time code and still one of the most commonly used. This is a very special STBC. It is the only orthogonal STBC that achieves rate-1. That is to say that it is the only STBC that can achieve its full diversity gain without needing to sacrifice its data rate. Strictly, this is only true for complex modulation symbols. Since almost all constellation diagrams rely on complex numbers however, this property usually gives Alamouti's code a significant advantage over the higher-order STBCs even though they achieve a better error-rate performance. HiperLAN is a European (ETSI) standardization initiative for a high Performance wireless local area network radio waves are used instead of a cable as a transmission medium to connect stations. Designing for the first version of the standard, named HiperLAN/1, started 1991, the aim of the HiperLAN was the high data rate, higher than 802.11. The standard was accepted in 1996. A second set of standards have been constructed for a new version of HiperLAN - HiperLAN/2. The idea of HiperLAN/2 is to be compatible with ATM. Intersymbol Interference **(**ISI**),** the facility for removing delay spread and multipathing in a proficient manner enables higher data rate throughput. Equalizing individual Orthogonal Frequency Division Multiplexing (OFDM) carriers is easier than equalizing the broader single-carrier signal. Therefore, modern international standards, such as those set by HiperLAN/2, have made OFDM the ideal technology, leading to its wide use in wireless communication. Multicarrier modulation (MCM) has attracted considerable attention in recent years as a practical and viable technology for high-speed data transmission channels (B. Farhang- Boroujeny, 2003, J. A. C. Bingham, 1990). Cyclic prefix samples are added to each block of data to compensate for multipath channel distortion (A. Goldsmith, 2005). Cosine-modulated filter banks working at a maximally decimated rate, on the other hand, are widely employed for signal compression, as well as realization of Trans multiplexer systems (M. Vetterli, 1986). Their application in MCM(B. Farhang- Boroujeny, 2003) has been studied by many researchers. A major disadvantage of discrete wavelet multi-tone (DWMT), however, is its computational complexity. A set of special equalizers, one for each sub-channel, is therefore needed; these equalizers are referred to as *post-combiners* (B. Farhang- Boroujeny, 2003, M. A. T. S. D. Sandberg, 1995). Adaptive modulation provides the possibility of decreasing the complexity. In general, pilot symbol assistant modulation systems, pilot symbols are sent to obtain channel status information; however, additional power is needed for sending the pilot symbols. Wavelet theory is the mathematics of modeling a signal, system, or process with a set of scaled and shifted versions of the basis functions, called *wavelets* (R. K. Young, 1993). This theory can be used in many applications, such as wireless communications, image processing, control systems, and so on (F. J. N. Albert Boggess, 2001, C. K. Chui, 1992, G. G. Walter, 1994). The fundamentals of wavelet theory are scaling and translating. Wavelets can be used to represent objects, such as signals and processes, or operations, such as channels, filters, and systems. Two main aspects of analyzing signals with wavelet transform (WT) are signal decomposition and reconstruction. WTs enable the analysis of the shifting and scaling of the signal that passes through the system. These two properties make it possible to detect multiple shifts or delays in the channel, as well as equalize the multipath channel in wireless communications. In wireless communications, the wireless channel may be rich in both Doppler shift and delay, which coexist in a single path. If the channel is a single path, the received signal can be moved back to the desired frequency. Wireless channels, however, typically contain multiple paths, and the overlapping of paths from multiple signals makes detection difficult. An alternative approach to looking at a communication system is to consider the transmitted symbol as one pixel in the wavelet domain, using the signal as the mother wavelet, that is, an image with one dimension representing delay, another representing scale. The other transmitted symbols are the scaled and delayed versions of the basic transmitted symbol. The channel operator has the same effect on every transmitted symbol in the wavelet domain image. With channel estimation, we can detect channel information, which can be seen as a filter blurring the pixel. De convolution needs information on how the signal is scaled and delayed. Using the WT, we can detect when the delays occur and by how much they are scaled. Since the early 1990s, WTs and wavelet packet transform have been extensively used in wireless communications. A number of modulation schemes based on wavelets have been proposed(V. S. Gracias, 1998, M. A. T. S. D. Sandberg, 1995, M. C. T. M. A. Tzannes, 1992) .In (D. X. Xiaofei Zhang, 2005), Zhang et al. proved that the space-time channel has fractal characteristics according to the dynamic mechanism of multipath fading. In (V. S. Gracias, 1998), Gracias et al. presented an equalization algorithm for a wavelet packet-based modulation scheme. In their method, a non-ideal channel can be divided into a set of bands, and each band can be approximated by simple attenuation and delay. In(R. C. Dong Guo, 2004), an adaptive Bayesian receiver based on WT was developed for blind detection in flat-fading channels. In (M. Martone, 2000), a wavelet-based separating kernel was proposed for the array processing of cellular DS/CDMA signals in a fast-fading channel. Because of the capacity for local time and frequency analysis, the majority of the WT applications in wireless communications are intended for either the wideband channel or the fast-fading channel. Wavelet packets have recently been extensively applied in multicarrier direct-spread CDMA (MC-DS-CDMA) because of their orthogonality. In this paper, the DWT-based design of orthogonal space-time block coding HiperLAN/2 systems, as well as the simulations results and evaluation tests of these proposed systems, are provided.. In the STBC-OFDM system, two types of transform FFT and WT were considered. The proposed structures for the DWT- based OSTBC-OFDM system are studied for the HiperLAN/2 technique and for a range of modulation and coding rates. Using a typical link-budget as basis, we compute the expected throughput for each scheme as a function of the base station-terminal separation distance. The Fourier-based OFDM uses complex exponential base functions, and is replaced with orthonormal wavelets to reduce the level of interference. It was found that Haar-based orthonormal wavelets are capable of reducing the ISI and ICI, which are caused by the loss in orthogonality between the carriers. In (M. J. Manglani and A. E. Bell, 2001, H. Zhang, 2004, S. R. Baig, 2005) simulation results show the BER performance of OFDM systems with different orthogonal bases (i.e., Fourier-based OFDM and wavelet-based OFDM). The simulations were found to have a great deal of channel dependence in the performance of wavelet and Fourier filters. The main motivation for using wavelet-based OFDM is the superior spectral containment properties of wavelet filters over Fourier filters. Under certain channel conditions, wavelet OFDM was found to outperform Fourier OFDM. However, under other channels (e.g., selective fading channel), the situation is reversed. Further performance gains can be achieved by looking into alternative orthogonal basis functions and finding a better transform than Fourier. The current implementations HiperLAN/2 OSTBC-OFDM are achieved using FFT and its inverse operation, IFFT, representing data modulation and demodulation. An OFDM system was introduced based on filters, called *wavelets*. This system has two or more low- and high-pass filters. The purpose of this multiplicity is to achieve more properties that other transforms (Fourier) are unable to combine(M. Vetterli, 1997). The succeeding section discusses the performance of design wavelet filter in OFDM; the performance of OSTBC HiperLAN/2.This paper is focused on performance evaluation of OSTBC HiperLAN/2 based wavelet signals. A physical layer improvement simulator of HiperLAN/2 was conceived in accordance with the standard defined by ETSI in (ETSI, 2001). This paper is structured as follows. In section 2 the simulation block diagram is described. Section 3 describes summarizes the results. Finally, Section 5 concludes the paper.

2. The Simulation Block Diagram

At first, a supplied a HiperLAN/2 physical layer model, from MathWorksTM in the MATLAB® & SIMULINK® R20013a software package, was modified and its performance measured. The new suggested transceivers for the OSTBC HiperLAN/2 physical layer model based wavelet signals in different channels will be studied in this paper. The block diagram in Figure 1 represents the whole system model for proposed design.

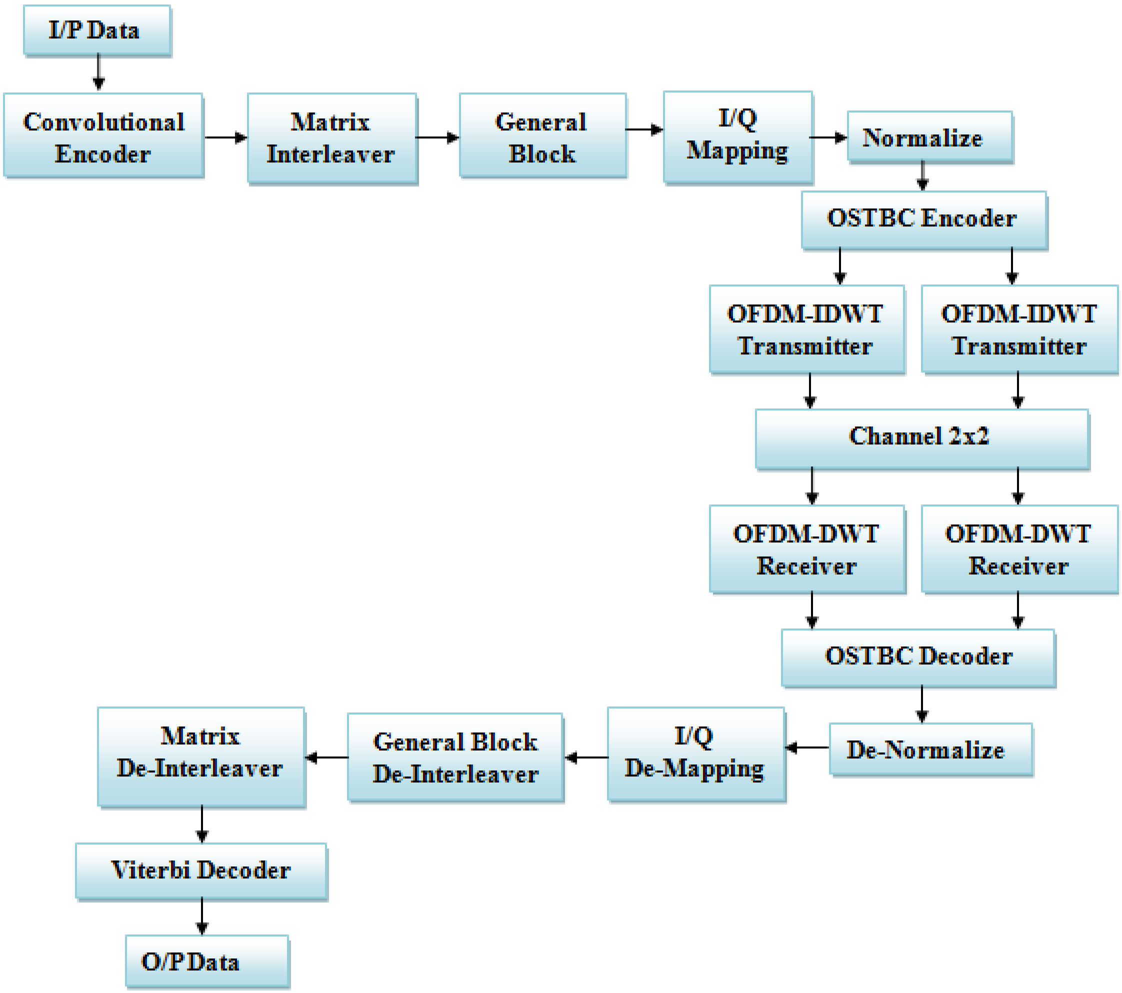

Figure 1. Simulation Block Diagram

The Block diagram in Figure 1 represents the whole system model for the OSTBC HiperLAN/2 transceiver based wavelet transform signals system is used for multicarrier modulation. The OSTBC HiperLAN/2 transceiver structure is divided into three main sections: transmitter, channel, and receiver: Data are generated from a random source and consist of a series of ones and zeros. Since transmission is conducted block-wise, when Forward Error Correction (FEC) is applied, the size of the data generated depends on the block size used. These data are converted into lower rate sequences via serial to parallel conversion the data are encoded when the encoding process consists of a concatenation of a Convolutional Code (R.A.N. Ahmed and M. Berwick, 2005). This means that the first data pass in the Convolutional encoder. It is a flexible coding process due to the puncturing of the signal and allows different coding rates. The last part of the encoder is a process of interleaving to avoid long error bursts using tail biting CCs with different coding rates (puncturing of codes is provided in the standard). Finally, interleaving is conducted using a two-stage permutation. The first stage aims to avoid the mapping of adjacent coded bits on adjacent subcarriers, while the second ensures that adjacent coded bits are mapped alternately onto relatively significant bits of the constellation, thereby avoiding long runs of lowly reliable bits. The training frame (pilot subcarriers frame) is inserted and sent prior to the information frame. The pilot frame is used to create channel estimation to compensate for the channel effects on the signal. The coded bits are then mapped to form symbols. The modulation scheme used as shown in Table.1

Table 1. Mode-dependent parameters (Angela Doufexi, 2002)

Mode	Modulation	Coding Rate *R*	Nominal Bitrates (Mb/s)	Coded Bits per Subcarrier	Coded Bits per OFDM Symbol	Data Bits per OFDM Symbol
1	BPSK	1/2	6	1	48	24
2	BPSK	3/4	9	1	48	36
3	QPSK	1/2	12	2	96	48
4	QPSK	3/4	18	2	96	72
5	16-QAM	9/16	27	4	192	108
6	16QAM	3/4	36	4	192	144
7	64QAM	3/4	54	6	288	216

This process converts data to corresponding value of M-ary constellation, which is a complex word (i.e., with a real and an imaginary part). The bandwidth (B =(1/T_s)) is divided into N equally spaced subcarriers at frequencies (*kΔf),k=0,1,2,...,N-1* with Δ*f=B/N* and , T_s , the sampling interval. At the transmitter, information bits are grouped and mapped into complex symbols. In this system, (QAM) with constellation C_{QAM} is assumed for the symbol mapping. The Space-time block-coded code is transmitted from the two antennas simultaneously during the first symbol period (l=1) for each$k\epsilon\kappa$. During the second symbol period, (l=2) are transmitted from the two antennas for each $k\epsilon\kappa$. The set $\kappa \cong \kappa\{(N - N_c/2), \ldots, (N + N_c/2) - 1\}$is the set of data-carrying sub-carrier indices, N_c and is the number of sub-carriers carrying data. N is the multicarrier size; consequently, the number of virtual carriers is N-N_c. We assume that half of the virtual carriers are on both ends of the spectral band [21]. Both the OFDM modulator and demodulator of the DWT-based OFDM are shown in Figure 1. The training frame (pilot sub-carriers frame) are inserted and sent prior to the information frame. This pilot frame is used to create channel estimation, which is used to compensate for the channel effects on the signal. To modulate spread data symbol on the orthogonal carriers, an N-point Inverse Wavelet Transform IDWT is used, as in conventional OFDM. Zeros are inserted in some bins of the IDWT to compress the transmitted spectrum and reduce the adjacent carriers' interference. The added zeros to some sub-carriers limit the bandwidth of the system, while the system without the zeros pad has a spectrum that is spread in frequency. The last case is unacceptable in communication systems, since one limitation of communication systems is the width of bandwidth. The addition of zeros to some sub-carriers means not all the sub-carriers are used; only the subset (N_c) of total subcarriers (N_F) is used. Therefore, the number of bits in OFDM symbol is equal to log_2 (M)* N_c. Orthogonality between carriers is normally destroyed when the transmitted signal is passed through a dispersive channel. When this occurs, the inverse transformation at the receiver cannot recover the data that was transmitted perfectly. Energy from one sub-channel leaks into others, leading to interference. However, it is possible to rescue orthogonality by introducing a cyclic prefix (CP). This CP consists of the final v samples of the original K samples to be transmitted, prefixed to the transmitted symbol. The length v is determined by the channel's impulse response and is chosen to minimize ISI. If the impulse response of the channel has a length of less than or equal to v, the CP is sufficient to eliminate ISI and ICI. The efficiency of the transceiver is reduced by a factor of$\frac{K}{K+V}$; thus, it is desirable to make the v as small or K as large as possible. Therefore, the drawbacks of the CP are the loss of data throughput as precious bandwidth is wasted on repeated data. For this reason, finding another structure for OFDM to mitigate these drawbacks is necessary. If the number of sub-channels is sufficiently large, the channel power spectral density can be assumed virtually flat within each sub-channel. In these types of channels, multicarrier modulation has long been known to be optimum when the number of sub-channels is large. The size of sub-channels required t approximate optimum performance depends on how rapidly the channel transfer function varies with frequency. is used. After which, the data converted from parallel to serial are fed to the channel models. After this, the data converted from the parallel to the serial form are fed to different channel models. In this model a set of five channels was chosen to address three different terrain types that are typical of the continental US. The parameters for the model were selected based upon some statistical models. The tables below depict the parametric view of the five channels more information about channel models in Table.2

Table 2. Channel models (Angela Doufexi, 2002)

Name	RMS Delay Spread	Characteristic	Environment
A	50 ns	Rayleigh	Office NLOS
B	100 ns	Rayleigh	NLOS
C	150 ns	Rayleigh	NLOS
D	140 ns	Rayleigh	LOS
E	250 ns	Rayleigh	NLOS

The receiver performs the same operations as the transmitter, but in a reverse order. In addition, multiwavelet OFDM includes operations for synchronization and compensation for the destructive channels.

3. Simulation Results of the Proposed Design:

The PHY layer simulation results take the form of packet (PDU or PSDU) error rate (PER) vs. average C/N. In this part the simulation of the modified HiperLAN/2 transceiver based wavelet transform signals structure based OFDM-DWT and comparing with OFDM-FFT system is achieved, beside the BER performance of the modified OSTBC HiperLAN/2 transceiver structure considered in five channel models. Figures (2-8) presents the compressions performance results between OSTBC HiperLAN/2 transceiver based Fourier and wavelet transform signals for the different modes of OSTBC HiperLAN/2 vs. average C/N for channel model A. Channel model A is typical of large office environments with non-line of- sight (NLOS) propagation. Note that similar results have been observed elsewhere (H. Li, 2000) . It can be seen that the C/N requirement increases for modes 1, 3, 2, 4, 5, 6, and 7 correspondingly. The degradation in performance in mode 2 (BPSK 3/4) is due to the fact that the punctured Convolutional code does not cope well with the lack of frequency diversity in channel A. Errors due to large and deep fades in the frequency domain are difficult to correct using this code. Since mode 2 is inferior to mode 3 in terms of both C/N condition and data rate, it is extra for operation in channel A or like conditions. A reasonable point of operation for packet services without delay restriction can lie in a PER of 10^{-3} percent (J. Khun-Jush et al, 1999, A. Doufexi et al, 2001). Performance comparison results between two structures in channel A for all modes found in Table 3.

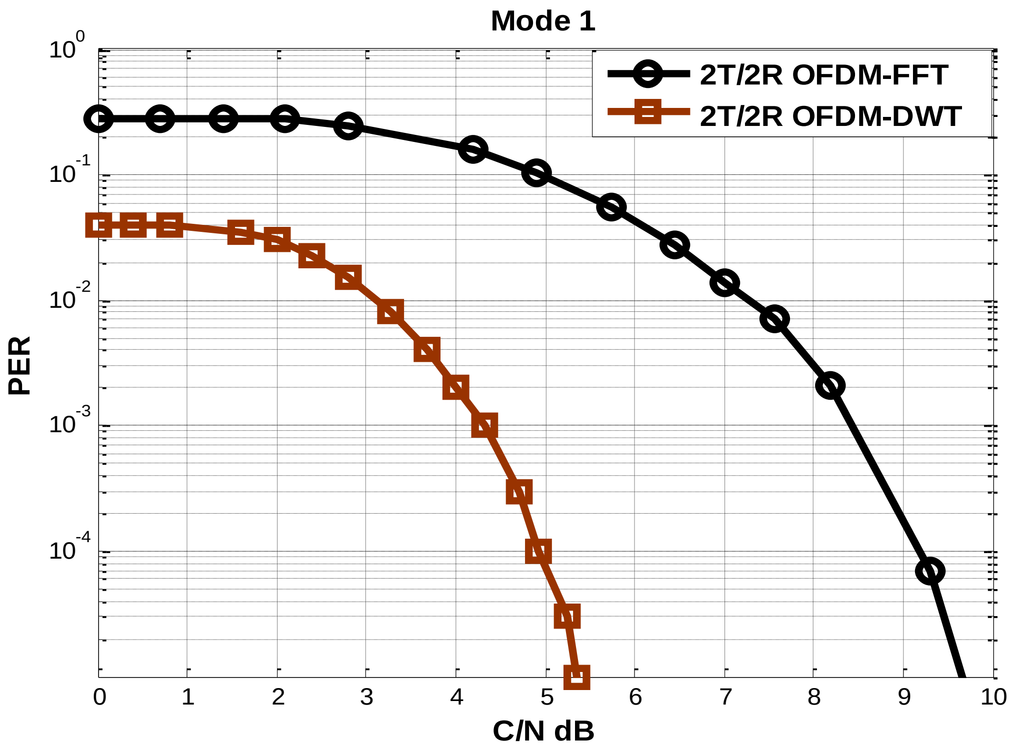

Figure 2. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in channel A for mode 1

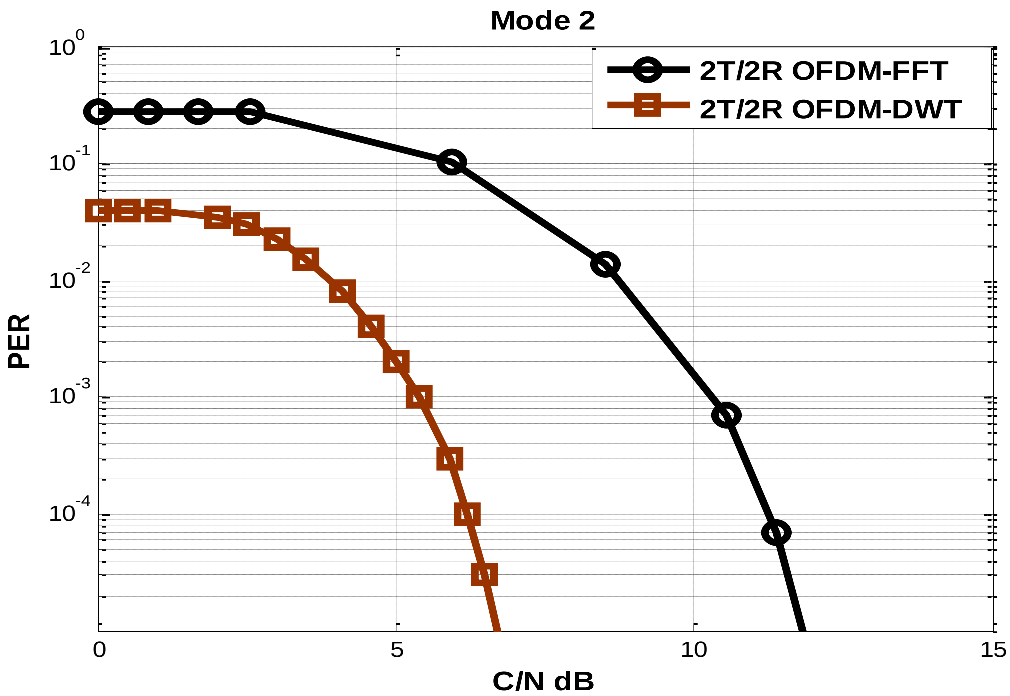

Figure 3. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in channel A for mode 2

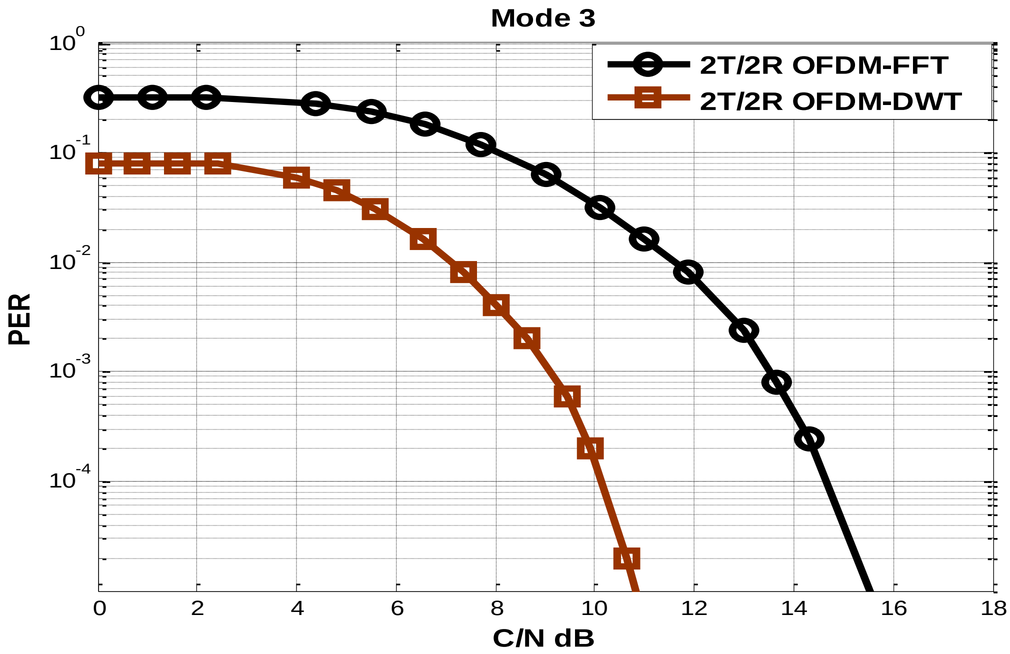

Figure 4. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in channel A for mode 3

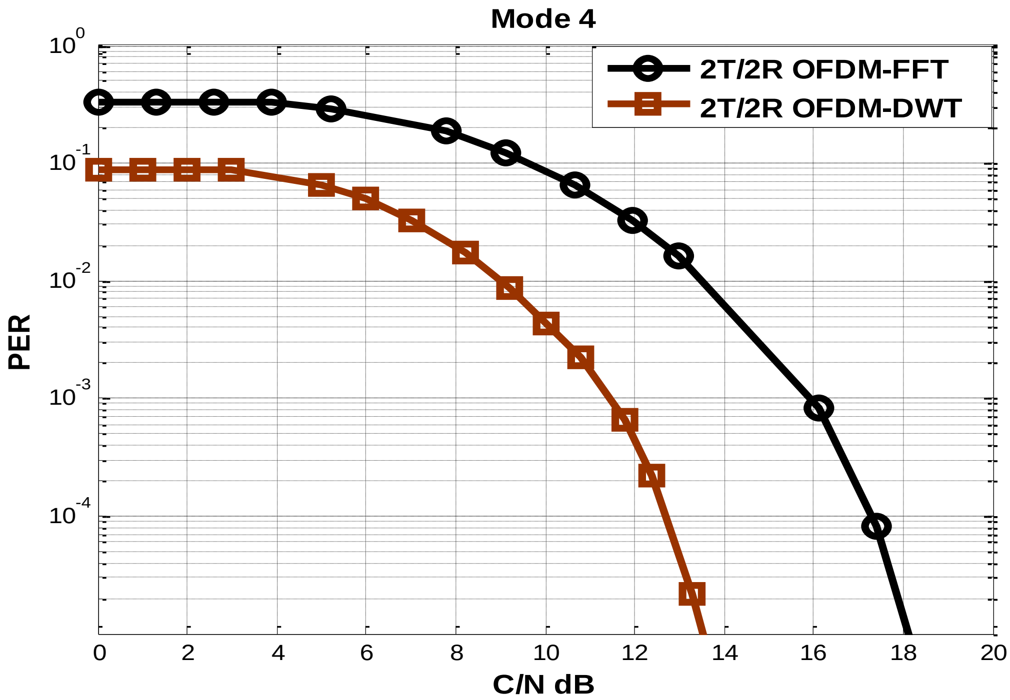

Figure 5. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in channel A for mode 4

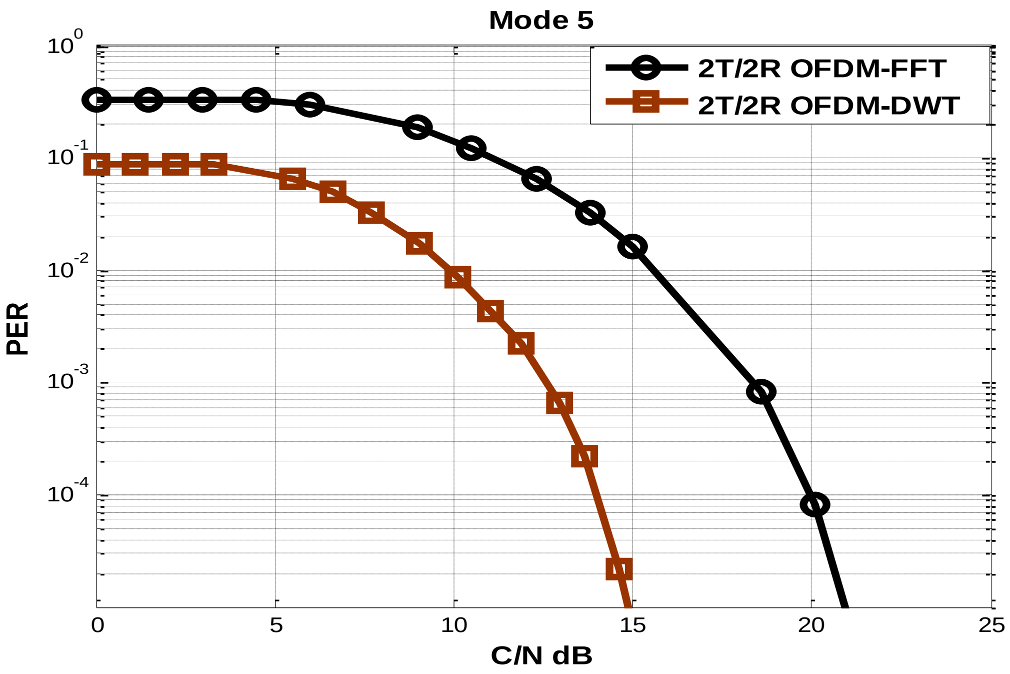

Figure 6. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in channel A for mode 5

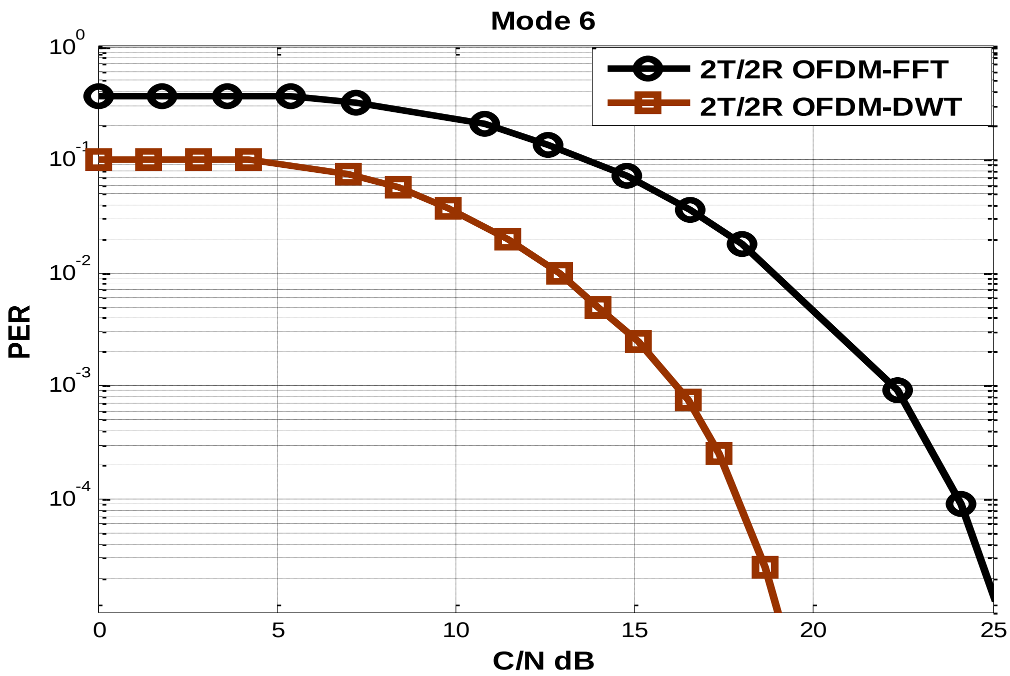

Figure 7. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in channel A for mode 6

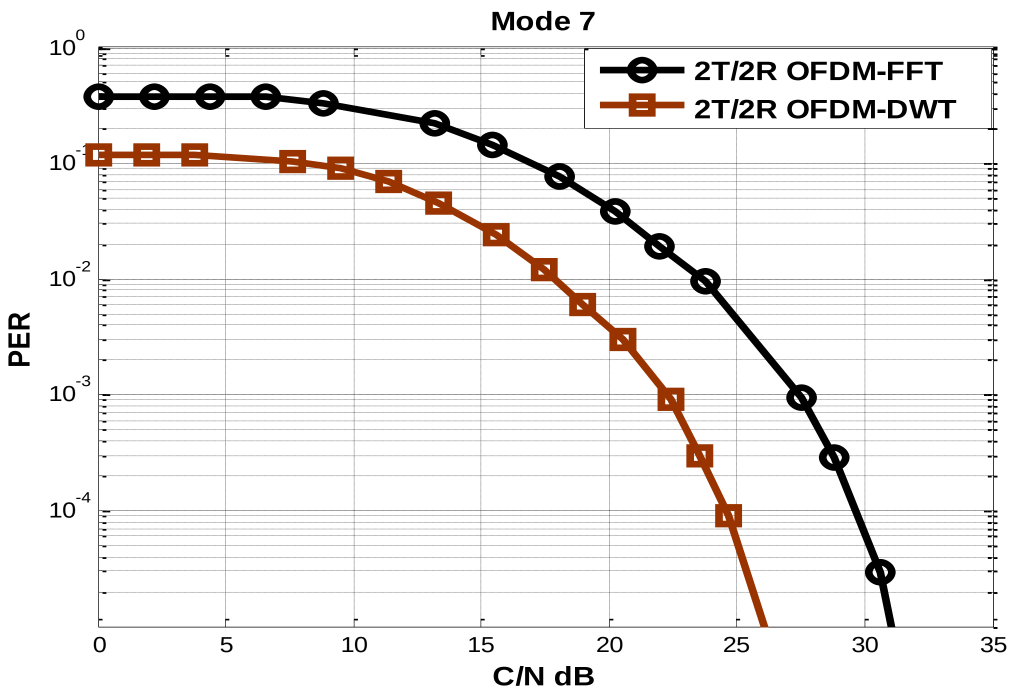

Figure 8. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in channel A for mode 7

Table 3. PER Performance comparison between conventional OSTBC HiperLAN/2 and modified OSTBC HiperLAN/2 in channel A for all modes

Channel For PER=10^{-3}	Mode 1 dB	Mode 2 dB	Mode 3 dB	Mode 4 dB	Mode 5 dB	Mode 6 dB	Mode 7 dB
OSTBC 2T/2R HiperLAN/2 OFDM-FFT	8.4	10.5	13.8	16	18.2	22.4	27.5
OSTBC 2T/2R HiperLAN/2 OFDM-DWT	4.3	5.7	9	11.5	12.6	16.5	22.5

Figures (9-13). Shows PER performance vs. mean C/N for mode 5 for all the specified channels for conventional HiperLAN/2. It can be seen that as the delay spread increases, the performance is improved in the Rayleigh channels until the delay spread becomes so large that ISI and ICI become limiting factors (as is the case for channel E). Channels B, C, and D have increasingly better performances than channel A due to the increased frequency diversity of the channels. As probable, channel D has somewhat better performance than channel C because it is modeled as a Rician channel. In channel E the excess channel delay is much larger than the guard interval. As a consequence, ISI cannot be completely eliminated.

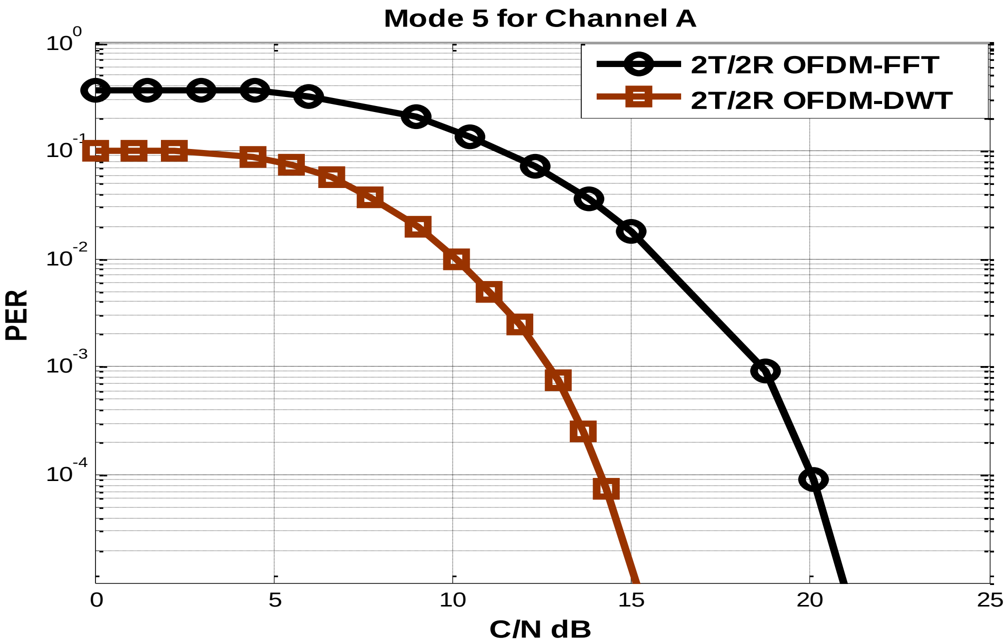

Figure 9. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in mode 5 for channel A

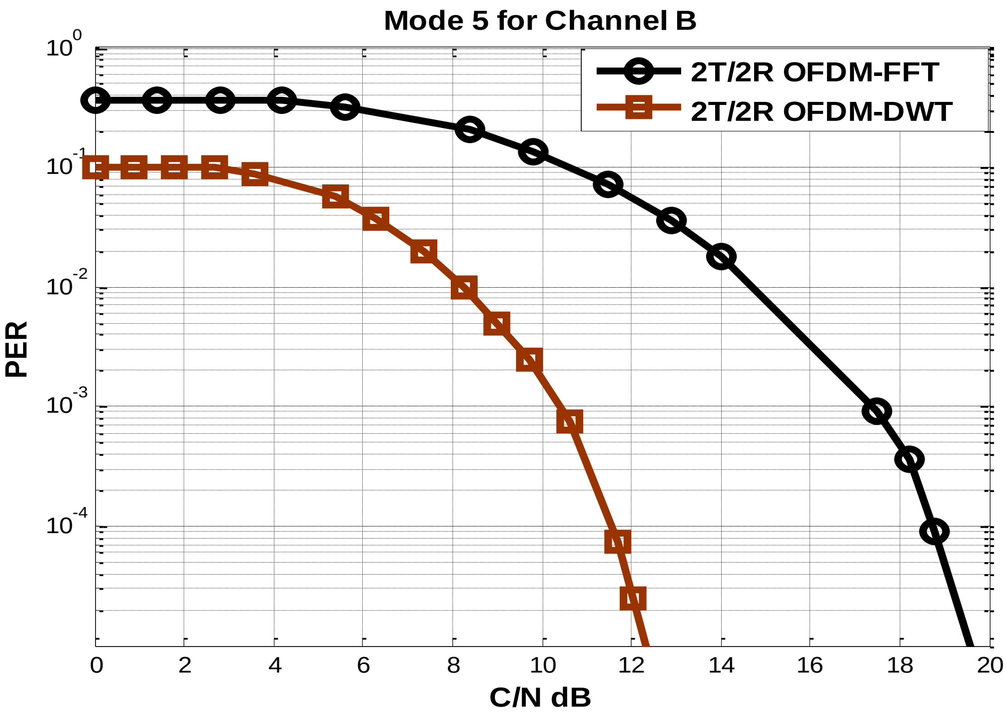

Figure 10. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in mode 5 for channel B

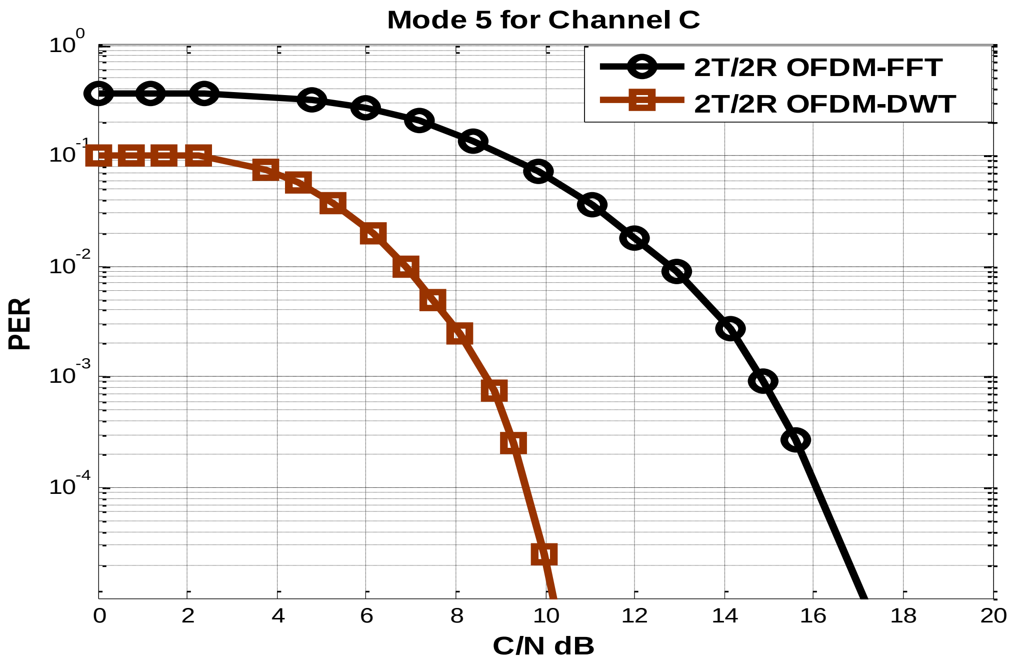

Figure 11. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in mode 5 for channel C

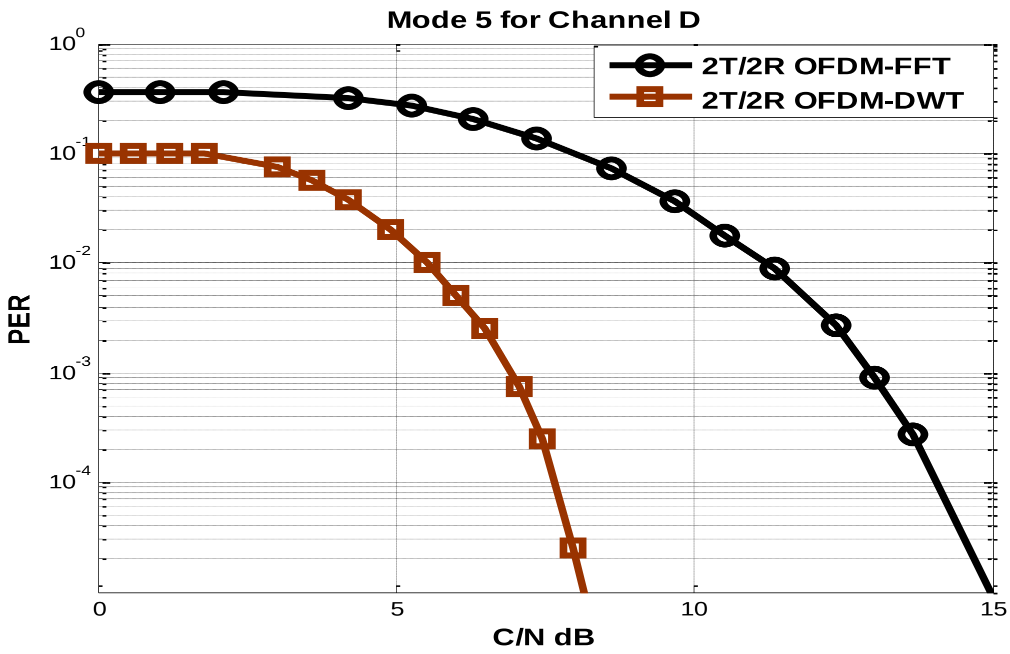

Figure 12. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in mode 5 for channel D

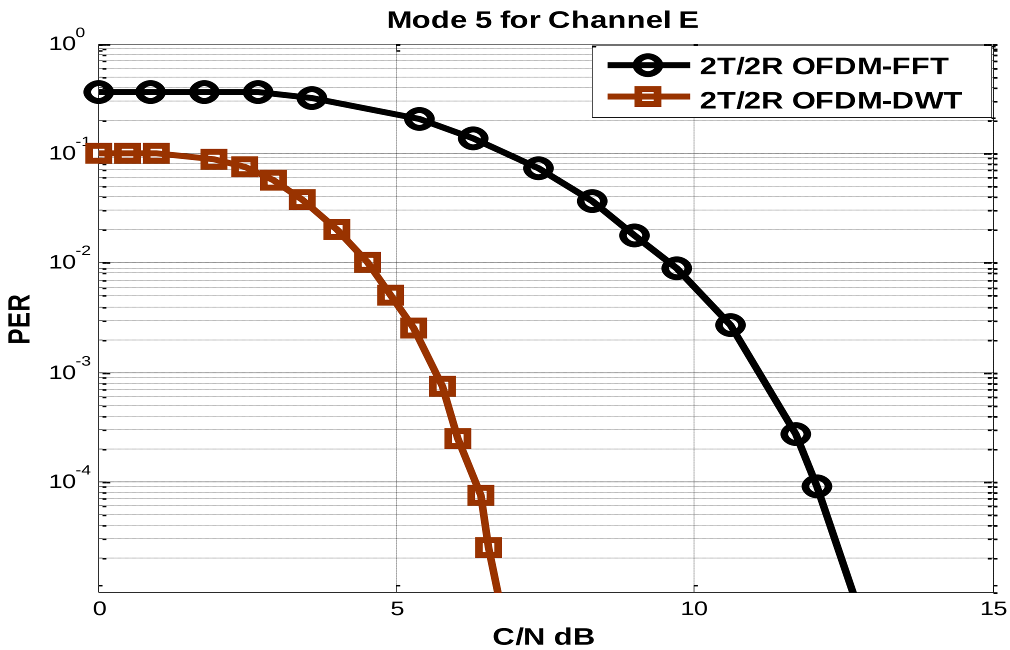

Figure 13. PER performance vs. mean C/N comparison between modified and conventional OSTBC HiperLAN/2 in mode 5 for channel E

Table 4. PER Performance comparison between conventional OSTBC HiperLAN/2 and modified OSTBC HiperLAN/ for mode 5 in all the specified channels

Channel For PER=10^{-3}	Channel A dB	Channel B dB	Channel C dB	Channel D dB	Channel E dB
OSTBC 2T/2R HiperLAN/2 OFDM-FFT	**18.5**	**17.5**	**14.9**	**13**	**11.5**
OSTBC 2T/2R HiperLAN/2 OFDM-DWT	**12.6**	**10.3**	**8.8**	**6.9**	**5.8**

A number of significant results can be taken from Tables 3, 4; in this simulation, in most scenarios, OSTBC HiperLAN/2 based OFDM-DMWT system was better than the conventional OSTBC HiperLAN/2 based OFDM-FFT. The OSTBC HiperLAN/2 based OFDM-DMWT system proved its effectiveness in combating the multipath effect on the all channels.

4. Conclusion

In this paper, the DWT-based HiperLAN/2 OSTBC-OFDM structure was proposed and tested. The tests were carried out to verify the successful operation and the possibility of implementation of DWT-based

OSTBC-OFDM. The results show that this structure achieves considerably lower bit error rates, assuming reasonable choice of the bases function and method of computation. In different channels mode, the wavelet-based OSTBC-OFDM outperforms the OSTBC-OFDM based FFT systems. Therefore, this structure can be considered an alternative to the conventional HiperLAN/2 OSTBC-OFDM. From the results obtained, we can conclude that C/N measure can be successfully increased using the proposed wavelet designed method within a desired wavelet basis function. Thus, wavelet-based OFDM outperforms the conventional ones. The means contribution of this paper is the implementation of the HiperLAN/2 PHY layer based the OSTBC DWT-OFDM structure. The simulations conducted proved that the proposed design achieves considerably lower bit error rates and performs better than HiperLAN/2 OSTBC FFT-OFDM. Hence, the Proposed DWT-OFDM systems is robust for multipath channels and does not require a cyclically prefixed guard interval, which means that it obtains higher spectral efficiency than does conventional OFDM.

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