

Design and Improvement of HiperLAN/2 Physical Layer Model Based Multiwavelet Signals

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Abstract
Currently, Wireless Local Area Networks (WLANs) supporting broadband multimedia communications are being advanced, and standardized. HIPERLAN/2 standard is defined by ETSI BRAN. In this paper, we improve HIPERLAN/2 based Orthogonal Frequency-Division Multiplexing OFDM, Discrete Multiwavelet Transform (DMWT) performance via a MATLAB/ Simulink simulation .These systems provide channel adaptive data rates up to 54 Mb/s (in a 20 MHz channel spacing) in the 5 GHz radio band. For different channels. MATLAB/ Simulink modeling demonstrated that the performance of multiwavelet OFDM has a remarkable degradation in the packet (PDU or PSDU) error rate (PER) compared to based OFDM Fast Fourier transform (FFT) due to the considerable channel models. With DMWT-OFDM, Carrier-to-Noise Ratio (C/N) improvement compared to FFT-OFDM is achieved.
Keywords: HiperLAN/2, OFDM, DMWT, IDMWT.

1. Introduction

The wireless local-area network (WLAN) standards are known by HIPERLAN/2 (high performance radio LAN Type 2) defined by ETSI BRAN (ETSI, 2001). The European Telecommunication Standards Institute (ETSI) has proposed OFDM for high-speed wireless LAN and it is being considered for 4G mobile. The HIPERLAN/2 was conceived in the unlicensed 5GHz band and the data rate of HIPERLAN/2 ranges from 6 to 54 Mbit/s through link adaptation modes in order to support broadband multimedia services depending on Quality of Service (QoS). HIPERLAN/2 is based on cellular network topology combined with ad hoc networking capabilities. It is designed to provide Wireless Local Loop (WLL) to core networks, e.g. Asynchronous Transfer Mode, GSM/UMTS or any IP-based multimedia network (J.Torsner and G. Malmgren, 1999). The link adoption scheme automatically determines the data rate, coding rate and modulation type depending on the channel conditions (J. Medbo and P. Schramm, 1998). Two operation modes are used: centralized mode (CM) and direct mode (DM). The direct mode enable ad hoc capabilities. The centralized operation mode applies to the cellular networking topology where each cell is controlled by an access point (AP) that covers a certain geographical area. In this mode, the communication between two mobile terminals is controlled mandatory by the access point. This mode of operation is mainly indicated to locals where the coverage area is larger than a cell. The directed mode applies to ad hoc networking topology where the coverage area is limited by one radio cell only (R.A.N. Ahmed and M. Berwick, 2005). In this mode, mobile terminals can exchange data directly with another without the necessity of the access point controls this communication (J. Torsner and G. Malmgren, 1999). The function of the access point in this case is limited to radio resource management (RRM) functions. ETSI's proposed HIPERLAN/2 standard describes the physical (PHY) layer based on orthogonal frequency division multiplexing (OFDM) technology and link adaptation (Heiskala, 2002). The first technique is attractive due to capacity to deal with frequency-selective fading while link adaptation enables the system to dynamically trade-off link reliability and data rate according to the quality of the available radio link. This trade-off is achieved through the different transmission modes. In present time HiperLAN/2 physical layer used OFDM based on Fourier signals to represent data modulation and demodulation(Van Nee, 2000). In 2004 Zhang et al (H. Zhang et al, 2004) carried out research on DFT-OFDM and DWT-OFDM on different transmission scenarios. The DFT based OFDM (DFT-OFDM) has currently drawn most of attention in the area of wireless communication. To combat ISI, and ICI, cyclic prefix is inserted between DFT-OFDM symbols, and this will take up nearly 25 percent of bandwidth. To improve the bandwidth efficiency and ISI, ICI, DWT (discrete wavelet transforms) based OFDM (DWT-OFDM) is proposed. In this paper we give the performance comparisons of DFT-OFDM and DWT-OFDM on three different channel models. Simulation results show that DFT-OFDM and DWT-OFDM perform different when the transmission scenarios are different. The concept of scalar wavelets has been exploited as wavelet modulation, multiwavelet modulation and multi-scale modulation for multi rate transmissions (N. Erdol, 1995, G. W. Wornell and A. V. Oppenheim, 1992, William W. Jones, 1994, M.J. Manglani and A. E. Bell, 2001, J. N. Livingston and C. Tung, 1996, L. Atzori, 2002).Multi-wavelet is a new concept has been proposed in recent years. Multi-wavelets have several advantages compared to single wavelets. A single wavelet cannot possess all the properties of orthogonality, symmetry, short support, and vanishing moments at the same time, but a multi-wavelet can (M. Cotronei, 1998, V. Strela P. N. Heller. G. S m e . P. Tooiwala and C. Heil. L 1999) ,For all the priorities of multi-wavelet, a natural thought is applying it in OFDM. In (Abbas Hasan Kattoush a, 2009) a new

OFDM system was being introduced, based on Multi-filters called Multi-wavelets. It has two or more low-pass and high-pass filters. The purpose of this multiplicity is to achieve more properties which cannot be combined in other transforms (Fourier and wavelet). A very important multi-wavelet filter is the GHM filter proposed by Geronimo, Hardian, and Massopust. The GHM basis offers a combination of orthogonality, symmetry, and compact support, which cannot be achieved by any scalar wavelet basis (Geronimo, 1994). The GHM will be used in the OFDM system block .This paper is focused on performance evaluation of HIPERLAN/2 based multiwavelet 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 organized 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

Initially, 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 proposed structures for the HiperLAN/2 physical layer model based multiwavelet signals in different channel models will be studied in this paper. The block diagram in Figure 1 represents the whole system model for proposed design.

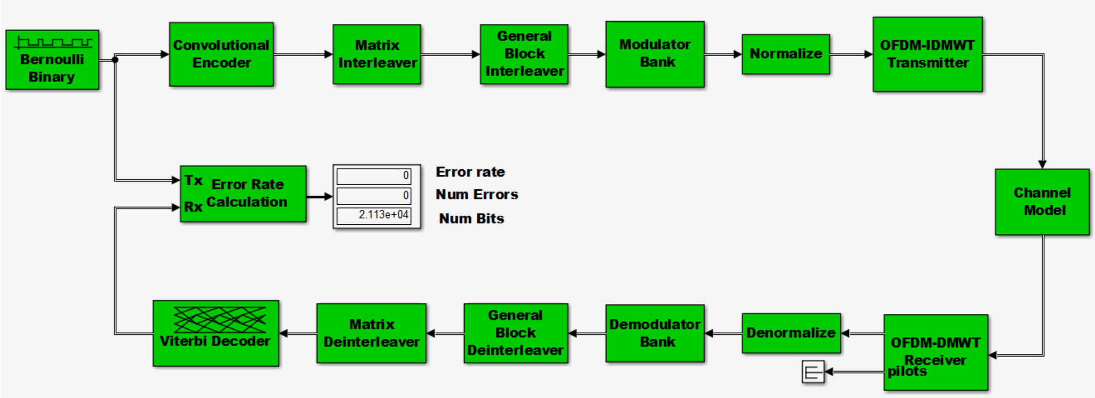

Figure 1. Simulation Block Diagram

The Block diagram in Figure 1 represents the whole system model for the HiperLAN/2 Transceiver based Multiwavelet Transform signals system is used for multicarrier modulation. The 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 (Angela Doufexi, 2002)

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 the corresponding value of constellation, which is a complex word (with a real and an imaginary part). The bandwidth (B = (1/T)) is divided into N equally spaced subcarriers at frequencies (kΔf), k=0, 1, 2... N-1 with Δf=B/N and, T, the sampling interval. The training frame (pilot subcarriers frame) is inserted and sent prior to the information frame. This pilot frame is used to create channel estimation, which is then used to compensate for the channel effects on the signal. To modulate spread data symbol on the orthogonal carriers, an N-point Inverse multi-wavelet transform IDMWT is used, as in conventional OFDM. Zeros are inserted in some bins of the IDMWT 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 ($\mathrm{N_c}$) of total subcarriers ($\mathrm{N_F}$) is used. Therefore, the number of bits in OFDM symbol is equal to $\log_2$ (M)* $\mathrm{N_c}$. 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 FFT-OFDM as DMWT-OFDM to mitigate these drawbacks is necessary. The Fourier based OFDM uses the complex exponential bases functions and it's replaced by orthonormal wavelets in order to reduce the level of interference. It is found that the Haar-based orthonormal wavelets are capable of reducing the ISI and ICI, which are caused by the loss in orthogonality between the carriers. Further performance gains can be made by looking into alternative orthogonal basis functions and finding a better transform rather than Fourier and wavelet transform, multiwavelet is a new concept has been proposed in recent years. Multiwavelets have several advantages compared to single wavelets. A single wavelet cannot possess all the properties of orthogonality, symmetry, short support, and vanishing moments at the same time, but a multiwavelet can [8], for all the priorities of multiwavelet, a natural thought is applying it in OFDM. The multiwavelet transform is a newer alternative to the wavelet transform. Multiwavelets are very like to wavelets but have some important differences. In particular, whereas wavelets have associated scaling $\phi(t)$ and wavelet functions $\psi(t)$, For notational convenience, the set of scaling functions be able to be written using the vector notation Φ (t) = [$\phi 1$ (t) $\phi 2$ (t) · · ϕr (t)] T, where Φ (t) is called the multiscaling function. The multiwavelet function is defined from the set of wavelet functions as Ψ (t) = [$\psi 1$ (t) $\psi 2$ (t) · · · ψr (t)]T When r = 1, $\Psi(t)$ is called a scalar wavelet, or simply wavelet. As in basically n can be arbitrarily large, the multiwavelets studied to date are primarily for r = 2. For GHM system H_k are four scaling matrices H_0, H_1, H_2, and H_3 (V. Strela, 1999):

$$\mathrm{H_0} = \begin{bmatrix} \frac{3}{5\sqrt{2}} & \frac{4}{5} \\ \frac{-1}{20} & \frac{-3}{10\sqrt{2}} \end{bmatrix}, \mathrm{H_1} = \begin{bmatrix} \frac{3}{5\sqrt{2}} & 0 \\ \frac{9}{20} & \frac{1}{\sqrt{2}} \end{bmatrix}, \mathrm{H_2} = \begin{bmatrix} 0 & 0 \\ \frac{9}{20} & \frac{-3}{10\sqrt{2}} \end{bmatrix}, \mathrm{H_3} = \begin{bmatrix} 0 & 0 \\ \frac{-1}{20} & 0 \end{bmatrix} \quad (1)$$

Moreover, there are also four scaling wavelet matrices for GHM system $\mathrm{G_0}, \mathrm{G_1}, \mathrm{G_2}$ and $\mathrm{G_3}$:

$$\mathrm{G_0} = \begin{bmatrix} \frac{-1}{20} & \frac{-3}{10\sqrt{2}} \\ \frac{1}{10\sqrt{2}} & \frac{3}{10} \end{bmatrix}, \mathrm{G_1} = \begin{bmatrix} \frac{9}{20} & \frac{-1}{\sqrt{2}} \\ \frac{-9}{10\sqrt{2}} & 0 \end{bmatrix}, \mathrm{G_2} = \begin{bmatrix} \frac{9}{20} & \frac{-3}{10\sqrt{2}} \\ \frac{9}{10\sqrt{2}} & \frac{-3}{10} \end{bmatrix}, \mathrm{G_3} = \begin{bmatrix} \frac{-1}{20} & 0 \\ \frac{-1}{10\sqrt{2}} & 0 \end{bmatrix} \quad (2)$$

However H_k and G_k, and are matrix filters (i.e., H_k and G_k *are* $n \times n$ matrices instead of scalars). a new OFDM system was being introduced, based on multifilters called multiwavelets. It has two or more lowpass and high-pass filters; the purpose of this multiplicity is to achieve more properties which cannot be combined in other transforms (Fourier and wavelet). A very significant multiwavelet filter is the GHM filter suggested by Geronimo, Hardian, and Massopust (Geronimo, 1994).In Multi-wavelet setting, Geronimo, Hardian, and Massopust (GHM) multi-scaling and multi-wavelet function coefficients are 2×2 matrices, and during transformation step they must multiply vectors (instead of scalars). This means that multi-filter bank needs 2 input rows. The aim of preprocessing is to associate the given scalar input signal of length N to a sequence of length-2 vectors in order to start the analysis algorithm, and to reduce the noise effects. In the one dimensional signals the "repeated row" scheme is convenient and powerful to implement. 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 time (t) approximate optimum performance depends on how rapidly the channel transfer function varies with frequency. The computation of DMWT and IDMWT for 64 point as in (Abbas Hasan Kattoush a, 2009)[8]. 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 multiwavelet transform signals structure based OFDM-DMWT and comparing with OFDM-FFT system is achieved, beside the PER performance of the modified HiperLAN/2 transceiver structure considered in five channel models as shown below:

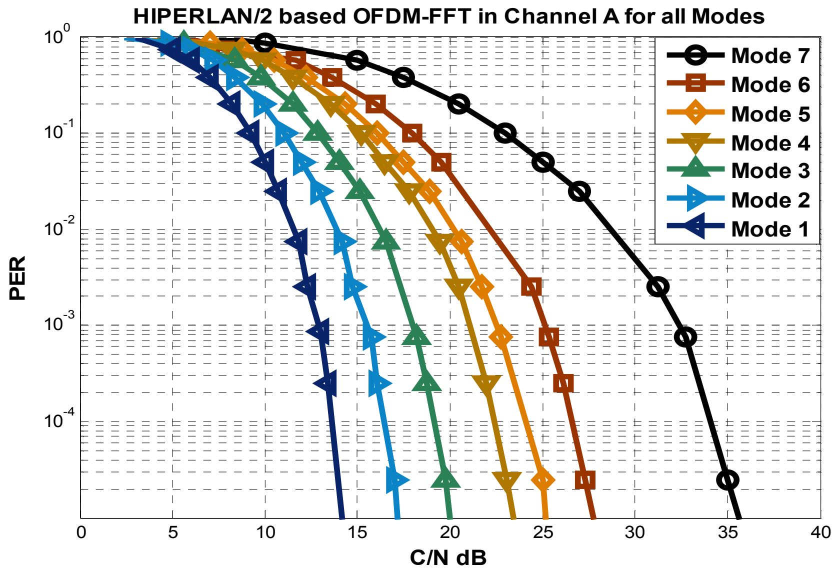

Figure 2. PER performance of conventional HiperLAN/2 based OFDM-FFT in channel A for all mode

Figure 2 presents the performance results for the different modes of 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 be able to be seen that the C/N condition increases for modes 1, 3, 2, 4, 5, 6, and 7 consecutively. The degradation in performance in mode 2 (BPSK 3/4) is due to the truth 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 superfluous for operation in channel A or similar 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).

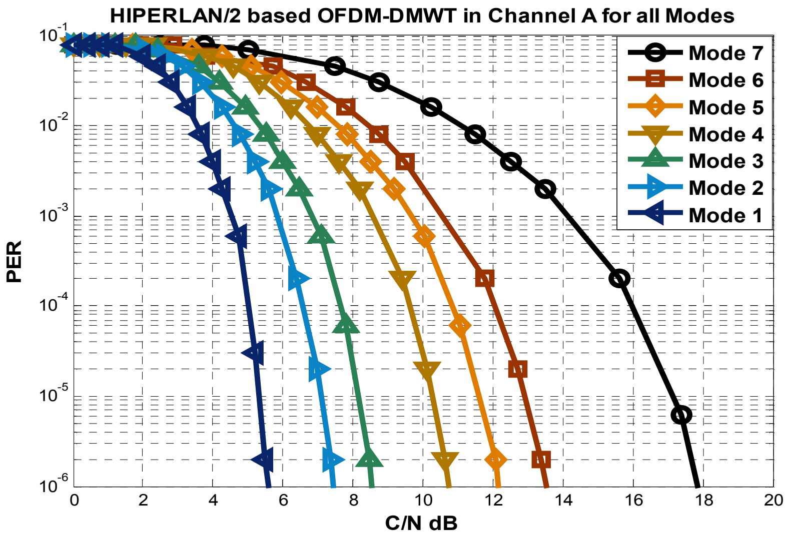

Figure 3. PER performance vs. mean C/N of modified HiperLAN/2 based OFDM-DMWT in channel A for all mode

Figure 3. Shows PER performance vs. mean C/N of modified HiperLAN/2 based OFDM-DMWT in channel A for all modes. Performance comparison results between two structures in channel A for all modes found in Table 3.

Table 3. PER Performance comparison between conventional HiperLAN/2 and modified 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
HiperLAN/2 OFDM-FFT	13	15.5	18	21.5	22.5	25	32.5
HiperLAN/2 OFDM-DMWT	4.5	5.97	6.95	8.5	9.95	10.5	14

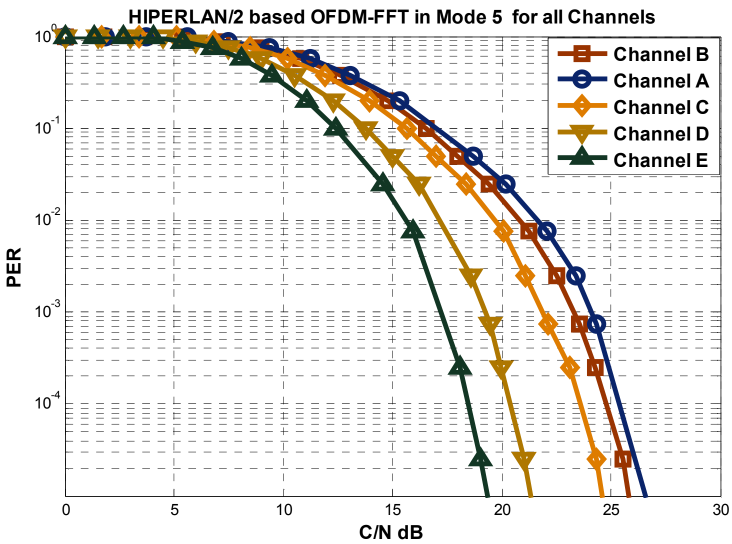

Figure 4. PER performance vs. mean C/N of conventional HiperLAN/2 based OFDM-FFT in mode 5 for all channels

Figure 4. 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 enhanced 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 result, ISI cannot be completely eliminated.

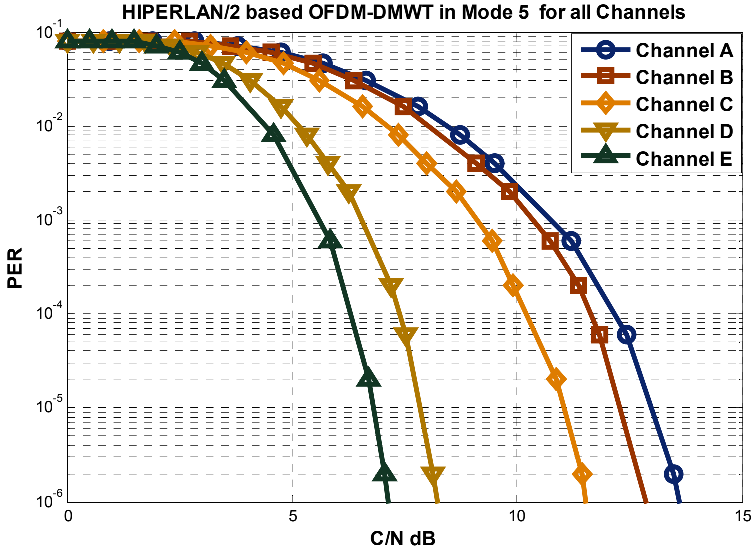

Figure 5. PER performance vs. mean C/N of modified HiperLAN/2 based OFDM-DMWT in mode 5 for all channels

Figure 5. Shows PER performance vs. mean C/N of modified HiperLAN/2 based OFDM-DMWT for mode 5 for all the specified channels. Performance comparison results between two structures for mode 5 in all the specified channels in Table 4.

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

Channel For BER=10^{-3}	**Channel A dB**	**Channel B dB**	**Channel C dB**	**Channel D dB**	**Channel E dB**
HiperLAN/2 OFDM-FFT	**24**	**23**	**22**	**19**	**17**
HiperLAN/2 OFDM-DMWT	**11**	**10.5**	**9**	**8**	**6**

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

4. Conclusion

Performance results in terms of PER have been presented for improvement HIPERLAN/2 standard, and for all transmission modes for the case of transmission over different channels. The key contribution of this paper is the implementation of the HiperLAN/2 transceiver based OFDM- DMWT structure PHY-layer which was proposed, simulated, and tested. These tests were carried out to verify its successful operation and possibility of implementation. It can be concluded that this structure achieves much lower bit error rates assuming reasonable choice of the bases function and method of computation. In different channels, simulations proved that the proposed design achieved much lower PER and better performance than OFDM-FFT assuming reasonable choice of the bases function and method of computations. The proposed OFDM-DMWT system is robust for multipath channels and does not require cyclically prefixed guard interval, which means that it obtains higher spectral efficiency than conventional OFDM, therefore, this structure can be considered an alternative to the conventional OFDM, and can be used at high transmission rates.

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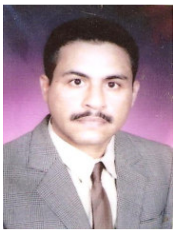

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