Design a New HiperLAN/2 Transceiver Based DCT-OFDM

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Abstract
Wireless LAN technologies like HiperLAN/2 transceiver are getting very important to realize mobile broadband systems. However, a shortage of allocated RF channels for the wireless LANs causes' interference signals that seriously degrade the system throughput in multi-cell environments. In this paper, a proposed model based on discrete cosine Transform (DCT) OFDM was suggested to improve the performance of HiperLAN/2 transceiver lies the under the Additive White Gaussian Noise (AWGN), flat fading, selective fading channels. This model is used to reduce the effect of multipath fading. The results extracted by a computer simulation for a model proposed, and then it compared with the original technique for HiperLAN/2 transceiver based on DCT for both systems. As a result, it can be seen from the proposed technique that a high performance improvement was obtained over the conventional HiperLAN/2 transceiver, where the Bit Error Rate (BER) is widely reduced under different channel characteristics for the AWGN, flat fading, and selective fading channels.
Keywords: HiperLAN/2, AWGN, BER, OFDM, DCT.

1. Introduction

Lately, demand for high-speed Internet access is quickly increasing and a lot of people enjoy broadband wired Internet access services using ADSL (Asymmetric Digital Subscriber Line) or cable modems at home. On the other hand, the cellular phone is getting very popular and users enjoy its location-free and wire-free services. The cellular phone also enables people to connect their laptop computers to the Internet in location- and wire free manners. However, current cellular systems like GSM (Global System for Mobile communications) can provide much lower data rates compared with those provided by the wired access systems, over a few Mbps (Mega bit per second). Even in the next generation cellular system, UMTS (Universal Mobile Telecommunications System), the maximum data rate of its initial service is limited up to 384kbps, therefore even UMTS cannot satisfy users' expectation of high speed wireless Internet access. Hence, recently, Mobile Broadband System (MBS) [1,2] is getting popular and important and wireless LAN (Local Area Network) such as ETSI (European Telecommunication Standardization Institute) HIPERLAN (High performance Radio Local Area Network) type2 (denoted as HL/2 in the rest of this paper) [3] and IEEE (Institute of Electrical and Electronics Engineers) 802.11 [4,5] is regarded as a key technology to realize the high-speed wireless access in MBS. at present, the MBS services are only obtainable at limited small areas covered by one or a few APs (Access Points), e.g. airport lounges or cafés, and portable computer users chiefly enjoy the services. In the near future, much smaller terminals similar to PDAs (Personal Digital Assistance) or cellular phones will have wireless LAN interfaces. Such sophisticated terminals will encourage much other people to enjoy the MBS services. Then MBS will be required to cover much wider service areas such as whole airport terminals or large shopping centers. Because coverage of an AP, i.e. cell, of the wireless LAN is much smaller than that of the cellular systems, the large-scale MBS should be composed of multiple cells. The most serious problem in the multi-cell MBS is degradation of system performances in terms of throughput or delay, which is caused by interference signals from other cells. In order to overcome the performance degradation, there are two approaches, system level and transceiver level approaches. The system level approach improves CIR (Carrier to co-channel Interference signal Ratio) level at receiver-sides. Means factors related to this approach are the number of obtainable channels, location of APs in the service area, frequency selection at each AP and propagation characteristics. On the other hands, the transceiver level approach improves the interference tolerance of transceivers, where error rate characteristics of physical layer and the link adaptation are key factors. In this paper, we evaluate the system performances of HL/2 in the multi-cell environments. Through the evaluations, we show quantitative improvements of the performances obtained by DCT-OFDM. Then we examine appropriate combinations of the technologies and clarify requirements for the technologies to realize, according to AWGN, Flat Fading and Selective Fading Channels.

2. OFDM System Based DCT

Instead of using complex exponential functions, cosinusoidal functions can be used as orthogonal basis to implement multi-carrier scheme. This can be synthesized using discrete cosine transform (DCT) [6]. For fast implementation algorithms DCT can provide fewer computational steps than FFT based OFDM[7,8]. The effect of carrier frequency offset (CFO) will introduce inter-carrier-interference (ICI) in both the DFT-OFDM and DCT-OFDM [9]. A single cosinusoidal functions set will be used as the orthogonal basis to implement in DCT-OFDM. The minimum required to satisfy Eq. (1) is 1/2T Hz.

$$\int_0^T \sqrt{\frac{2}{T}} Cos\,(2\pi f t) \sqrt{\frac{2}{T}} Cos\,(2\pi m f t) dt = \begin{cases} 1 & k = m \\ 0 & k \# m \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The continuous-time output signal of a DCT based OFDM system can be written as

$$X(t) = \sqrt{\frac{2}{N_S}} \sum_{n=0}^{N_{S-1}} d_n\, B_n cos\left(\frac{n\pi t}{T_S}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where *d0, d1*……. *DNs-1* are *Ns* independent data symbols obtained from a modulation constellation and

$$B_n = \begin{cases} \frac{1}{\sqrt{2}} & n = 0 \\ 1 & n = 1, 2, \ldots N_{S-1} \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The BER performance of DCT-OFDM is better than DFT-OFDM, the signal energy in DCT is concentrated in a few low-index DCT coefficients, while the remaining coefficients are zero or are negligibly small. Also it has been shown that the DCT is close to optimal in terms of energy-compaction capabilities. [10]

A zero-padding guard-interval scheme is used in DCT-OFDM system. The zero-padding scheme will eliminate ISI, and also improve transmission efficiency. In DFT-OFDM was reported in [11] where it was shown that the zero-padded (ZP) DFT-OFDM can achieve a better BER performance than cyclic prefix (CP) DFT-OFDM.

3. A proposed of HiperLAN/2 Transceiver Based Discrete Cosine Transform (DCT)

HiperLAN/2 is a European (ETSI) standard for high-rate wireless LANs, based on OFDM, operating in the 5GHz band and offering raw data rates up to 54Mbit/s. This is a reference model showing TX side coding and modulation for the 16QAM, 3/4 code rate mode, with a corresponding ideal receiver chain and AWGN channel. The model is a good example of the use of frame-based processing in Simulink simulations as the OFDM symbols provide a natural frame size for the model. In this section, the proposed HiperLAN/2 transceiver based on Discrete Cosine Transform (DCT) will be described, and its performance will be discussed. Fig. (1), it can be seen that the Inverse Discrete Cosine Transform (IDCT) and Discrete Cosine Transform (DCT) blocks in fig. (1), the other blocks at the transmitter and receiver parts are staying the same as in the traditional model.

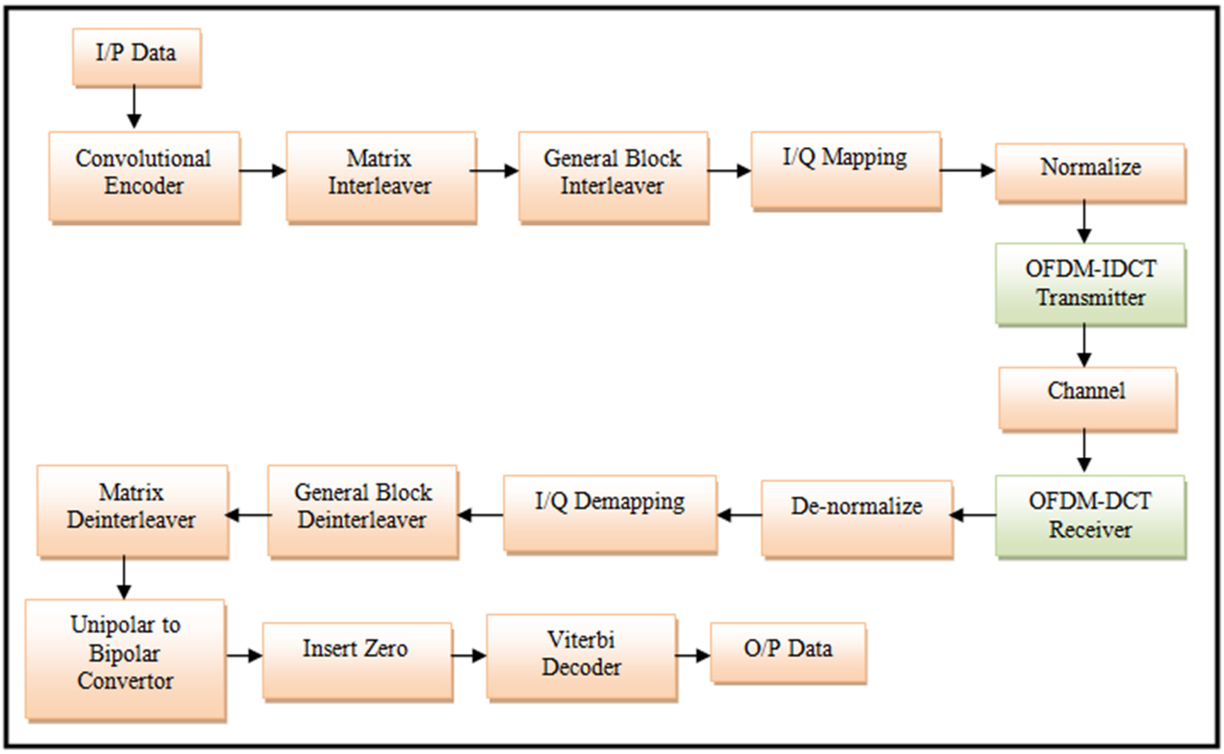

Fig. (1) Block diagram of a proposed HiperLAN/2 Transceiver Based Discrete Cosine Transform

The Block diagram in Fig (1) represents the whole system model for the HiperLAN/2 Transceiver based Discrete Cosine 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 an Convolutional Code. 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 is the 16QAM coding rate (3/4) with gray coding in the constellation map. 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 IDCT is used similar to that in conventional OFDM. Zeros are inserted in some bins of the IDCT to compress the transmitted spectrum and reduce interference from adjacent carriers. The added zeros to some subcarriers 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 because one limitation of communication systems is the width of the bandwidth. The addition of zeros to some subcarriers means that not all subcarriers are used; only the subset (N) of total subcarriers (N) is used. Therefore, the number of bits in OFDM symbol is equal to log (M)* N. 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 were transmitted perfectly .The computations of FFT and IFFT for 256 points, after which data are converted from parallel to serial, are fed to the channel HiperLAN/2 model. The receiver performs the same operations as the transmitter, but in a reverse order. It also contains operations for synchronization and compensation for the destructive channel.

4. Simulation Results of the Proposed Systems:

In this section the simulation of the proposed HiperLAN/2 model system in MATLAB version 13 is achieved, beside the BER performance of the OFDM system considered in different channel models, the AWGN channel, the flat fading channel, and the selective fading channel. Table (1) shows the parameters of the system used in the simulation.

Table (1) parameters of the system used in the simulation.

Frequency band	5GHz
Data rate	54Mbit/s
Modulation Types	16QAM
Number of sub-carriers	256
Number of DCT points	256
Coding rate	3/4
Channel model	AWGN Flat fading + AWGN Frequency selective fading +AWGN

A. BER Performance of Modified HiperLAN/2 Transceiver in AWGN channel:

In this section, the result of the simulation for the proposed HiperLAN/2 Transceiver is calculated and shown in Fig (2) which gives the BER performance of HiperLAN/2 model in AWGN channel. It is shown clearly that the DCT-OFDM is much better than the system FFT-OFDM. This is a reflection of the fact that the orthogonal base of the DCT is more significant than the orthogonal bases used in FFT-OFDM.

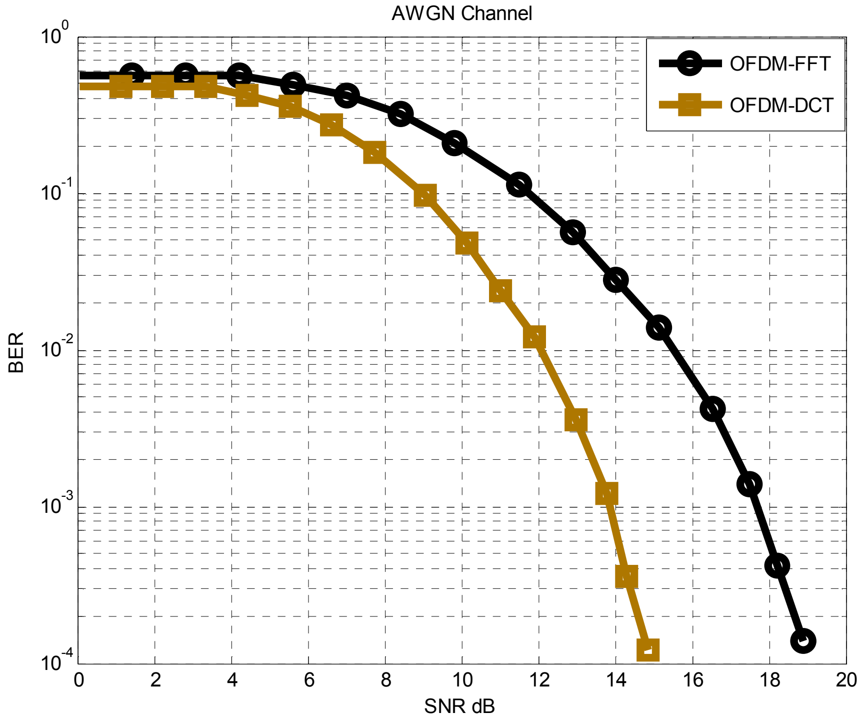

Fig (2) BER performance of HiperLAN/2 Transceiver Based DCT-OFDM in AWGN channel

B. BER Performance of Modified HiperLAN/2 Transceiver in Flat Fading Channel:

In this type of channel, the signal will be affected by the flat fading in addition to AWGN; in this case all the frequency components in the signal will be affected by a constant attenuation and linear phase distortion of the channel, which has been chosen to have a Rayleigh's distribution. A Doppler frequency of 10 Hz is used in this simulation. From Fig (3) it can be seen that for BER=10^{-3} the SNR required for DCT-OFDM is about 24.2dB while in FFT-OFDM about 29dB. From Fig (3) it is found that the DCT-OFDM outperforms significantly other two systems for this channel model.

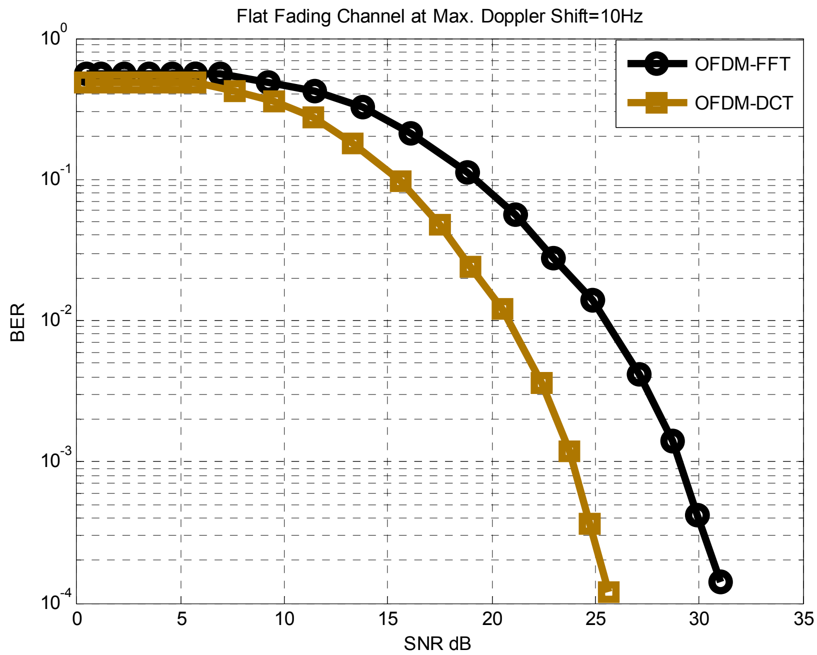

Fig (2): The BER performance of HiperLAN/2 Transceiver Based DCT-OFDM in Flat Fading Channel at Max. Doppler Shift=10Hz.

C. BER Performance of Modified HiperLAN/2 Transceiver in Selective Fading Channel:
In this section, the channel model is assumed to be selective fading channel, where the parameters of the channel in this case corresponding to multipaths where two paths are chosen the LOS and second path the LOS path having Average Path Gain equal 0dB and Path Delay 0, where the second path has Average Path Gain -8dB and path Delay one sample as shown in Fig (4). It is clear from this Figure, that BER performance of DCT-OFDM is better also than the FFT-OFDM. The DCT-OFDM has BER performance of 10^{-3} about 32.5dB and the FFT-OFDM has the same BER performance at 44.5dB

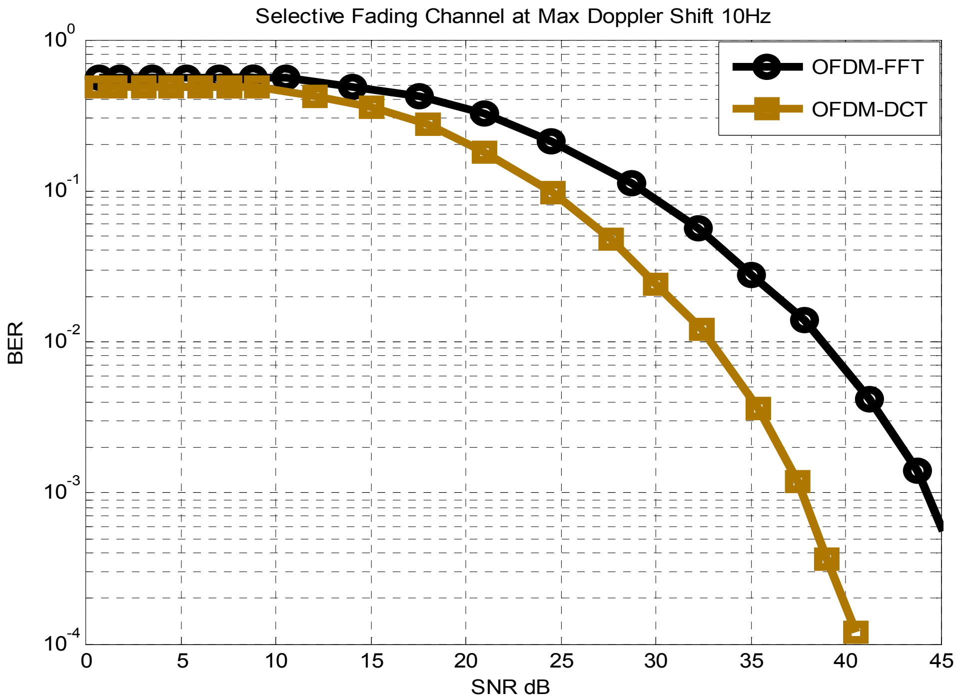

Fig (3): The BER performance of HiperLAN/2 Transceiver Based DCT-OFDM in Selective Fading Channel at Max Doppler Shift=10Hz.

5. Conclusion

Simulation results show that The BER performance of HiperLAN/2 Transceiver Based DCT-OFDM based scheme yields the lowest average bit error rate than HiperLAN/2 Transceiver Based FFT-OFDM for an AWGN channel. The second experiment is BER performance of HiperLAN/2 Transceiver Based DCT-OFDM in Flat Fading Channel at Max. Doppler Shift=10Hz show the performance OFDM-DCT is better than the transceiver based FFT- OFDM. The third experiment is BER performance of HiperLAN/2 Transceiver Based DCT-OFDM in selective Fading Channel at Max. Doppler Shift=10Hz show also the performance DCT-OFDM is better than the transceivers based OFDM-

References

[1] J. Mikkonen et al., "Emerging Wireless Broadband Net-works," IEEE Commun. Mag., vol. 36, no. 2, Feb.1998, pp. 112–17.
[2] M. Dinis, J. Fernandes, "Provision of Sufficient Transmission Capacity for Broadband Mobile Multimedia: A Step toward 4G", IEEE Commun. Mag., vol. 39, no. 8, Aug. 2001, pp. 46–54.
[3] ETSI TR 101 683 V1.1.1 (2000-02), Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; System Overview
[4] IEEE 802.11a-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications High-speed Physical Layer in the 5 GHz Band"
[5] IEEE 802.11b-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Higher-Speed Physical Layer Extension in the 2.4 GHz Band".
[6] K. A. 1 and S. Zahir M. Hussain1, "Studies on DWT-OFDM and FFT-OFDM Systems, "INTERNATIONAL CONFERENCE ONCOMMUNICATION, COMPUTER AND POWER, FEBRUARY, 2009.
[7] S. Sharma1 and S. Kumar2, "BER Performance Evaluation of FFT-OFDM and DWT-OFDM,"

International Journal of Network and Mobile Technologies, vol. 2, pp. 110–116, 2011.

[8] NEGASH B.G., NIKOOKAR H.: 'Wavelet based OFDM for wireless channels', Proc. IEEE VTC, 2001, 1, (Spring), pp. 688–691

[9] JAMIN A., MAHONEN P.: 'Wavelet packet based modulation for wireless communications', Wiley Wirel. Commun. Netw. J., 2005, 5, (2), pp. 123–137

[10] A. N. Akansu, "Wavelets and filter banks: A signal proc-essing perspective," Tutorial in Circuit and Devices, No-vember 1994.