Navigate Symbol Assisted Channel Estimation Algorithms under Various Channel Distribution

Dr. Raja Murali Prasad

Professor, Vardhaman College of Engineering, Hyderabad, Telangana, India

***Abstract*— *In order to reduce the effect of elements of noise, navigate symbol assisted (NSA) channel estimation (CE) algorithms based on the transform domain such as discrete Fourier transform (DFT) and discrete cosine transform (DCT)seemenchanting owing to their capacity. Here, an improved algorithm for a better channel estimation has been proposed based on expurgated discrete cosine transform (E-DCT) with additive white Gaussian noise (AWGN), Rayleigh distribution (RD) and Rician distribution (RcD) to obviate the leakage of energy using the property of symmetric and also compared with the conventional channel estimation algorithms such as Least Square (LS), DFT and mirror weighted DCT even that of E-DCT with additive white Gaussian noise (AWGN) distribution. Simulation results demonstrate that the E-DCT-RD can reduce the energy leakage more efficiently, and performed far better than the existing CE algorithms.*

Keywords*— *Channel distribution, DFT, navigate symbol assisted, Rayleigh distribution, Rician distribution.

I. INTRODUCTION

OFDM is a multiple access technique [1] in which the symbol duration will be increased by transmitting the large number of narrowband sub channels over a large bandwidth in parallel, which in results the reduction of inter symbol interference (ISI) [2]. For fighting against multipath fading while transmitting the high bit rate data over wireless mobile environments is an important task [2]. To do so OFDM is used as an effective approach. Major advantages of OFDM systems are

- High spectral efficiency
- Simple digital realization by using the FFT operation
- Due to the ISI avoidance, the complexity in the receiver will be reduced
- Various modulation schemes will be used to achieve the best performance of the system

Due to the above mentioned advantages, OFDM has been used in many wireless applications such as Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN) [4], Wireless Metropolitan Area Network (WMAN), Digital Audio Broadcasting (DAB) [3] and Digital Video Broadcasting (DVB) [5]. It is also being considered for IEEE 802.20, 802.16 [6], [7] and 3GPP-LTE. With the use of cyclic prefix for eliminating the effect of ISI, there is a need for a simple one tap equalizer at the OFDM receiver. OFDM brings in unparalleled bandwidth savings, which leads to high spectral efficiency. The channel coefficients of OFDM should be estimated with the minimum error to achieve the more potential advantages with higher efficiency.

A. System Model

The general OFDM system model has given in fig1. Firstly, the binary data has given as an input to the M-QAM/QPSK modulator. After mapping and grouping the input data the comb-pilot insertion will be done to split the transmitted data into N low rate modulated symbols $X(k)$, where k= 0,1,2, ……, N-1. Then the time domain signal $x(n)$ can be written as a frequency domain signal $X(k)$ after performing the IFFT:

$$x(n) = IDFT\{X(k)\}$$
$$IDFT\{X(k)\} = \sum_{k=0}^{N-1} X(k) exp(j2\pi nk/N) \quad (1)$$

Where N is the number sub carriers

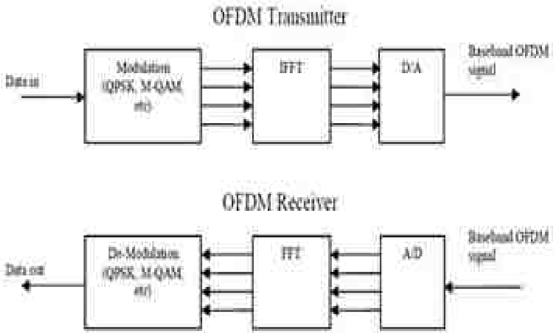

Fig.1: General OFDM block diagram

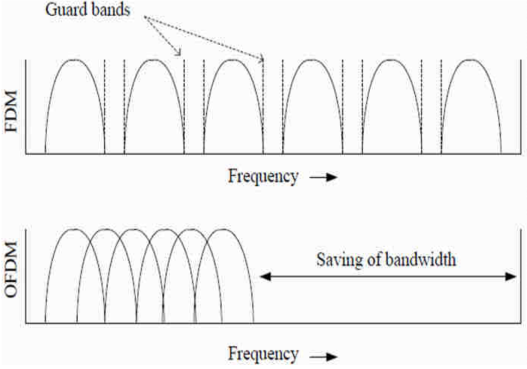

Fig.2: Comparison of FDM vs OFDM

$$x_g(n) = \begin{cases} x(N_g + n) & n = -N_g, -N_g + 1, \dots, -1 \\ x(n) & n = 0,1, \dots .\ N - 1 \end{cases} \quad (2)$$

Where $N_g$is the cyclic prefix (CP) length which reduces the ISI and as well as inter carrier interference (ICI).

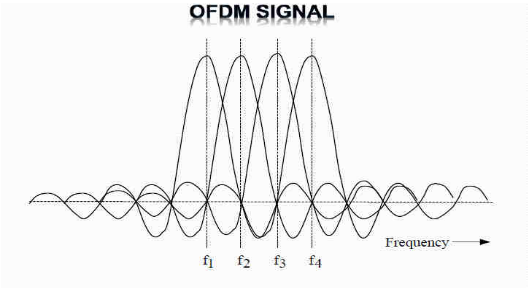

Fig.3: Output of the OFDM transmitter

The impulse response of a discrete channel can be described by a formula:

$$h(n) = \frac{1}{N}\sum_{l=0}^{L-1} \alpha_i e^{-j\frac{\pi(n+(N-1)\tau_l)}{N}} \frac{\sin(\pi\tau_l/T_c)}{\sin(\pi(\tau_l/T-N)/N)} \quad (3)$$

Where T_c=sampling period

L=number of multi paths and τ_l=time delay of L

II. RELATED WORK

In the past decades, there are so many channel estimation schemes have been proposed. Among those, the channel estimations based on NSA will help us to increase data rate. There are two parts in NSA-CE methods, those are: No prior information of channel and Prior information of channel based methods. The authors in [8] and [9], proposes a least squares (LS) approach and Minimum Mean Square Error (MMSE) which are categorized under no prior information of channel. Among those, LS estimator is a simplest method and it has lower computational complexity when we compared with the MMSE estimator. But, however the results of MMSE are better than the LS estimator. Different interpolation methods are given in [9] and [10], which will be used in NSA-CE. Compared with the existing methods, transformation based methods will perform excellent with moderate complexity increase. In [11], the author explained DFT based CE method. It can improve the system efficiency by reducing the computational complexity by exploiting the fast Fourier transform (FFT) algorithm. However, it can't provide an excellent performance when a sample spaced path delay will be existed by the multi path fading channels. To overcome this drawback, windowed DFT-CE method has been proposed in [12] to improve the performance of the system. But, it reduces the utilization of frequency band. Then after to improve the performance of the system more accurately, the DCT based NSA-CE methods have been proposed in [13], [14] and [15]. These methods have got excellent performance at high SNR region, but at low SNR values it gives very poor performance. In order to improve the system performance even at low SNR values, here in this paper we proposed a novel NSA-CE method based on E-DCT-RD. the proposed algorithm utilizes the DCT characteristics which compresses the power to the low frequency reign. By observing the simulation results, proposed algorithm has dominated the existing NSA-CE methods with higher SNR and lower bit error rate (BER) values.

III. EXISTING CEALGORITHMS

If the length of the channel is less than the CP then the received signal can be expressed as follows:

$$y_g(n) = x_g(n) \otimes h(n) + w(n)$$

Where$n =\ 0,1,2, \dots .,N - 1$, $\otimes$ =circular convolution and $w(n)$ = additive white gaussian noise (AWGN). After applying discrete Fourier transform (DFT)

$$Y(k) = \sum_{n=0}^{N-1} y(n) e^{-\frac{j2\pi nk}{N}} = X(k)H(k) + W(k)(4)$$

Where $H(k) = \sum_{l=0}^{L-1} h(k) e^{-j2\pi k\tau_l/NT_c}$= transfer function of channel in frequency domain, $W(k) = \sum_{k=0}^{N-1} w(n) e^{-j2\pi nk/N}$ is known as AWGN noise samples.

A. LS Approach

It is very simple and flexible approach, the channel estimation can be done by multiplying the sub symbols of received pilot carriers with the inverse of the sub symbols of reference pilot carriers, which can be described as follows:

$$\widehat{H}_p^{LS} = X_p{}^{-1}Y_p = \left[X_{p_0}{}^{-1}Y_{p_0} \ \dots\dots\dots\ X_{p_{p-1}}{}^{-1}Y_{p_{p-1}}\right]^T (5)$$

Where X_p= reference pilot carrier sub symbols

Y_p= received pilot carrier sub symbols and $(p_0, p_1, \dots\dots\dots\ p_{p-1})$are the set of sub carriers which will be used to carry sub symbols of pilot. Then after, it estimates the channel by interpolating $\widehat{H}_{pz}^{LS}$, which are obtained at positions of pilot, where$z = 0,1, \dots, P-1$, over the entire band to get the$\widehat{H}_{LS}(k)$.

B. DFT Approach

The frequency response can be estimated according to eq. (4)

$$\widehat{H}_p(k) = \frac{Y_p(k)}{X_p(k)} + \frac{W(k)}{X_p(k)} = H_p(k) + \frac{W(k)}{X_p(k)} \qquad (6)$$

Where $H_p(k)$ is channel estimation value in a pilot symbol, $k = 0,1,2,. \dots, M-1$ and M= number of pilot sub carriers. The phase of $\widehat{H}_p(k)$ executes pre-deflection.

$$H'_p(k) = \widehat{H}_p(k) e^{j2\pi\alpha/M} \qquad (7)$$

α is a minimal normalized integer of channel delay. After applying the IDFT to the eq. (7) then the channel response can be obtained by using

$$\hat{h}_p = IDFT\{H'_p(k)\} = \frac{1}{M}\sum_{k=0}^{M-1} H'_p(k) e^{j\frac{2\pi vk}{M}} \qquad (8)$$

Performing DFT to the above equation:

$$\widehat{H}(k) = \sum_{n=0}^{N-1} \hat{h}(n) e^{-j\frac{2\pi jk}{N}}, k = 0,1,2, \dots., N-1 (9)$$

The impulse response phase performs anti-deflection

$$\widehat{H}(k) = H'(k) e^{-j\pi k\alpha/M} 0 \le k \le M-1 \qquad (10)$$

DFT method has implicit periodicity. After DFT operation, original data will become infinite sequence due to the extension of finite non-periodic data. There should be high frequency components if the response of channel is discontinuous at both ends. Due to this interpolation operation DFT causes the aliasing error. To eliminate this error, the mirror weighted DCT approach has been proposed.

C. Mirror Weighted DCT Approach (MW-DCT)

Fig 4 shows that the block diagram of MW-DCT channel estimator. This algorithm will remove the aliasing effect due to the symmetric property. The channel estimation through MW-DCT can be expressed as follows:

$$\widehat{H}_{2M}(k) = \begin{cases} \widehat{H}_p(k) & 0 \le k \le M-1 \\ 0 & k = M \\ \widehat{H}_p(2M-k) e^{\frac{-j\pi(2M-1)}{M}} & M+1 \le k \le 2M-1 \end{cases} \qquad (11)$$

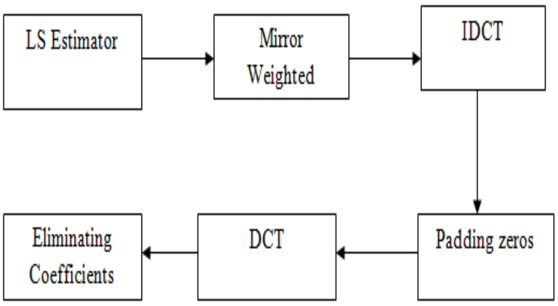

Fig.4: Block diagram of MW-DCT Channel Estimator

Algorithm:

1. First, M points $\widehat{H}_p(k)$ will be multiplied by the weighted coefficient i.e., defined by

$$\widehat{H}'_p(k) = \begin{cases} \frac{1}{\sqrt{2}} \widehat{H}_p(k) & k = 0 \\ e^{\frac{j\pi k}{2M}} \widehat{H}_p(k) & 1 \le k \le M-1 \end{cases} \qquad (12)$$

2. Now, $\widehat{H}'_p(k)$will be trasformed to time domain by Inverse DCT

$$\hat{h}_p(n) = \sum_{k=0}^{M-1} v(k) \widehat{H}'_p(k) \cos\left(\frac{\pi(2k+1)n}{2M}\right) \qquad (13)$$

$$m = 0,1,2, \dots, M-1$$

Where $v(k) = \begin{cases} \frac{1}{\sqrt{M}} & k = 0 \\ \sqrt{\frac{2}{M}} & k \ne 0 \end{cases}$

3. Now, the data can be extended to N points by padding the N-M zeros to the$\hat{h}(n)$to get the desired time domain signal. This extended data will be transferred by N-DCT.
4. Finally, to get the interpolated channel response, the weighted coefficients will be eliminated, it can be expressed as follows:

$$H(k) = \begin{cases} \sqrt{\frac{2N}{M}} H_p(k) & k = 0 \\ \sqrt{\frac{N}{M}} H_p(k) & 1 \le k \le N-1 \end{cases} \qquad (14)$$

When we compared the both DFT and DCT based channel estimators, the algorithms which are based on DCT can reduce few of high frequency elements in transformation domain. With the operation of MW-DCT, the lack of continuity of a signal problem can be saved and it makes the sequence much smoother in period edges.

D. Additive White Gaussian Noise Channel

It adds white gaussian noise to a complex/real input signal. If the input signal is real, then it adds real Gaussian noise and will produces a real output signal. It produces the complex output signal by adding the complex gaussian noise when the input signal is complex.Below are the various modes of noise variance that can be generated by the AWGN Channel:

Specifying the Variance Directly or Indirectly

a. Signal-to-Noise ratio (E_b/N_0), where the AWGN calculates the variances from these quantities:
    - The ratio of energy per bit to noise PSD,E_b/N_0,
    - Number of bits per symbol N_s
    - Input signal power
    - Symbol period
b. Signal to noise ratio (Es/No), where the AWGN calculates the variances from these quantities:

    - Es/No, the ratio between energy of signal to PSD noise
    - Input signal power
    - Symbol period

c. Signal to noise ratio (SNR), where the AWGN calculates the variances from these quantities
    - SNR
    - Input signal power

Changing the symbol period in the AWGN Channel will affects the noise variance added per sample, which can also causes a change in the final error rate.

IV. PROPOSED ALGORITHM

This section explains the proposed E-DCT algorithm with AWGN and Rayleigh distribution. Followed by the characteristics of DCT, the original sequence power in frequency domain is digested to the low frequency reign by DCT, the high frequency power reign considered as channel noise. Hence, we adopted a method which filters this surplus noise by setting the threshold as shortened coefficients. The shortened coefficients has been represented by N_{sh}

$$\begin{cases}\hat{h}_p(k)=\hat{h}_p(k) & 1\le k\le N_p\le M\\ \hat{h}_p(n)=0 & k>N_p>0\end{cases} \qquad (15)$$

Where $\hat{h}_p(k)$is known as a time domain signal after applying IDCT

- First, perform the LS algorithm to get the channel response$\hat{H}_p(k)$:

$$H(k)=H_p(k)+W_p(k) \qquad (16)$$

Where $W_p(k)$= AWGN in pilot sequence

- By using eq. (14), multiply $\hat{H}_p(k)$ by the weighted coefficients.

$$\frac{\sum_{i=0}^{N_p}\left|\widehat{h_p}(n)\right|^2}{\sum_{i=0}^{M-1}\left|\widehat{h_p}(n)\right|^2}=\beta$$

- By using the above formula, the length of shortened coefficients will be confirmed and then the total power will be set to the range from zero to N_p.
- Now, in order to remove the noise, the estimator can be implemented by M-point DCT and finally it eliminates the coefficients by using the formula (14).
- Now, by using the impulse response of channel in pilot sequences, channel estimation can be obtained in a valid data sequences.

Here, an improved and efficient scheme for DCT based channel estimator has been implemented also compared with LS, DFT and MW-DCT. Proposed algorithm performs effectively to reduce the channel noise and achieve significant performance without any channel prior information.

A. Rayleigh Distribution

Rayleigh fading is a rational model, when an environment that consists of many objects can scatter the transmitted signal before the arrival of signal at receiver. The central limit theorem holds that, the channel impulse response can be modeled well as a gaussian process irrespective of individual components distribution when there are enough much scatter [16]. When we apply Central Limit Theorem (CLT) to the large number of paths, then each path can be modeled with time as the variable as circularly symmetric complex Gaussian random variable (GRV), which is known as Rayleigh channel model [17]. When there is no prevalent component to the scatter such model will have the mean of zero and the phase between 0 and 2π radians. Therefore the channel response envelope is Rayleigh distributed.

B. Rician Distribution

It occurs when a transmitted signal will deviate from its normal path and cancels itself automatically. It is a non-deterministic model. The transmitted signal can arrive at the receiver end by several different paths, and at least there is change in one path. When the path is much stronger than the others, typically a line of sight (LoS) signal is known as Rician fading (RF). In this, a Rician distribution is used to characterize the gain of the amplitude. When there is noLoSpath between the transmitter and the receiver of OFDM then the Rayleigh fading [18] can categorize the RF. RF can be defined by two parameters known as $K$and Ω. Parameter $K$is called a Rise factor and it is defined as the ratio between the direct paths power to the other scattered paths power. And the Ω is the total power of both paths, which can acts as a scaling factor for the Rician distribution. The resulting PDF is then given by,

$$f(x)=\frac{2(K+1)x}{\Omega}exp\left(-K-\frac{(K+1)x^2}{\Omega}\right)I_0\left(2\sqrt{\frac{K(K+1)}{\Omega}}x\right)$$

Where the$I_0$is the 0_{th}order modified Bessel function of first kind. If the value of $K$is zero then the RF envelope will produced down to the Rayleigh faded envelope.

V. SIMULATION RESULTS

All the experiments have been done in the MATLAB 2014a environment with high speed CPU specifications. We examined all the above discussed algorithms performance and compared with each other. Here, QPSK-OFDM system has considered with a number of sub carriers N=64, 128, 256 512, … and so on, which includes 32 pilot sequences. Assumed the SNR is from 1 to 40 dB, path delay 1.0e-2, symbol rate for AWGN =10000sec and for Rayleigh = 20 micro seconds, Doppler frequency=100Hz, power delay = {0, -5, -10} dB are the system specifications for estimating the channel using the proposed and existing CE algorithms.

First, randomly generated digital input data has shown in fig6 then the OFDM signal for transmission has shown in fig7. Fig8 shows that the performance of signal to noise ratio (SNR) to mean squared error (MSE) with the proposed S-DCT and conventional LS, DFT, MW-DCT algorithms. It shows that the proposed CE algorithm with AWGN has the less MSE. Comparison of shortened coefficients in AWGN channel has given in fig9. Performance of proposed algorithm with Rayleigh distribution has displayed in fig10, which performs even better than the AWGN specifications by reducing the channel noise further with reduced error.

Fig11 shown that the comparison of proposed CE algorithm with the various channel distributions such as AWGN, Rayleigh distribution and Rician distribution, also compared with the conventional CE algorithms.

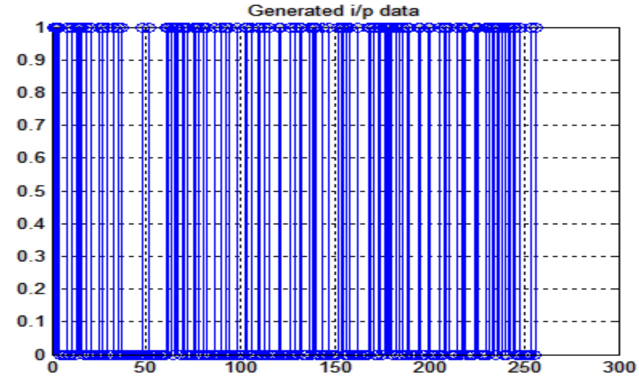

Fig.6: Generated input data

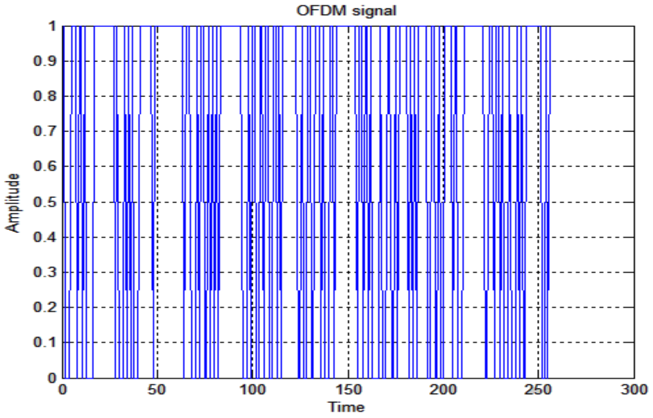

Fig.7: OFDM signal for transmission

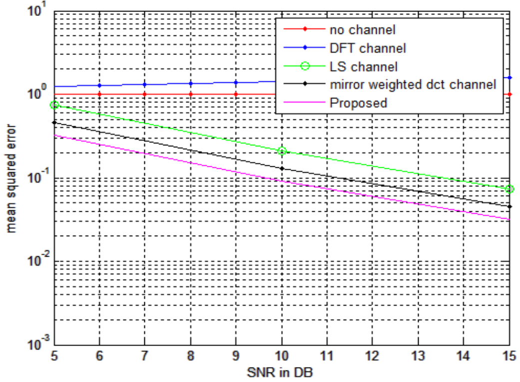

Fig.8: Performance of SNR Vs MSE with S-DCT-AWGN approach

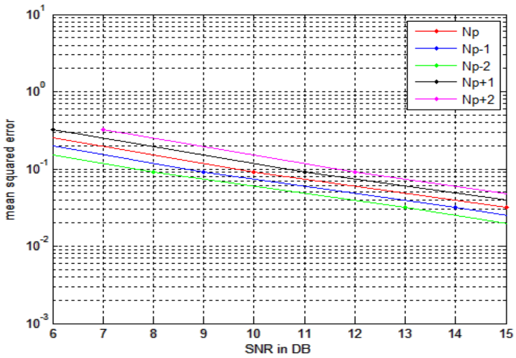

Fig.9: Performance of N_p for E-DCT-AWGN approach

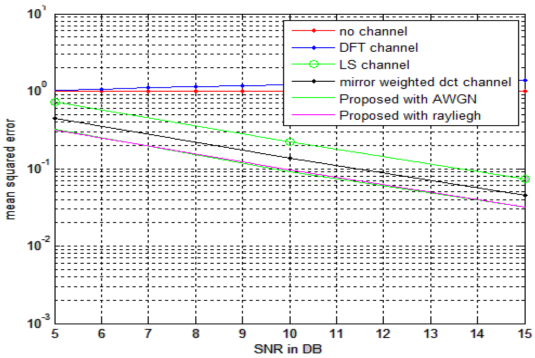

Fig.10: Performance of SNR Vs MSE with E-DCT-RD

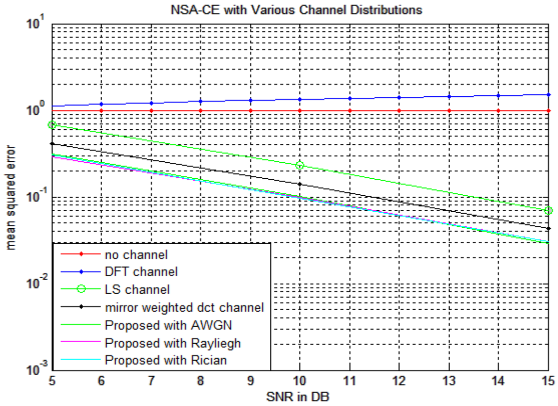

Fig.11: NSA-CE with various channel distributions

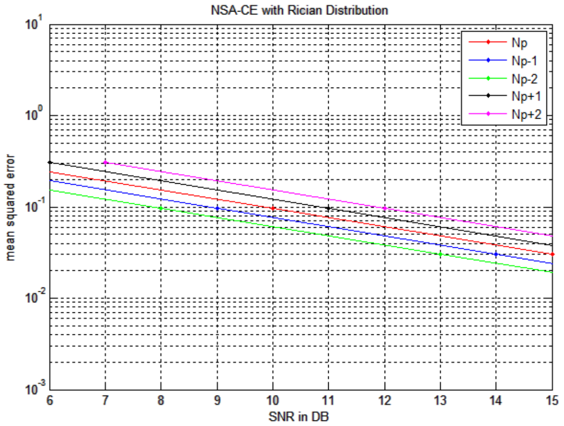

Fig.12: N_pPerformancefor E-DCT-RcD

VI. CONCLUSION

Here, a novel channel estimator algorithm has been proposed by using E-DCT under the Rayleigh distribution. Also performed the analysis of channel estimator algorithms based on LS, DFT and MW-DCT under AWGN channels. Proposed algorithm has been tested with AWGN, Rayleigh distribution and Rician distribution. Simulation results show that the proposed E-DCT-RD and E-DCT-RcDhas performed superior to the existing channel estimators in terms of channel noise and mean square error.

REFERENCES

[1] Wu Y., W. Y. Zou, “Orthogonal frequency division multiplexing: A multi-carrier modulation scheme,” IEEE Transactions on Consumer Electronics, vol. 41, no. 3, pp.392–399, Aug. 1995.

[2] Van Nee R., Prasad R., OFDM for wireless Multimedia Communications, Artech House, 2003.

[3] ETSI, “Radio broadcasting systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers”, European Telecommunication Standard, Standard EN-300401, May 1997.

[4] Hiperlan2, “Broadband Radio Access Networks (BRAN), HIPERLAN Type 2; Physical (PHY) layer”, ETSI, Tech. Rep., 1999.

[5] ETSI, “Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television”, European Telecommunication Standard, Standard EN-300-744, 2004-2006.

[6] Part 16: Air Interface for Fixed Broadband Wireless Access Systems Amendment 2: “Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz”, IEEE, Standard IEEE Std. 802.16a-2003, 2003.

[7] Part 16: Air interface for fixed broadband wireless access systems. “Amendment for physical and medium access control layers for combined fixed and mobile operation in licensed bands," IEEE, Standard IEEE Std 802.16e/D12, October 2005.

[8] SinemColeri, Mustafa Ergen, AnujPuri, and Ahmad Bahai, “Channel Estimation Techniques Based on Pilot Arrangement in OFDM Systems,” IEEE transactions on broadcasting, vol. 48, no. 3, September 2002.

[9] SinemColeri, Mustafa Ergen,AnujPuri, Ahmad Bahai, “A Study of Channel Estimation in OFDM Systems,” Vehicular Technology Conference, 2002. Proceedings. VTC 2002-Fall. 2002 IEEE 56th, Page(s): 894 – 898 vol.2.

[10] Xiaodai Dong, Wu-Sheng Lu, Anthony C. K. “Linear Interpolation in Pilot Symbol Assisted Channel Estimation for OFDM” IEEE transactions on wireless communications, VOL. 6, NO. 5, MAY 2007

[11] Zhang Jie, Huang Liqun, “An Improved DFT-based Channel Estimation Algorithm for MIMO-OFDM Systems,” Consumer Electronics, Communications and Networks (CECNet), 2011 International Conference on Page(s):3929 – 3932.

[12] SaqibSaleem, Qamar-ul-Islam, “On Comparison of DFT-Based and DCT-Based Channel Estimation for OFDM System,” IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 3, No. 2, May 2011.

[13] MoussaDiallo, RodrigueRabineau, Laurent Cariou, MarylineHélard. “Transform Domain based Channel Estimation for 3GPP/LTE Systems” Communications and Networking September 2010.

[14] Y. Wang, L. Li, P. Zhang and Z. Liu, “Channel estimation for OFDM systems in non-sample-spaced multipath channels,” Electronics Letters, vol. 45, January. 2009.

[15] H. Kobayaki and k. Mori. “Proposal of OFDM channelestimation methodusingdiscretecosinetransform”. Personal, Indoor and Mobile Radio Communications, 2004. Vol.3, Page(s):1797 – 1801.

[16] Robertson, P.; Kaiser, S. "The effects of Doppler spreads in OFDM (A) mobile radio systems", Vehicular Technology Conference, 1999. VTC 1999 - Fall. IEEE VTS.

[17] Bernard Sklar (July 1997). "Rayleigh Fading Channels in Mobile Digital Communication Systems Part I:

Characterization". IEEE Communications Magazine 35 (7): 90–100.

[18] Abdi, A. and Tepedelenlioglu, C. and Kaveh, M. and Giannakis, G., "On the estimation of the K parameter for the Rice fading distribution", IEEE Communications Letters, March 2001, p. 92 -94.

AUTHOR BIBILOGRAPHY

Raja Murali Prasad received his bachelor's degree from the Institution of Engineers in 1989 and M. Tech in ECE from Pondicherry Engineering College in 1993. He worked in various engineering colleges as faculty member. Presently, he is working as faculty member in the Department of Electronics and Communication Engineering, Vardhaman College of Engineering, Hyderabad. He completed PhD at JNT University Anantapur. His research interests include digital communications, control systems and wireless communications.