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Impact of Iterative Channel Equalization Schemes on Text Message Transmission in a FEC Encoded Multi Carrier CDMA Wireless Communication System

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Abstract: In this study, a comprehensive MATLAB simulation based study has been made for the performance evaluation study of a FEC encoded Multi Carrier (MC)-CDMA wireless communication system. The investigated system implements different channel equalization scheme, such as Least Mean Square (LMS), Normalized Least Mean Square (NLMS) and Recursive Least Square (RLS) under four digital modulation schemes (QPSK, BPSK, DPSK and QAM). Although, the iterative LMS and NLMS channel equalization algorithms are being widely used due to their simplicity, robustness and low computational complexity but these schemes are incapable to meet up convergence criteria. The simulation results show that the proposed system with BPSK and RLS outperforms as compared to other digital modulations and channel equalization schemes. It is observed that the system performance deteriorates with increase in order of digital modulation and noise power as compared to signal power.

Key words: Multicarrier-Code Division Multiple Access (MC-CDMA), Least Mean Square (LMS), Normalized Least Mean Square (NLMS), Recursive Least Square (RLS), Bit Error Rate (BER)

INTRODUCTION

About 4G compatible Multicarrier Code Division Multiple Access (MC-CDMA) has been recognized as a compatible advanced broadband wireless technology for its robustness against frequency selective fading channel, flexibility in system design, low detection complexity and lower peak-to-average power ratio. Recently, MC-CDMA transmission scheme is being discussed extensively to implement in future generation mobile communication (5th Generation: 5G) and Cognitive Radio (CR) networks (Chang, 2012). The MC-CDMA is a hybrid transmission technique employing an amalgam of Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) and is expected to combine the benefits of pure CDMA and OFDM techniques. The MC-CDMA is an attractive choice for high speed wireless communication as it mitigates the problem of Inters Symbol Interference (ISI) with exploitation of frequency diversity. It supports multiple users with high speed data communications. The CDMA technique is widely used in current 3rd Generation (3G) wireless communication systems (W-CDMA) Wideband Code Division Multiple Access, (UMTS) Universal Mobile Telecommunications, etc., presenting a wide range higher data rate supported services, such as voice/video/data (IP television, video on demand, video conferencing, tele-medicine) (Pallavi and Dutta, 2010; Badoi *et al*., 2011). Orthogonal Frequency-Division Multiplexing (OFDM) has emerged as a successful air-interface multicarrier digital modulation technique advocated by many European standards, such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting for Terrestrial television (DVB-T), Digital Video Broadcasting for Handheld terminals (DVB-H), Wireless Local Area Networks (WLANs) and Broadband Radio Access Networks (BRANs). In perspective of wired environments, the OFDM transmission techniques known as Discrete Multi-Tone (DMT) are employed in the American National Standards Institute's (ANSI's), Asymmetric Digital Subscriber Line (ADSL), High-bit-rate Digital Subscriber Line (HDSL) and Very-high-speed Digital Subscriber Line (VDSL) standards, as well as in the European Telecommunication Standard Institute's (ETSI's) VDSL applications (Hanzo *et al*., 2011). In 2008, a novel Code Division Multiple Access (CDMA) system under implementation of two-layer spreading scheme has been proposed. This Two-layer Spreading-CDMA (TLS-CDMA) system can combat Multiple Access Interference (MAI) and Multipath Interference (MPI) simultaneously and effectively in a multi-user scenario over frequency selective fading channels. With flexible adaptation of the two-layer spreading factors, the

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proposed TLS-CDMA system is able to support variable data rates among multiple users according to the cell structure, the channel propagation conditions and the number of active users (Peng *et al*., 2008). The present study has been made on the performance evaluative study of MCCDMA system under implementation of various channel equalization scheme.

MATERIALS AND METHODS

Mathematical model: The LMS algorithm is a type of adaptive filter known as stochastic gradient-based algorithm as it utilizes the gradient vector of the filter tap weights to converge on the optimal wiener solution (Rupp, 2012). It is well known and widely used due to its computational simplicity.

If x(n) is the tap input vector at time n, d(n) is the desired response, y(n) is the estimate of the desired response (output of the filter) and e(n) is the estimation error, we can write:

$$e(n) = d(n) - y(n) \tag{1}$$

$$y(n) = w^T(n)x(n) \tag{2}$$

Where, w(n) is the weight vector given in Eq. 3:

$$\begin{aligned} w(n) &= \left[w_0(n)w_1(n)w_2(n)...w_{M-1}(n)\right]^T \\ x(n) &= \left[x(n)x(n-1)x(n-2)...x(n-M+1)\right]^T \end{aligned} \tag{3}$$

Superscript T denotes the transpose of the w(n). LMS algorithm updates its weight according to:

$$w(n+1) = w(n) + ue(n)x(n) \tag{4}$$

Where, μ is a step size that regulates convergence rate. In order to achieve a fast initial convergence speed and to retain a fast tracking ability in the steady state, large value for step size is chosen (Rocher *et al*., 2010). On the other hand, large step size will result in large steady state mis-adjustment error.

The main drawback of the pure LMS algorithm is that it is sensitive to the scaling of its input x(n). This makes it very hard (if not impossible) to choose a learning rate μ that guarantees stability of the algorithm. The Normalized Least Mean Squares filter (NLMS) is a variant of the LMS algorithm that solves this problem by normalizing with the power of the input. The Normalized Least Mean Square (NLMS) algorithm is one of the most popular adaptation algorithms for adaptive equalizer due to its computational simplicity.

NLMS algorithm updates its weight according to (Charhate *et al*., 2012):

$$w(n+1) = w(n) + \mu(n)e(n)x(n) \tag{5}$$

Where:

$$\mu(n) = \frac{\mu}{x(n)x(n)^T + \delta} \tag{6}$$

$x(n)\,x(n)^T$ is tap input power and is given by:

$$x(n)x(n)^T = x(n)^2 + x(n-1)^2 + ... + x(n-M+1)^2 \tag{7}$$

The μ is a step size constant that regulates convergence rate. The value of the step size constant μ for the NLMS algorithm to be convergent in the mean square should be $0<\mu<2$ (Gu *et al*., 2009).

Compared to the LMS algorithm, the RLS algorithm has the advantage of fast convergence but this comes at the cost of increasing the complexity. Initialization of inverse matrix is done by:

$$\rho(0) = \delta^{-1} \tag{8}$$

Where, **δ** is small positive constant for high SNR and large positive constant for low SNR. The filter output is calculated using the filter tap weights from the previous iteration and the current input vector:

$$y(n) = w^T(n-1)x(n) \tag{9}$$

The intermediate gain vector is calculated using k(n):

$$k(n) = \frac{\lambda^{-1}p(n-1)x(n)}{1+\lambda^{-1}x^T(n)p(n-1)x(n)} \tag{10}$$

Where, λ is a forgetting factor lying in the range $0<\lambda<1$ (Al-Naffouri *et al*., 2011). Estimation error can be given as $\xi^*(n)$:

$$\xi(n) = d(n) - y(n) \tag{11}$$

The filter tap weight vector is updated according to:

$$\hat{w}(n) = \hat{w}(n-1) + k(n)\xi(n) \tag{12}$$

And inverse matrix can be update using:

$$p(n) = \lambda^{-1}p(n-1) - \lambda^{-1}k(n)x^T(n)p(n-1) \tag{13}$$

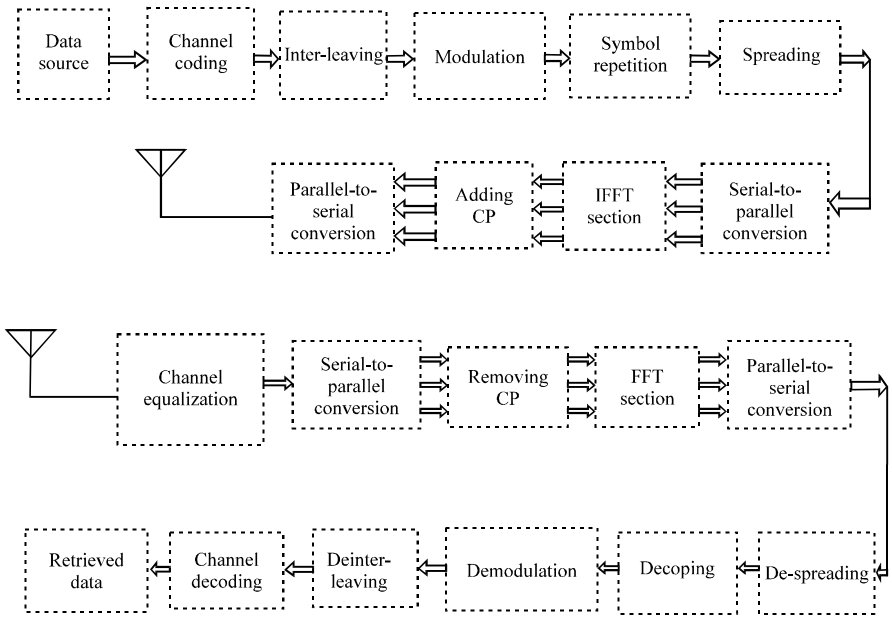

Fig 1: Block diagram of channel equalization model based MC-CDMA wireless communication system

The λ is a positive constant lying in the range 0<λ<1 (Charhate *et al*., 2012).

Each iteration of the RLS algorithm requires $4N^2$ multiplication operations and $3N^2$ additions. This makes it very costly to implement, thus LMS based algorithms while they do not perform as well are more favorable in practical situations.

Communiction system model: A simulated model for channel equalization based MC-CDMA wireless communication system as depicted in Fig. 1 utilizes 1/2-rated convolutional channel coding scheme. In such a communication system, single user is transmitting text message. The transmitted text messages of a single user are converted into binary bits and these bits are then channel encoded. The channel encoded bits are digitally modulated using various types of digital modulations, such as Binary Phase Shift Keying (BPSK), Differential Phase Shift Keying (DPSK), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM) and the number of digitally modulated symbols is increased (copied) 128 times (as the processing gain/sequence length of the Walsh-Hadamard (WH) transformed orthogonal codes is 128) and subsequently multiplied with Walsh-Hadamard codes assigned for the user. The output is, then sent up into serial to parallel converter. The Serial to Parallely (S/P) converted complex data symbols are fed into the OFDM modulator with 1024 sub carriers which performs an IFFT on each OFDM block followed by a parallel-to-serial conversion.

A Cyclic Prefix (CP) of length LCP ($0.1\times1024\approx103$) containing a copy of the last LCP samples of spreaded output of the 1024-point IFFT is then prepended. The CP is essentially a guard interval which serves to eliminate interference between OFDM symbols. The incoming symbols are then converted by parallel converter. However, the resulting spreaded symbols are lunched from the single transmitting antenna system. In receiving section, all the transmitted signals are detected with linear converter and cyclic prefix is removed and subsequently second dispreading scheme is performed. The symbols are then fed into OFDM demodulator which performs FFT operation on each OFDM block. The FFT demodulated incoming symbols are converted by parallel-to-serial converter. The output is multiplied with assigned Walsh-Hadamard code. The complex symbols are digitally demodulated, decopied and convolutionally decoding and recover the original data and recover the transmitted text message.

RESULTS AND DISCUSSION

Researchers have conducted computer simulations to evaluate the BER performance of the MC-CDMA wireless communication system based on the parameters given in Table 1. It is assumed that the Channel State Information (CSI) is available at the receiver and the fading process is approximately constant during one OFDM block length. The graphical illustrations presented in Fig. 2. Figure 2 shows the system performance comparison with implementation of LMS, NLMS and RLS based channel equalization schemes under various low order digital modulations. In all cases, the system outperforms in BPSK and shows worst performance in QPSK digital modulation.

Table 1: Summary of the simulated model parameters

Paramerters	Values
No. of iteration	500
Channel coding	1/2 rated convolutional encoding
Modulation	BPSK, DPSK, QAM and QPSK
No. of OFDM subcarriers	1024
Spreading code	Walsh-hadamard
CP length	103
LMS parameter	$\mu = 0.008$
NLMS parameter	$\mu = 0.008$, $\delta = 0.0001$
RLS parameter	$\lambda = 0.99$, $\delta = 0.004$
Signal to Noise Ratio (SNR)	1-10 dB
Delay	7

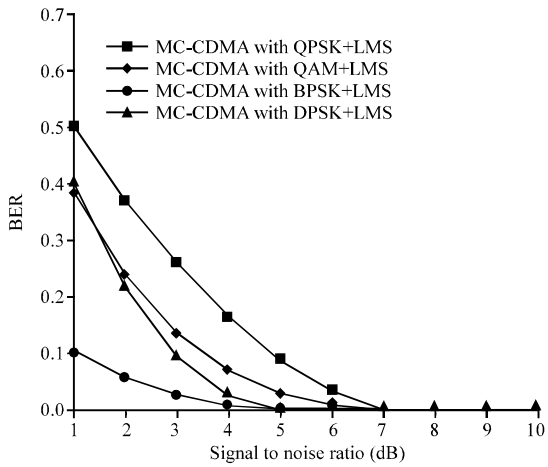

Fig. 2: BER evaluation in a channel equalization based MC-CDMA wireless communication system under implementation of different digital modulation schemes and LMS channel equalization scheme

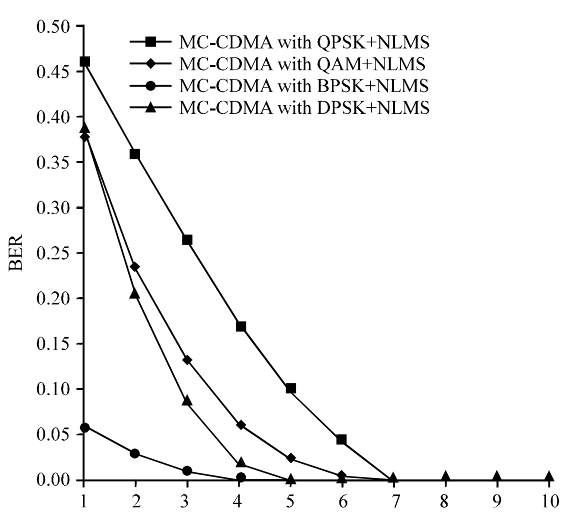

Fig. 3: BER evaluation in a channel equalization based MC-CDMA wireless communication system under implementation of different digital modulation schemes and NLMS channel equalization scheme

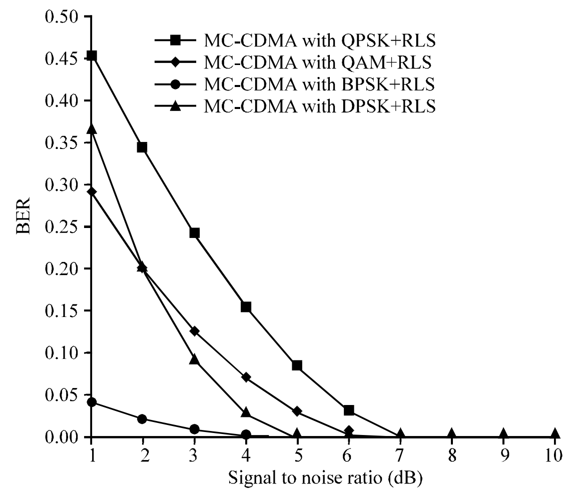

Fig. 4: BER evaluation in a channel equalization based MC-CDMA wireless communication system under implementation of different digital modulation schemes and RLS channel equalization scheme

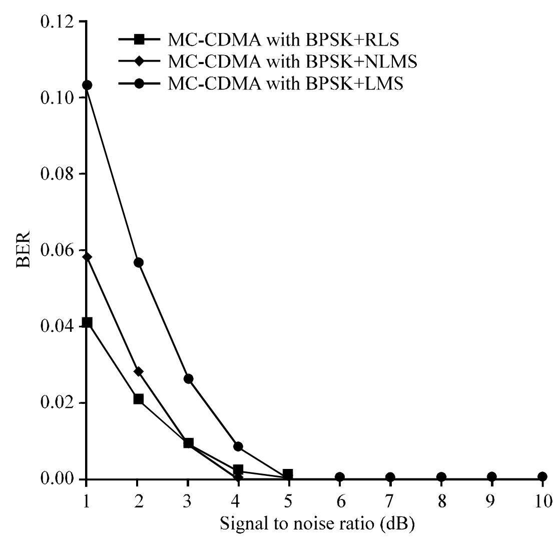

Fig. 5: BER evaluation in a channel equalization based MC-CDMA system under implementation of BPSK digital modulation scheme and different channel equalization schemes

The BER performance difference is quite obvious in lower SNR areas and the system's BER declines with increase in SNR values. In Fig. 2, it is noticeable that for a typically assumed SNR value of 3 dB, the BER values are 0.0259 and 0.2599 in case of BPSK and QPSK digital modulations viz., the system achieves a gain of 10.02 dB in BPSK as compared to QPSK. In Fig. 3, the BER values in case of BPSK and QPSK are 0.0094 and 0.2620 for

(a) Original transmitted message

The recent digital transmission systems impose the application of channel equalizers with short training time and high tracking rate

(b) Retrieved message at SNR value of 0 dB with BER 0.5005

The ruvI h2lu_GBYvL [Q6} Hq`z [+_U7:~aE?L_|_fo9lVIh_Jwq_-M$-__W.u|-whc>;____ Z_j~5 [OpZ {__ag.'r-{;E = J}R_)6___%q%j<ÇR|$lE? {'b-)0r_g.

(c) Retrieved message at SNR value of 4 dB with BER 0.1260

The pecent digital_PvanYoiss_k A_ystM_3 lmpkse the`apqlicct)O^g_d/3ia~nel equalizEvs 7i_Qm.hOst_trgining tiuf anD_iqgh`6reckIng rat%

(d) Retrieved message at SNR value of 8 dB with BER 9.7656e-004

The recent digital transmission systems impose the application of channel equalizerr with short training time and high tracking rat %

Fig. 6: Transmitted and retrieved text messages for single user. Red mark indicates erroneous and noisy transmission

a 3 dB SNR value that implies achievable system performance by 14.45 dB for BPSK-modulated MC-CDMA employing Normalized Least Mean Square (NLMS) channel equalization scheme.

Figure 4 illustrates the achievable performance of BPSK-modulated system under deployment of RLS channel equalization scheme, the system achieves a gain of 14.52 dB at SNR value of 3 dB (BER values: 0.0085 and 0.2407 in case of BPSK and QPSK). In Fig. 5, it is observable that at very low SNR value area, the system performance is comparatively better under deployment of the Recursive Least Square (RLS) channel equalization scheme. In Fig. 6, the transmitted and retrieved text messages of the user have been presented. It is noticeable that the quality of retrieved message is improved with increase in SNR value. The bit error rate at 0, 4 and 8 dB are 0.5005, 0.1260 and 0.0009, respectively.

CONCLUSION

In this study, researchers have presented simulation results concerning the adaptation of various equalization techniques in a FEC encoded MC-CDMA wireless communication system has been presented. A range of system performance results highlights the impact of equalization technique on text message transmission. In the context of system performance, it can be concluded that the convolutionally encoded and BPSK-modulated MC-CDMA wireless communication system with RLS channel equalization technique provides satisfactory result as compared with NLMS and LMS for such a MC-CDMA wireless communication system.

REFERENCES

Al-Naffouri, T.Y., M. Moinuddin and M.S. Sohail, 2011. Mean weight behavior of the NLMS algorithm for correlated Gaussian inputs. IEEE Signal Process. Lett., 18: 7-10.

Badoi, C.I., N. Prasad, V. Croitoru and R. Prasad, 2011. 5G based on cognitive radio. Wireless Personal Commun., 57: 441-464.

Chang, C.W., 2012. An interference-avoidance code assignment strategy for the hierarchical two-dimensional-spread MC-DS-CDMA system: A prototype of cognitive radio femtocell system. IEEE Trans. Veh. Technol., 61: 166-184.

Charhate, S.V., L.D. Malviya and S.K. Suman, 2012. Performance comparison of LMS, NLMS and RLS algorithms for adaptive equalizer. Int. J. Adv. Electron. Commun. Syst., Vol. 1, No. 1.

Gu, Y., J. Jin and S. Mei, 2009. Norm constraint LMS algorithm for sparse system identification. IEEE Signal Process. Lett., 16: 774-777.

Hanzo, L.L., Y. Akhtman, L. Wang and M. Jiang, 2011. MIMO-OFDM for LTE, Wi-Fi and WiMAX: Coherent versus Non-Coherent and Cooperative Turbo Transceivers. 2nd Edn., John Wiley and Sons Ltd., UK., ISBN-13: 9781119957454, Pages: 692.

Pallavi, P. and P. Dutta, 2010. Muti-carrier CDMA overview with BPSK modulation in Rayleigh channel. Proceedings of the 3rd IEEE International Conference on Computer Science and Information Technology, Volume 4, July 9-11, 2010, Chengdu, China, pp: 464-469.

Peng, X., K.B. Png, Z. Lei, F. Chin and C.C. Ko, 2008. Two-layer spreading CDMA: An improved method for broadband uplink transmission. IEEE Trans. Veh. Technol., 57: 3563-3577.

Rocher, R., D. Menard, O. Sentieys and P. Scalart, 2010. Accuracy evaluation of fixed-point based LMS algorithm. Digital Signal Process., 20: 640-652.

Rupp, M., 2012. Robust design of adaptive equalizers. IEEE Trans. Signal Process., 60: 1612-1626.