Enhancement of Signal to Noise Ratio for QAM Signal in Noisy Channel

Ali Salah Mahdi(✉)

Department of Information and Communication Al_Khwarizmi College of Engineering, University of Baghdad, Baghdad, Iraq
ali_info27@kecbu.uobaghdad.edu.iq

Abstract. At the receiver Channel parameters is an important matter in the wireless communication especially with fast fading Rayleigh channel because of the rapid change of the channel envelop. Data message will suffer during transmission, therefore, there should be a good channel estimation to overcome channel effect. In this paper, modified reduced constellation algorithm MRCA is presented as a solution to estimate Rayleigh fading channel with comb-type tones insertion in Quadrature amplitude modulation modulated signals for OFDM system. The MRCA filter aim to reduce number of tones to estimate Rayleigh fading channel and the number of reduced tone approach to 1/90 (one pilot tones for each 90 data bit) to avoid data rate reduction or bandwidth expansion. The performance of the proposed algorithm was superior on reduced constellation algorithm (RCA) algorithm to estimate channel as showed in the simulation results, as well the performance of the MRCA and RCA, it has been compared with different S/N points in addition to measuring BER verses SNR.

Keywords: OFDM · Modified reduced constellation algorithm · reduced constellation algorithm

1 Introduction

In radio communication systems, throughput, maximum channel capacity, signal to noise ratio and fading are especially important points to deal with. Recently, orthogonal frequency division multiplexing applied widely to solve the mentioned point. In communication systems, channel estimation takes two branches, first, blind estimation tries to calculate channel elements without need any information about what was transmit on contrary of second type, non-blind estimation, transmitter sent some pilot tones as a technique of channel coding. Actually there are two type of pilot insertion either block type insertion as appeared in Fig. 1, this approach suitable for slow fading channel and can be estimated by using minimum mean square error or least square estimator, or the second approach, comb-type as shown in the Fig. 2, this assumption is developed to meet requirements of fast fading such as Rayleigh channel [3]. In the comb-type pilot insertion, to interpolate channel at all subcarriers, there are many methods such as cubic

S. Nandan Mohanty et al. (Eds.): ICISML 2022, LNICST 470, pp. 278–287, 2023.
https://doi.org/10.1007/978-3-031-35078-8_23

spline interpolation, numerical interpolation, [4], or piecewise constant interpolation [3]. Recently, performance of tracking fast fading channel, it has been calculated between recursive least square and extend recursive least square E-RLS, E-RLS was better than RLS [1]. Also, in [2] investigated tracking performance of fading channel between Recursive Least Squares (RLS) and epsilon normalized least mean square (NLMS) and NLMS attend better result than RLS. Because of the more pilot have been inserted, bandwidth expanded time manipulation as well increased and throughput reduction. In comb-type method, channel estimation can be based on LS, Least Mean-Square (LMS), MMSE, as in [3, 5, 6] the pilot rate was 1/8, but in our proposed algorithm the pilot rate reduced to 1/90 with good estimation for the channel, which means the throughput is increased and process time is decreased without need extra bandwidth.

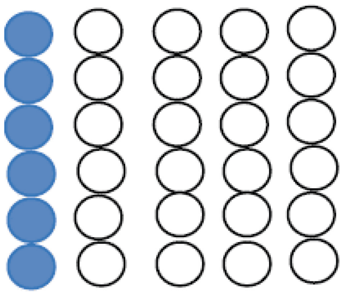

Fig. 1. Pilot tones arrangement with Block-Type

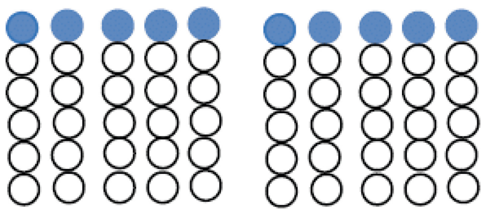

Fig. 2. Pilot tones arrangement with Comb-Type

2 System Model

Figure 3 described the classic orthogonal frequency division multiplexing system, it consists of three major parts transmitter, channel, and receiver. The main idea of OFDM system is to divide the frequency spectrum into many sub-carriers in an orthogonal manner, for this it is called OFDM, and thoughtful OFDM system with pilot tone technology. On the input of the given system in the Fig. 3, binary data input data are modulated with multi amplitude different phase signals (QAM modulation) technology then follow to s/p block to convert to parallel form. The control bit is inserted in each OFDM symbol uniformly. After control bit insertion, the data X(k) are sent to IDFT block to transform into x(n) via the inverse DFT matrix (F) as in

$$x(n) = IDFT(X(k)) = F^{-1} * X(k) \tag{1}$$

where

$$[F]_{nk} \triangleq \frac{1}{\sqrt{N}} e^{\frac{-j2\pi nk}{N}} n, k = 0, 1, 2 \ldots\ldots, N-1, j = -1 \tag{2}$$

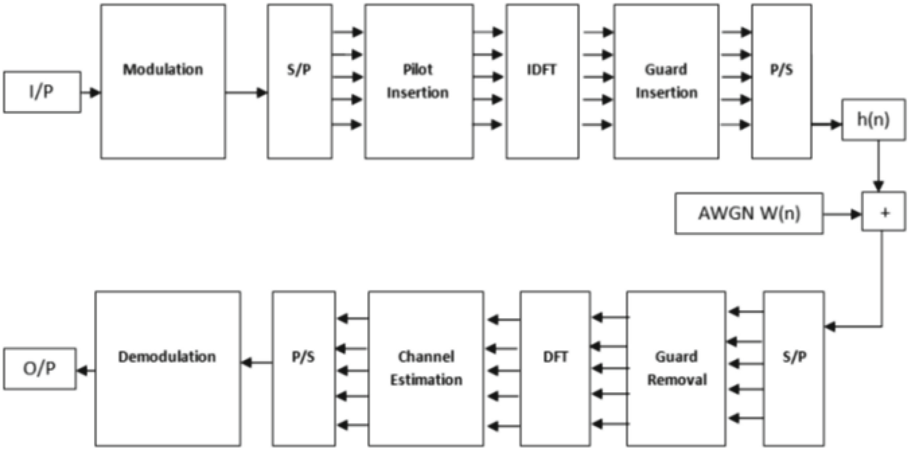

Fig. 3. OFDM system model [6]

Where N is referred to FFT size. In the guard insertion block, insert bits with length bigger than channel delay to overcome the inter symbol interference, the output samples $X_g(n)$ as in

$$x_g(n) = \begin{cases} x(N+n) & n = -N_g, -N_g+1, \ldots\ldots, -1 \\ x(n) & n = 0, 1, \ldots\ldots, N-1 \end{cases} \tag{3}$$

where

N_g _ Length of Guard band.

At the p/s block, the result converted to serial form and sent it over fading channel type of Rayleigh.

Now at the received side, the arrived signal as described below in the Eq. 4:

$$y_g(n) = x_g(n) \otimes h(n) + w(n) \tag{4}$$

where

h(n): Channel response.

w(n): Additive white Gaussian noise AWGN (Fig. 4).

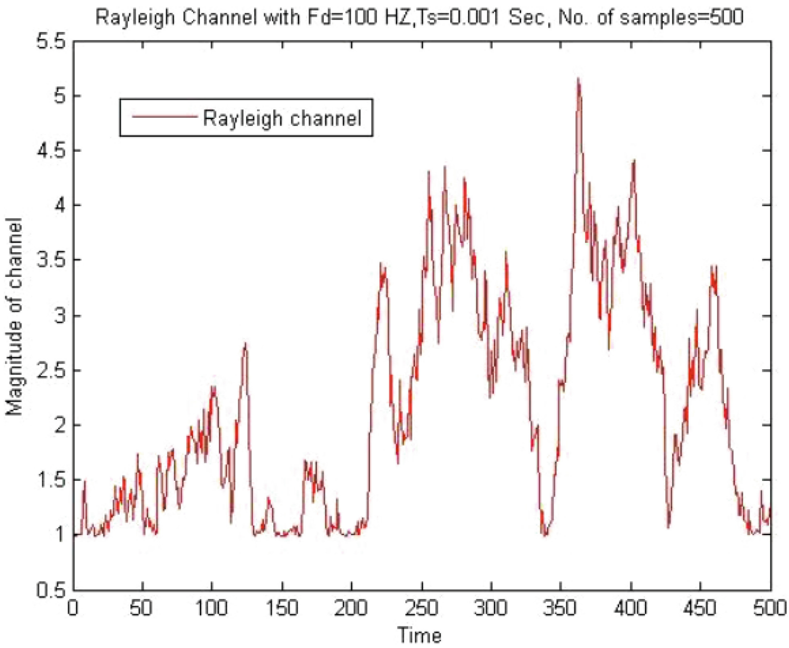

Fig. 4. Rayleigh fading channel.

After serial to parallel conversion in the s/p block, guard band are removed from $y_g(n)$ to be in the form $y(n)$

then followed to a DFT block recover signals as below in the eq. 5:

$$Y(K) = DFT(y(n)) = F * y(n) \tag{5}$$

At the channel estimation block, the channel response at the pilot tones have been estimated then interpolated to $H_e(K)$. As well, transmitted data is calculated, as in

$$X_e \equiv \frac{E(K)}{H_e(K)} \tag{6}$$

At end, the binary bit converted to serial data and demodulated in the block of (QAM-demodulation) to obtain original data again.

3 Channel Estimation and Interpolation

In the present paper, we consider the channel is fast time varying Rayleigh fading channel, the channel response changes rapidly even each OFDM symbol. Therefore, the comb-type tones technique is used to estimate the channel behavior. For comb-type tones insertion, the k_p pilot signals $X_p(m)$, m = 0, 1, 2, …, k_p are homogeneously inserted into X(k). The pilot tones are inserted in front of subcarrier. The OFDM signal modulated on the N_{th} subcarrier as in (7)

$$X(k) = X(mL + i) = \begin{cases} X_p(m) & i = 0 \\ Messages & i = 1, \ldots, L-1 \end{cases} \tag{7}$$

where

$X_p(m)$: Number of pilot carrier value.

The received pilot signal as expressed below in the Eq. 8

$$Y_p = X_p H_p + W_p \tag{8}$$

where

H_p: Frequency response of estimated channel with length equal to tones sub-carriers as described below

$$H_p = [H_p(0), H_p(1), \ldots\ldots, H_p(k_p-1)]^T \tag{9}$$

The signals estimation according to RCA strategy, is shown below by Eqs. (10) and (11a& 11b).

$$H_{p,RCA} = [H_{p,RCA}(0), H_{p,RCA}(1), \ldots\ldots, H_{p,RCA}(N-1)]^T \tag{10}$$

$$J_r(w) = E\{(\lambda csgn(x_i) - y_i)^2\} \tag{11a}$$

$$\text{Where}\lambda = \frac{E\{|yi|^2\}}{E\{|y_i|\}} \tag{11b}$$

where a sign function. The RCA estimate of H_p is need high number of pilot tones reach to (pilot ratio = 1/8) for acceptable estimation such,still, using extra tones lead to extend bandwidth or data rate decreasing. While the proposed algorithm (MRCA) as given below

$$H_{p,modRCA} = E\left\{\lambda c\mathrm{Sg}\eta\left(Q_p^T\right)^T\left(Y_p * X_p^*\right)/\sqrt{N}\right\} \tag{12}$$

$$H_{p,modRCA} = \mathrm{mean}\left(H_{p,modRCA}\right) \tag{13}$$

where is a sub matrix of F^{-1}

reduced pilot ratio to 1/90 and the simulation result showed a superior performance with a little number of pilot tones are used. After the inserted pilot tones estimated H_p (in comb-type method, time domain interpolation is used in the simulation program to interpolate channel with length equal to data length because it is a high-resolution interpolation based on zero-padding and FFT/IFFT [7]. We first convert it to time domain by IFFT, as in Eq. 14:

$$G(n) = \sum_{k=0}^{N_p-1} H_p(k) e^{\frac{j2\pi kn}{N_p}} \; \mathrm{n} = 0, 1, \ldots, k_p - 1 \tag{14}$$

where

k_p: pilot tones number.

The signal is interpolated by transforming the points into points with the following method [8]

$$G_N = \begin{cases} G_p \; 0 \le n < M - 2 \\ 0 \quad \frac{k_p}{2} \le N - M \\ G_p \; -M \le n - N < -1 \end{cases} \tag{15}$$

where

$$M = \frac{k_p}{2} + 1$$

4 Simulation Result

The data have been used in our simulation image to give us more clarity about comparison between performance of the proposed algorithm (MRCA) and RCA algorithm. Before displaying the results of simulation, we first describe the simulated OFDM system parameters of the simulated in Table 1.

Table 1. Simulation Parameters

Parameters	Specification
Subcarrier	512
IFFT, FFT level	512
Modulation	4-QAM
Channel model	Rayleigh channel with Doppler frequency = 100Hz, time sampling = 1 ms
Pilot Ratio	1/90
Guard Type	Cyclic Extension

Simulations are conducted for different SNR and the images in the Figs. 5, 6, 7, 8, 9, 10 below shows the difference between performances of the two algorithms in details. Figure 11 gives the bit error rate BER performance of the MRCA and RCA algorithm versus SNR for 4-QAM.

Fig. 5. Original Image

Fig. 6. Estimated images depend on RCA, SNR = 15 dB

Fig. 7. Estimated images depend on MRCA, SNR = 15 dB

Fig. 8. Original image

Fig. 9. Estimated images depend on RCA, SNR = 25 dB

Fig. 10. Estimated images depend on MRCA, SNR = 25 dB

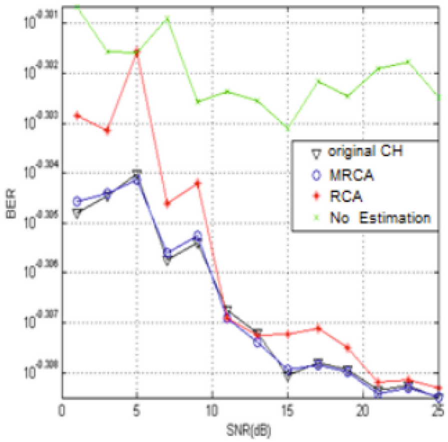

Fig. 11. BER versus SNR in dB

From the above images that appears in the Figs. 5, 6, 7, 8, 9, 10 and Fig. 11, the modified algorithm has a superior performance with different values of SNR especially with minimum number of pilot tones approached to (1/90).

5 Conclusion

In this paper, a low complexity and simple approach non-blind channel estimation for the OFDM system by using MRCA in the case of comb-pilot insertion has proposed and the advantages of MRCA algorithm are pilot tones ratio reduction and increase data rate, these advantages avoid system from bandwidth expansion at the same time, it gives a good result with low SNR, Rayleigh fading channel and high FFT size comparing with least square algorithm.

6 Future Work

With the increase in the applications used that support modern technology, especially today, we see that drones are used in many fields, including the media, in military surveillance, and other upcoming applications in the not-too-long term, which will be drones for very long distances [9–11], and thus the communication channel between the ground controller and the drones is suffer from distortion, noise and interference, so there must be an efficient adaptive algorithms to handle these effect and estimate the channel.

References

1. Mahdi, A.S.: A comparison between recursive least-squares (RLS) and extended least-squares E-RLS) for tracking multiple fast time variation rayleigh fading channel. Al-Khwarizmi Eng. J. **12**(1), pp. 73-78 (2016)

2. Mahdi, A.S., Abdulameer, L.F., Morad, A.H.: Comparison between epsilon normalized least means square (NLMS) and recursive least squares (RLS) adaptive algorithms. international conference on computing sciences and engineering (ICCSE). IEEE, Kuwait (2018)
3. Coleri, S., Ergen, M., Puri, A., Bahai, A.: Channel estimation techniques based on pilot arrangement in OFDM systems. IEEE Trans. Broadcasting **48**(3) (2002)
4. Ozbek, B., Le Ruyet, D., Panazio, C.: Pilot-symbol –aided iterative channel estimation for OFDM based systems. Electronics and Communications Laboratory, Conservatoire National des Arts et M'etiers (CNAM) 292 rue Saint Martin, 75141 Paris, France
5. Mahmoud, H.M., Mousa, A.S., Saleem, R.: Channel estimation based in comb-type pilots arrangement for OFDM system over time varying channel. J. Networks **5**(7), (2010)
6. Hala, M., Allam, M., Kalman, R.S.: Filter channel estimation based on comb- type pilotsfor OFDM system in time and frequency –selective fading environments. Mosharaka International Conference on Communications, Computers and Applications, IEEE, MIC-CCA- (2008)
7. Zhao, Y., Huang, A.: A novel channel estimation method for OFDM mobile communications systems based on pilot signals and transform domain processing. In: Proceedings IEEE 47th Vehicular Technology Conference, Phoenix, USA, pp. 2089–2093 (1997)
8. Oppenheim, A.V., Schafer, R.W.: Discrete-Time Signal Processing. Prentice-HallInc, New Jersey (1999)
9. Al-Darraji, et al.: A technical framework for selection of autonomous UAV navigation technologies and sensors. 2021 CMC-COMPUTERS MATERIALS & CONTINUA TECH SCIENCE PRESS
10. Al-Darraji, I., Derbali, M., Tsaramirsis, G.: Tilting-rotors quadcopters: a new dynamics modelling and simulation based on the newton-euler method with lead compensator control. In: 2021 8th International Conference on Computing for Sustainable Global Development (INDIACom), IEEE
11. Al-Darraji, I., et al.: Adaptive robust controller design-based RBF Neural network for aerial robot arm model. 2021 Electronics, Multidisciplinary Digital Publishing Institute