A dual-Mode Algorithm for CMA Blind Equalizer Of Asymmetric QAM Signal

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Abstract

Adaptive channel equalization accomplished without a training sequence is known as blind equalization. A dual-mode **DM** blind equalization technique for adaptive channel equalization of asymmetric constellation **AC** of QAM is introduced. **DM** algorithm has been proposed as a solution to the problem of slow convergence of blind equalization algorithm, such as Constant Modulus Algorithm. The adaptation of the equalizer weight coefficients changes from the standard algorithm to the dual mode algorithm depending on the error level. In this paper the proposed technique is applied to a **QAM** received signal corrupted by an additive Gaussian noise. Computer simulations have been performed to verify the performance of the proposed method dominates the conventional equalizers.

Keywords:
" Constant Modulus Algorithm "; '' Blind equalization " ; " Asymmetric QAM Constellation" .

I. Introduction

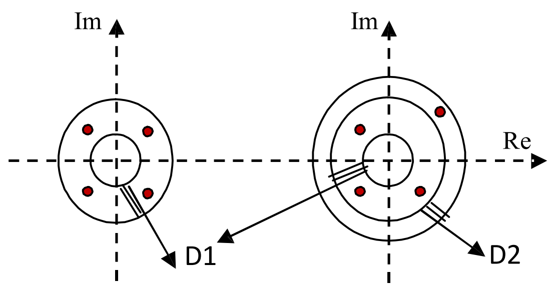
In [1], a digital communications system, data are mapped to symbols from a finite constellation or alphabet and hence to an analog waveform. Having passed through a channel, the waveform is processed by a receiver to produce estimates of the transmitted data sequence. Symbol decisions lead to the recovery of the transmitted data and are used to adjust receiver parameters. A training sequence of known symbols can be used to set an absolute reference phase.

Training sequences are particularly useful in channels with inter-symbol interference, so that the receiver can very quickly determine a set of good initial parameter values for equalizing the outputs [2]. In a blind system the transmitter does not send training sequences to the receiver. The receiver must rely on statistics of processed channel outputs to recover the phase of the received signal.

All of the commonly-used symbol constellations - PAM, PSK, QAM and others are symmetric when the symbols are equiprobable. Blind statistics of these constellations cannot produce an absolute phase estimate. To overcome this problem, asymmetric constellations (**AC**) as an alternative to symmetric constellations (**SC**), is employed [3][8][9][10].The organization of this paper is as follows: the description of (**AC**) technique is presented in Section II. The **DM** system is described in Section III. In Section IV, computer simulation results are presented. Concluding remarks are summarized in Section V.

II. Asymmetric Constellations Algorithm

Three techniques are applied in the literature to introduce asymmetry to symmetric constellation with equiprobable symbols. These techniques are based on changing symbol probabilities by varying data rates ,or changing the DC value of the constellation ,and or changing the relative symbol location(symbol separation) [3] .



(a) **(b)**

Fig.1: Decision Regions for 4-QAM
a) Symmetric constellation SC
b) Asymmetric constellation AC

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In this article, asymmetric constellation is obtained using symbol separation technique by adding a DC value to a symmetric constellation, then a DC value is subtracted from each symbol, and the symbols are scaled by a common constant to meet the average power constraint, though the constellation mean is zero, and the angular distribution is the same as that of a symmetric 4-QAM, there is no symbol power for which symbols in the constellation are symmetric. Because one symbol has an increased power, the remaining symbols must have decreased power, and so are closer together as shown in fig.1.
Fig.2(a,b) represent symmetric and asymmetry 16-QAM constellations with fixed bits/symbol and constant average power.

The asymmetry of the constellation **AC** was obtained by shifting the symbol according to the relations:

$$S \geq N_S \geq S/4 \qquad (1)$$

$$\delta\,(1+j)\,,\ 1/S > \delta > 0 \qquad (2)$$

Where
N_S is the number of shifting symbols, and
S is the number of symbols for QAM
δ is the DC value

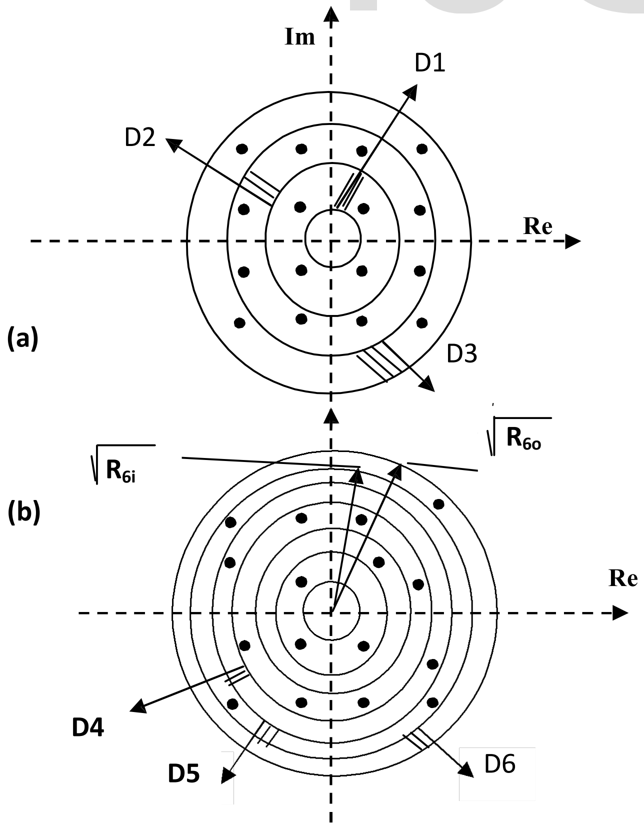


Fig.2: Decision Regions for 16-QAM
(a) Symmetric Constellation
(b) Asymmetric Constellation

III. DM-AC algorithm

To illustrate the dual-mode technique [4] , the channel *h(n)* is modeled as a complex finite impulse response filter with an order L1+L2+1 , and the transmitted sequence ***a(n)*** is assumed to be independent and identically distributed (IID) quadrature amplitude modulated (QAM) source.

Fig.3 depicts a simplified model for the equalizer.

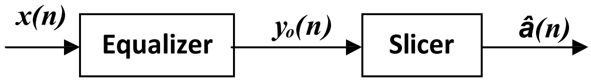


Fig.3. Simplified equalizer

The received sequence is given by:

$$x(n) = \sum_{k=L1}^{L2} h(n)\, a(n-k) + \eta(n) \qquad (1)$$

Where $\eta(n)$ is a zero mean white Gaussian noise independent of $a(n)$.
Let $y_O(n)$ be the output of the linear equalizer **CMA**, [5] , which is given by :

$$y_O(n) = \sum_{k=M1}^{M2} w(n)\, x(n-k) \qquad (2)$$

Where $w(n)$ and $(M1+M2+1)$ represent the **CMA** equalizer coefficients and order respectively . The adaptation algorithm for the **CMA** is as follow:

$$w(n+1) = w(n) + \mu_f\,(|y_o(n)|^2 - R)\, y_o(n)\, X^*(n) \qquad (3)$$

Where $w(n) = [w_{M1}(n), \ldots\ldots\ldots, w_{M2}(n)]^T$,
R is the modulus given by:

$$R = E\{|a(n)|^4\} / E\{|a(n)|^2\} \qquad (4)$$

μ_f is the step size given by :

$$\mu_f = .001 / E[|a(n)|^4] \qquad (5)$$

Where $X^*(n)$ is the corresponding input vector, * refers to complex conjugate.

In the dual-mode (DM) algorithm, the equalizer switches between the normal mode of CMA and a mode similar to the decision directed equalization [5]. The error signal $e_{CMA}(n)$ in the CMA mode is given by:-

$$e_{CMA}(n) = [\ |yo\ (n)\ |2 - R\ ]\ yo(n) \qquad (6)$$

while the error signal $e_{DDA}(n)$ in the DDA mode is given by:

$$e_{DDA}(n) = yo(n) - \hat{a}(n) \qquad (7)$$

The error signal $e_{DM}(n)$ of the dual mode is given by:

$$e_{DM}(n) = \begin{cases} e_{CMA}(n) & \text{if } yo\ (n) \in D_K \\ e_{DDA}(n) & \text{if } yo\ (n) \notin D_K \end{cases}$$

Here $U\ D_K$ denotes the union of the sets D_k

In the proposed technique the constellation diagram is divided into K decision regions according to modulation techniques and also types of QAM as shown in table (1), each decision region encloses a data point of the **QAM** constellation. A decision region D_k is defined by an annular region between the square of the inner and outer radii R_{ki} and R_{k_o} respectively. Furthermore, R_k represents the square of the radial distance to the constellation point inside D_k. as shown as in fig.1, fig.2a, and fig. 2b.

Finally, $d_{ki} = (R_k - R_{ki})$ and $d_{k0} = (R_{ko} - R_k)$

items	Modulation Technique	
	4 QAM (N=2)	16 QAM (N=4)
No. of symbols $S=2^N$	4	16
Minimum no. of shifting symbols N_S	$4 \geq N_S \geq 1$	$16 \geq N_S \geq 4$
No. of Decision region D_K for SC (K=N-1)	1	3
No. of Decision region DK for AC ($K=N_S+1$)	2 For Ns=1	6 For Ns=5

Table (1) Optimum values for decision region DK
SC: Symmetric Constellation
AC: Asymmetric Constellation

The output of the equalizer will be inside one of these regions D_K, then the proposed algorithm update the coefficients of equalizer by using equation (8).

Otherwise the algorithm continues to update the coefficients by using equation (9).

The adaptation algorithm in the **DM** is given by:

$$w(n+1) = w(n) + \mu f\ e_{CMA}(n)\ X^*(n) \qquad yo\ (n) \in D_K \qquad (8)$$

$$w(n+1) = w(n) + \mu f\ e_{DDA}(n)\ X^*(n) \qquad yo\ (n) \notin U\ D_K \qquad (9)$$

IV. Computer Simulation Results

Matlab is used for the simulation to verify the performance of symmetric, asymmetric constellation (SC & AC) and dual mode algorithms DM for CMA equalizer.. The proposed system is applied to of 4 , 16 Rectangular QAM modulation technique with additive white Gaussian noise. The performance of the **DM** system is obtained via simulation for the following two channels which are given below and were considered in [5], [6] and [7].

Channel one:
(0.2393-j 0.0077),(1+j 0.0)
(-0.9491+j0.1524),(0.1632+j 0.2056)

Channel two:
(0.2393- J 0.0077), (1+ J 0.0);
(-0.9491+ J 0.1524) , (0.1632+ J 0.2056) (-0.0077+ J 0.2393) , (1+ J 0.0)
(0.1632 + J 0.2056) ,
(- 0.9491 + J 0.1524)

The parameters used in the simulation are: $M_1=M_2=N=15$. Depicted results shown in figures, give the MSE versus iterations.

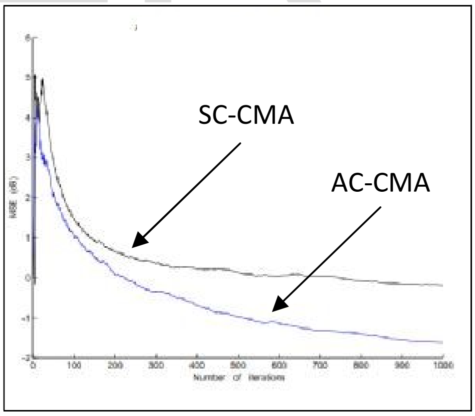


Fig.4. Comparison between asymmetric and symmetric Constellation for 16 QAM, channel one, and SNR = 10 dB,

In figure **4**, the SNR= 10 dB, $\delta = 0.061$ and channel one are taken as parameters.

It is clear that the performance of asymmetric 16 QAM constellations **AC** blind equalizer is better than symmetric constellation applying for CMA blind equalizer.

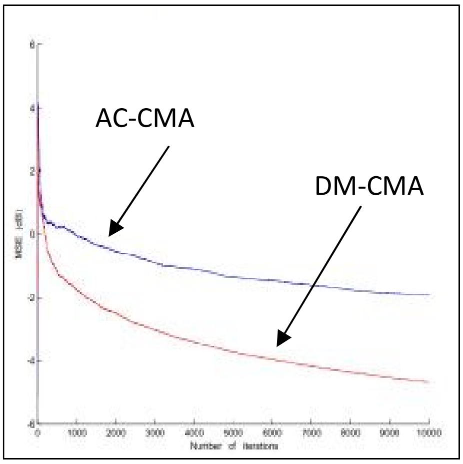
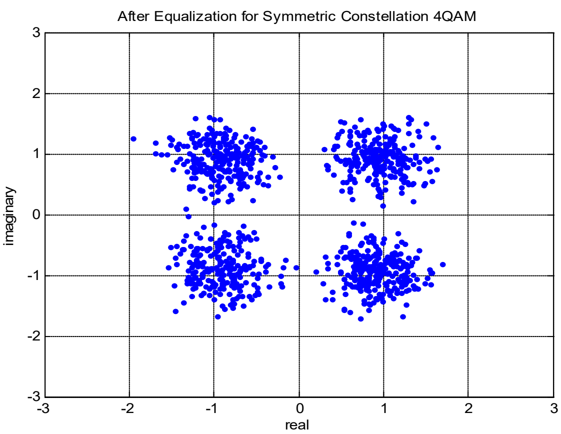


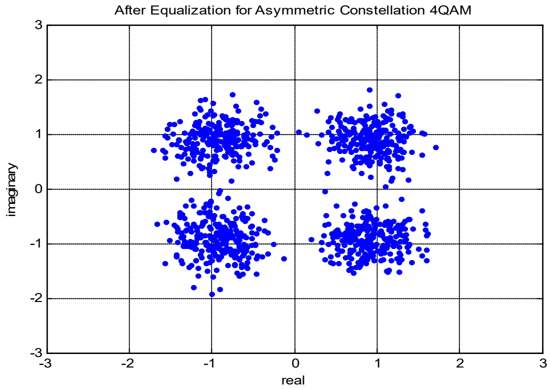
Fig.5. Comparison between dual mode asymmetric DM and asymmetric Constellation for 16 QAM, channel two, and SNR = 10 dB,

Figures **5** give performance comparison between **AC** and **DM** systems. The depicted results show that the **DM** dominates always the AC and SC.

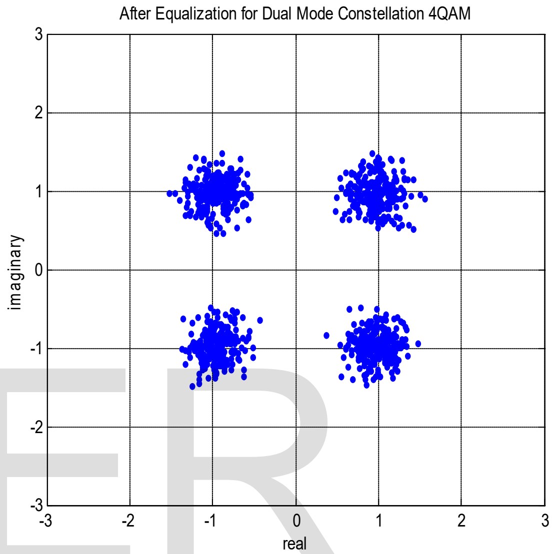
Figures 6,7 shows the output signal constellation diagrams after the convergence of the three kinds of algorithms SC,AC,DM
It can be seen from the fig.6,7 that the constellation diagram of the SC of 4 and QAM is the least concentrated , the constellation points of the AC_4QAM is more concentrated than the SC_4QAM . The constellation diagram of DM is the most compact which is due to a smaller residual error after the convergence of the algorithm. So the convergence precision of the DM is the highest



(a) SC_CMA_4QAM

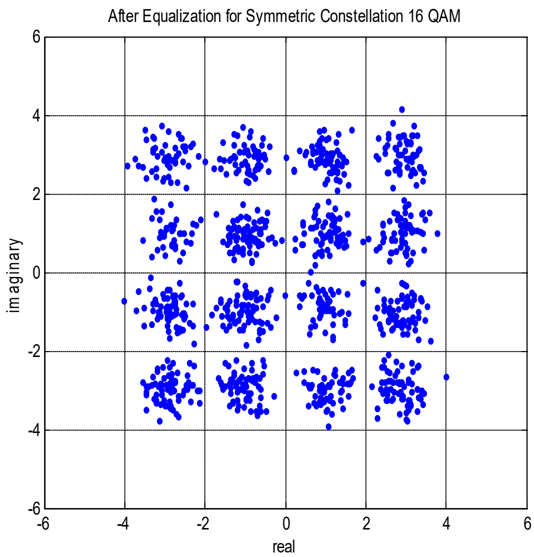


(b) AC_CMA_4QAM

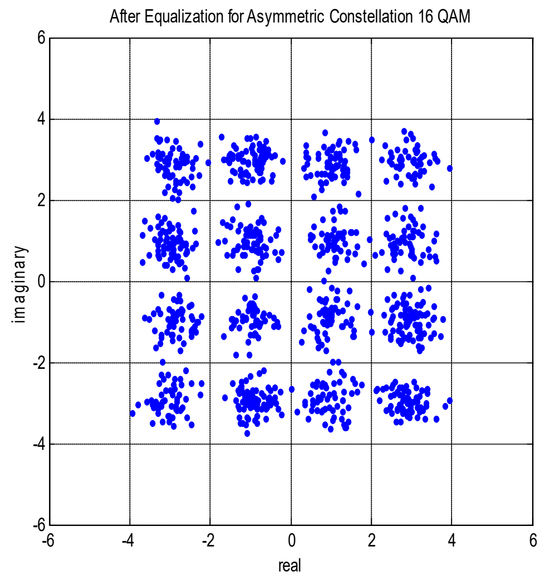


(c) DM_CMA_4QAM

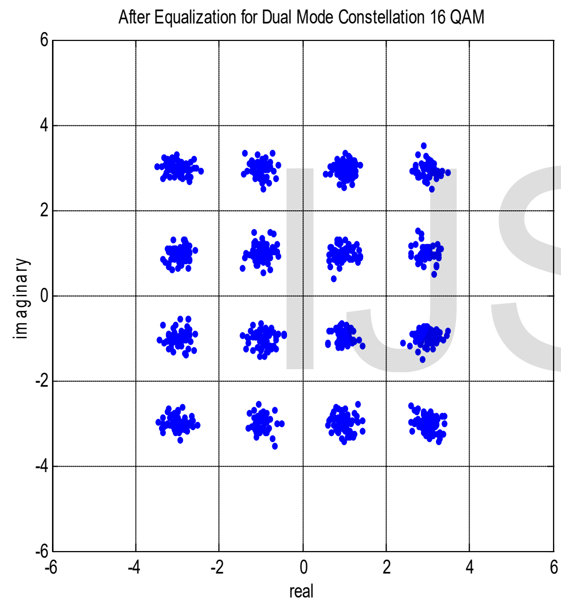
Fig.6 The output constellation of three algorithms of 4 QAM



(a) SC_CMA_16QAM



(b) AC_CMA_16QAM



(c) DM_CMA_16QAM

Fig.7 The output constellation of three algorithms of 16 QAM

V. CONCLUSION

This paper, propose a new blind equalizer which provides an effective and robust way for adaptive blind equalization. The proposed algorithm **DM**algorithm has a better equalization performance compared with traditional blind equalizer. Then **DM** algorithm with the idea of using both switching dual-mode and normal algorithm
the new dual- mode algorithm has a smaller residual error and a quicker convergence rate. We can conclude that **DM** algorithm is a practical blind equalization algorithm with an excellent overall performance. So the proposed algorithm **DM** system is strongly recommended in digital communication

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