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A Dual-Mode Algorithm for CMA Blind Equalizer of Asymmetric QAM Signal

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Abstract: Blind equalization used to over comes inter symbol interference. 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 dual mode equalizer by changing from the standard algorithm to the dual mode algorithm depending on the error level. In this paper the proposed technique is applied to a 16 QAM. M 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], digital communications system, Quadrature amplitude modulation (QAM) is a digital modulation scheme; data are mapped to symbols from a finite constellation as rectangular constellation technique. Symbol decisions lead to the recovery of the transmitted data and are used to adjust receiver parameters. 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 [1], but the receiver depend on statistics of processed channel outputs to recover the received signal. Rectangular constellation of QAM is symmetric (SC) when the symbols are equiprobable, blind equalization in this case cannot produce an absolute phase estimate. So we use rectangular asymmetric constellation (AC) of QAM to overcome this problem, [3-10]. The organization of this paper is as follows: The asymmetric constellation technique (AC) is discussed in Section II. The proposed algorithm (DM) is discussed in Section III. Computer simulation results are presented in Section IV Concluding remarks are summarized in Section V.

II. ASYMMETRIC CONSTELLATIONS ALGORITHM

Rectangular asymmetric constellation of QAM when the symbols are not equiprobable as in symmetric, to get this type of constellation, several techniques are applied to introduce asymmetry to symmetric constellation with equiprobable symbols, this done by three methods:-

- **a)** Changing symbol probabilities by varying data rates.
- **b)** Changing the DC value of the constellation.
- **c)** Changing the relative symbol location (symbol separation) [3].

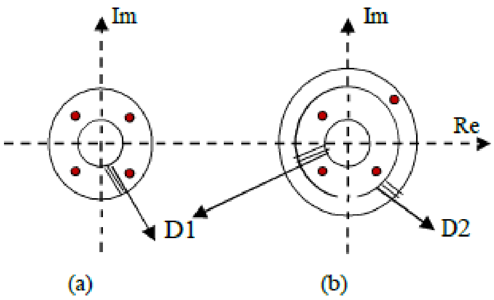

Figure 1: Decision regions for 4-QAM.

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a) Symmetric constellation SC.
b) Asymmetric constellation AC.

In this paper, asymmetric constellation is obtained by using the third method by adding a DC value to a symmetric constellation, and the symbols are scaled by a common constant to meet the average power constraint, because some symbols have increased power, the remaining symbols must have decreased power, also the angular distribution is the same as that of a symmetric QAM. (Figures 1 and 2) represent rectangular symmetric and asymmetry constellation of 4- QAM and 16-QAM respectively [4-6].

a) $S \geqslant NS \geqslant S/4$
b) $\delta\,(1+j)\,,\ 1/S > \delta > 0$

The asymmetry of the constellation AC was obtained by shifting the symbol according to relations A and B
Where,
NS is the number of shifting symbols, and
S is the number of symbols for QAM
δ is the DC value

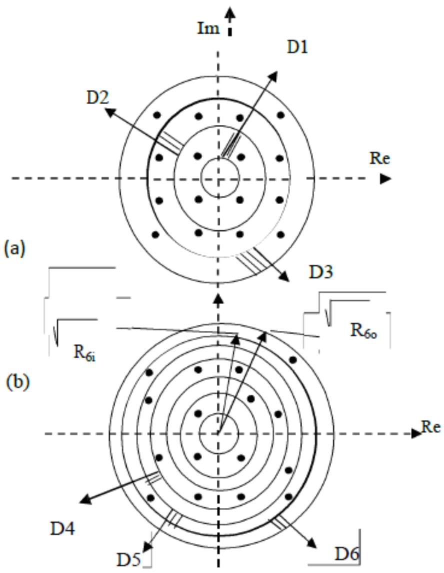

Figure 2: Decision regions for 16-QAM.

a) Symmetric Constellation.
b) Asymmetric Constellation

III. DM-AC ALGORITHM

To illustrate the dual-mode algorithm DM-AC , first we introduce a simplified model for the equalizer as in Figure 3, where a(n) is the transmitted sequence and assumed to be rectangular Quadrature amplitude modulated(QAM) signal, and the channel *h(n)* is modelled as a complex finite impulse response filter with an order L1+L2+1.

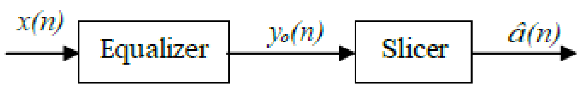

Figure 3: Simplified equalizer.

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The received sequence is given by:

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

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

$$yo(n) = \sum_{k=M1}^{M2} W(n)\, x(n-k) \quad (2)$$

Where, w(n) represents the CMA equalizer coefficients, and M1+ M2+ 1 represents the order of equalizer
The dual mode CMA equalizer adaptive his coefficients as follow:

$$w(n+1) = w(n) + \mu f\, (|\, yo\,(n)\, |2 - R\,)\, yo\,(n)\, X * (n) \quad (3)$$

Where, w(n) = [wM1(n),........., wM2(n)] T
R is the modulus given by:

$$R = E\{|\, a(n)\, |4\,\} \,/\, E\{|\, a(n)\, |2\,\} \quad (4)$$

μf is the step size given by :

$$\mu f = 0.001/\, E[|\, a(n)\, |4\,] \quad (5)$$

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

Now we will introduce dual-mode (DM) algorithm, in this algorithm the equalizer switches between the normal mode of CMA and a mode similar the decision directed equalization [5].

The error signal of the dual mode is given by:

$$e_{DM}(n) = \begin{cases} e_{CMA}(n) \text{ if } y_0(n) \in D_k \\ e_{DDA}(n) \text{ if } y_0(n) \in \underline{U}D_k \end{cases} \quad (6)$$

$$e_{DM}(n) = \begin{cases} e_{CMA}(n) \text{ if } y0(n) \in D_k \\ e_{DDA}(n) \text{ if } y0(n) \in \underline{U}D_k \end{cases}$$

Where,

$$eCMA(n) = [\,|\, yo\,(n)\, |2 - R\,]\, yo(n) \quad (7)$$

$$eDDA\,(n) = yo(n) - \hat{a}(n) \quad (8)$$

Here U_{DK} denotes the union of the sets D_k
In the proposed technique the constellation diagram is divided into K decision regions as shown in Table 1, each decision region D_K 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 Rki and Rko respectively. Furthermore, R_k represents the square of the radial distance to the constellation point inside D_k as shown as in Figures 1 and 2.
Finally, $d_{ki} = (R_k - R_{ki})$ and $d_{k0} = (R_{ko} - R_k)$

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

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 DK, 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:

$w(n+1)=w(n)+ \mu f\, e_{CMA}(n)\, X^*(n)\, y_0(n) \in UD_k$ (9)

$w(n+1)=w(n)+ \mu f\, eDDA(n)\, X^*(n)\, y_0(n) \notin UDk$ (10)

IV. COMPUTER SIMULATION RESULTS

Matlab is used for the simulation to verify the performance of symmetric, asymmetric constellation (SC and 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 parameters:
M1=M2=N=15.
Two channels which are given below and were considered in [5-7].

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)

Depicted results shown in Figure 4, give the MSE versus iterations.

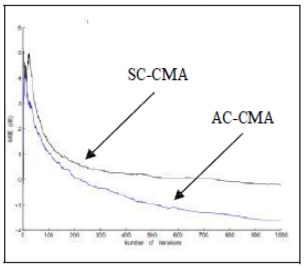

Figure 4: MSE for asymmetric and symmetric constellation for 16 QAM, channel one, δ=0.061, and SNR=10 dB.

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In Figure 4, we notice that asymmetric Constellation AC is better than symmetric Constellation for CMA equalizer. Figure 5 shows the MSE of dual mode DM and asymmetric constellation AC for CMA equalizer of 16 QAM.

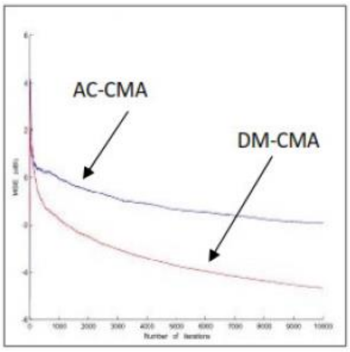
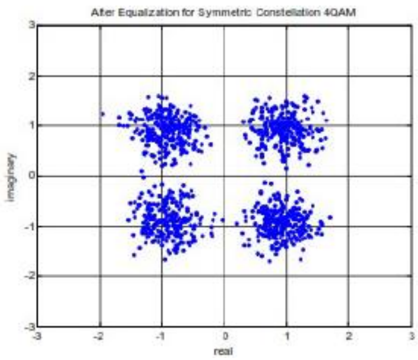
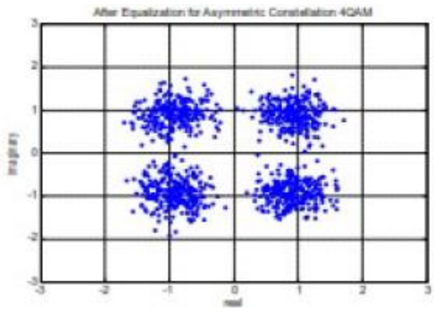


Figure 5: MSE for dual mode and asymmetric constellation for 16 QAM, channel two, and SNR=10 dB.

The depicted results in Figures 4 and 5 shows that the DM dominates always the AC and SC and give better performance of CMA equalizer Figures 6 and 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 (Figures 6 and 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.

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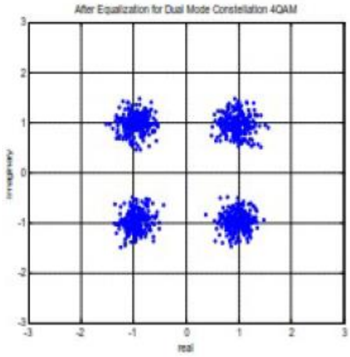
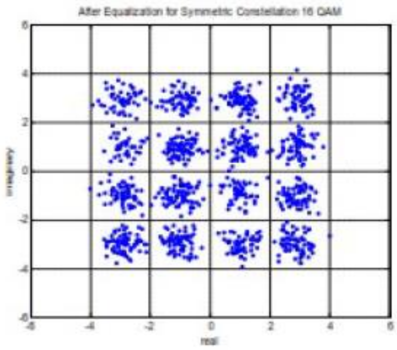
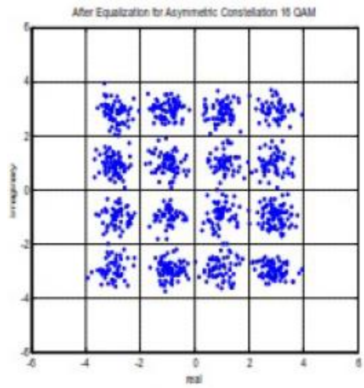


(c) DM_CMA_4QAM.

Figure 6: The output constellation of three algorithms of 4 QAM.



(a) SC_CMA_16QAM.



(b) AC_CMA_16QAM.

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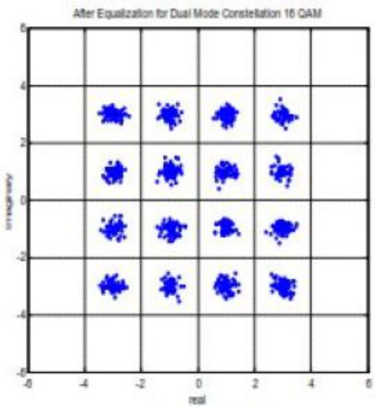

(c) DM_CMA_16QAM.

Figure 7: The output constellation of three algorithms of 16 QAM.

V. CONCLUSION

This paper, propose a new blind equalizer which provides improvement 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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