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Non Data Aided Phase Estimation Techniques for QAM Communication System: A Review

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Abstract— ***Phase recovery is a problem of paramount importance in synchronous digital communication system, especially for high bit rate signaling such as QAM modulation. The phase estimation must be performed in a blind manner, means without using known training sequences of known transmitted symbols i.e. known as non-data-aided (NDA) method. This is done to obtain high efficienc.y. Accuracy in estimation of phase is very important because if it is little off, cross talk occurs. Recent advances in phase estimation have paved the way for simple calculation and improved results. Many authors have addressed this topic over the last year, yielding a wide variety of recovery methods. In this paper, complete review for NDA phase estimation techniques explained with its achievements and limitations.***

Keywords — Higher order statistics, quadrature amplitude modulation, blind phase estimation, constellation.

I- INTRODUCTION

Quadrature amplitude modulation is currently more common modulation technique in digital communication. It is also used in analog communication. It is a combination of modulation of amplitude and phase. This modulation scheme also known as Quadrature Carrier Multiplexing. This modulation scheme allows two modulated signal to occupy the same transmission bandwidth and therefore it allows for the separation of the two message signal at the receiver output. It is therefore also known as Bandwidth Conservation Scheme [1]. QAM modulation technique increase the efficiency of transmission by utilizing both amplitude and phase variations. Reducing or eliminating intermodulation interference caused by a continuous carrier near the modulation sidebands. For a given available bandwidth, QAM enables data transmission at twice the rate of standard pulse amplitude modulation (PAM) without any degradation in the bit error ratio (BER). QAM use unique combination of phase and amplitude each combination assigned a unique digital bit pattern. Combination of bits is known as symbol. Bits per symbol is given by the formula

Bit per symbol $= log_2(M)$, Where M is number of symbols in symbol map

QAM finds application in color television, WiMax, OFDM, and in digital satellite communication system. There are two main types of QAM constellation square and cross type constellation. 4-QAM, 16-QAM, 64-QAM are square type, where 8-QAM, 32-QAM, 128-QAM are cross type

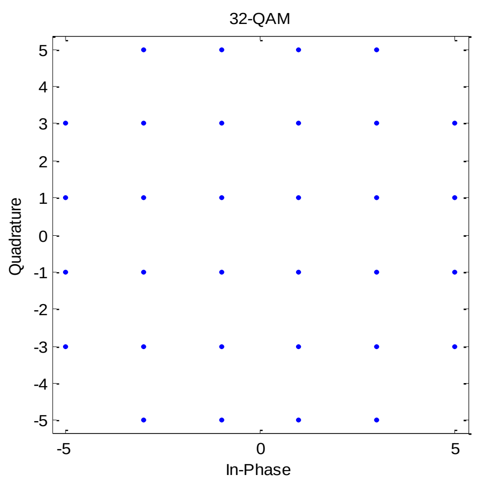

Fig.1: 32 QAM constellation diagram

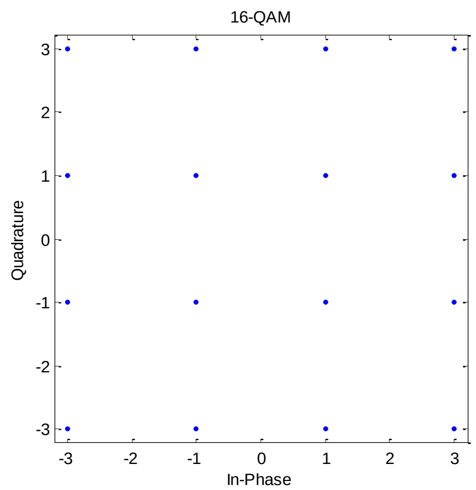

Fig.2: 16 QAM constellation diagram

QAM is one of the most popular M-ary schemes. BER varies as we change the M value. The relation between them is shown in figure 7. This shows that BER increase as the value of M increases.

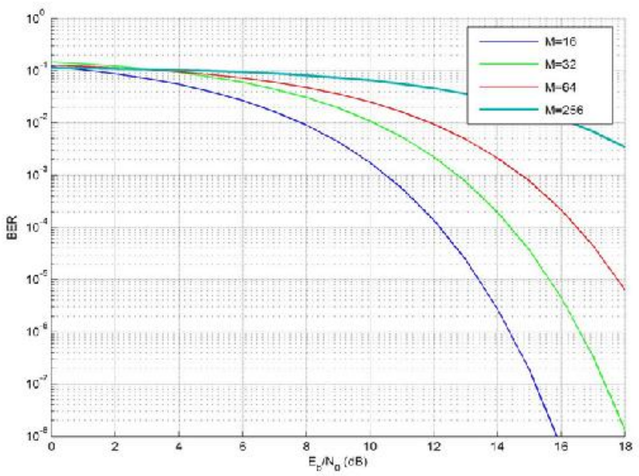

Figure 3: BER graph for different values of M.

Phase estimation is nothing but to find angle of received data by the receiver. Phase recovery is a problem of paramount importance in synchronous digital communication system, especially for high bit rate signaling such as QAM modulation. QAM is particularly attractive for high-throughput-efficiency application and better performance compared to PSK as size of constellation increases. The phase estimation must be performed in a blind manner, that is, without using known training sequences of known transmitted symbols. This is done so as to obtain high efficiency. Accuracy in estimation of phase is very important because if it is little off cross talk occurs. There are number of techniques for the determination of phase. System for phase estimation can be grouped into two areas, First which require established gain control and second which do not require gain control. The fourth-power phase estimator [6], the eighth-order estimator (EOE) [7], and the concentration ellipse orientation (CEO) estimator [9] do not require any gain control. The former category involves the reduced-constellation fourth power estimator [3], and two methods of Georghiades. The rest of the paper is organized as follows. First part consists of introduction of QAM and need of phase estimation in QAM communication system. Second section consists of complete literature review. Third section consists of problem formulation and possible future work. At the end references are given.

II- LITERATURE REVIEW

Chen [2] has introduced a method of blind phase recovery for square QAM communication system using higher order statistics. Their method assumed in-phase and quadrature-phase components are independent of each other. Their method not work for cross QAM such as 32-QAM, or for any non square QAM system. The method introduce by Chen require the knowledge of the order of transmitted QAM system for estimating phase. An estimation of phase based on fourth power method works extremely poor for cross QAM constellations. Indeed Georghiades [3] has introduced the reduced constellation method, which provided improved performance, but it also requires established gain control. Georghiades also demonstrated that the variance of the fourth power estimator is extremely large for cross constellations, and it does not improve as SNR increases due to self-noise of the constellation. He presents two methods and both of these methods perform substantially better than the fourth power method for medium to large SNR, but unfortunately are inferior to it at low SNR. SNR high deviation in phase is less as compare to the low value of signal to noise ratio. Modification of [2] performed by Cartwright [4] for non square (i.e. cross) QAM system relaxing the requirement that in-phase and quadrature-phase component be independent. Cartwright use alternative fourth order statistic that does not need any gain control. Advantage of his method is that it is not necessary to know the order of transmitted QAM system unlike the method of Chen.

From [4], the received signal is given by

$$Y = Xe^{j\theta} + N \quad (1)$$

Where, Y is received signal it can be rewritten in terms of received in-phase Y_r and quadrature-phase componentsY_i.

$$Y_r = X_r cos\theta - X_i \sin(\theta) + N_r \quad (2)$$

$$Y_i = X_r sin\theta + X_i \cos(\theta) + N_i \quad (3)$$

X is complex transmitted symbol (X = $X_r + jX_i$), θ is Phase angle, N is complex Gaussian noise (N=$N_r + jN_i$). Aim is to find 'θ' phase in blind manner. In this method, independence of the in-phase and quadrature-phase components is no longer assumed. Following assumption is made for X:

$$E[X_r^3 X_I] = E[X_i^3 X_R] \quad (4)$$

Both M-PSK and non-square M-QAM constellation satisfy the above assumption. And in this method estimate of phase is found by equation

\ $$\theta = \frac{1}{4} tan^{-1}\left(\frac{-4\,(\gamma_a - \gamma_b)}{-\gamma}\right) \tag{5}$$

The fourth-power method of phase estimator for M-QAM is known as the maximum-likelihood (ML) phase estimator, as SNR goes to zero [5]. It also uses four quadrant inverse tangent functions.

Fourth power phase estimator does not perform well for cross QAM. Cartwright [6] proposed alternative constellation that is used with the fourth power method instead of cross QAM. Performance is improved with this new constellation, reasonably low increase in required constellation energy. He designed dimensional rectangular constellation for the transmission of an odd number of bits that produce variances on the same order of magnitude as that produced by square QAM constellation. Constellations can be designed that trade-off amount of energy increase with respect to variance generated by the fourth power phase estimator. Alternative two-dimensional odd-bit constellation called M-COB constellations example 32-COB, 128-COB, 512-COB, 2048-COB constellation. For M>32 there are three different versions present- 128A-COB, 128B-COB, 128C-COB constellation.

Another phase estimation scheme that does not require established gain control, it uses eight order statistics [7]. It gives improved performance for cross QAM system as compare to the results of fourth power phase estimation but Complexity increases. In this technique numbers of samples are reduced by a factor of at least four. Example- fourth power requires 4000 sample, eighth-order requires only 700, 800, 1000 for 32-QAM, 128-QAM, and 512-QAM. Non-Gaussian is random variables with symmetrical distributions that satisfy $E(X_r^7 X_i) = E(X_i^7 X_r)$ and $E(X_r^3 X_i^5) = E(X_r^5 X_i^3)$ where E is expectation operator. Both square and cross QAM transmitted signals are allowed as they satisfy these requirements. Constellations, whose in-phase and quadrature-phase are correlated, also satisfy these requirements. Phase estimator is asymptotically unbiased. By this technique simulation result give same root mean square error (RMSE) for 32-QAM and 128-QAM constellation with 700 and 800 samples.

The true Cramer-Rao lower bounds (CRLBs) for estimation of phase offset for common quadrature amplitude modulation (QAM) ,PSK, and PAM signals in AWGN channels [8].

Another phase estimation approach is developed that can be employed for both square and cross QAM constellation. It is based on the estimation of the orientation of concentration ellipses of bivariate Gaussian distribution having the same second order moment of the two random variables considering the real and imaginary part of fourth power of received data. This is very novel method because it only requires knowledge of transmitted symbol constellation type (square and cross) and does not need gain control [9]. The detection of the constellation type can be achieved through a statistic test based on the measurement of eccentricity of the concentration ellipses. Square constellations always result in lower value of the eccentricity of concentration ellipses with respect to cross constellations. The phase estimation can be performed by calculating the orientation of the principal axis of the concentration ellipses. For cross QAM constellation, a π/2 correction must be taken into account. In figure, the fourth power of the noisy samples is displaced for θ/24 in the case of 16-QAM.

The orientation of principal axis of concentration ellipses with respect to the horizontal axis is measured by the angle whose tangent is given by [9]

$$\tan(2\alpha) = \frac{2(m_{R,I}^{(1,1)} - m_R m_I)}{m_R^{(2)} - (m_R)^2 - m_R^{(2)} + (m_I)^2} \tag{6}$$

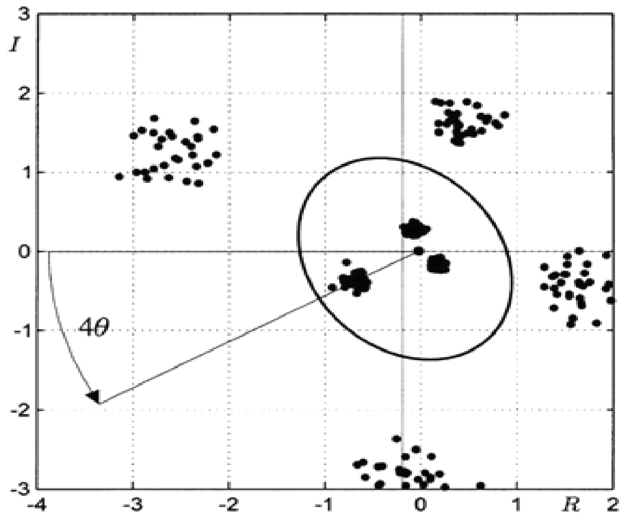

Figure 4: Fourth-power of 32-QAM constellation and corresponding ellipse (noisy case)[9].

A new iterative method for blind phase estimation of QAM signals are presented which use diamond contour. There are maximum three possible contours shapes square, circular and diamond. Diamond contour used for phase estimation. This method for cross-QAM constellation gives similar or even better result than eighth order method at similar computational cost, this method avoid high power operations over the observed data. For square QAM constellation results are close to the fourth power estimate [10].

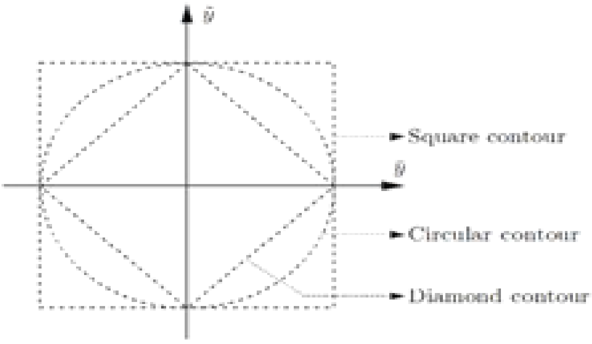

Figure 5: Possible contours[10]

The eight-order phase estimation is modified to work for an eight symbol symmetrical constellation. This larger signal-to-noise (SNR) performance is not limited by self-noise. By using only the eight highest energy points of cross-QAM constellations, a reduced constellation eight-order estimator (RCEOE) is proposed [11]. This approach is applied to any constellation, which can be reduced to an 8-symbol quadrant symmetrical sub-constellation. APP estimator works well for square QAM or low-level cross QAM constellations. APP estimator has the lowest variance for 32-QAM and 128-QAM. APP estimator utilizes only constellation points that lie on the diagonals so that the variance of the estimator is not limited by self-noise al larger SNR ratios. So improvement is required for large cross QAM constellations, this can be obtained from RCEOE. For this, the system is assumed equalized, frequency-synchronized, and timing and relative gain control had already achieved. RCEOE estimator form an estimate of the phase based only on the received points that exceed a threshold. Threshold is set halfway between the two outermost shells of the constellations. RCEOE has lower variance than the APP estimator. After that, Cost function was used for simultaneous blind equalization and phase recovery of QAM signals. A simple blind equalization algorithm based on cost function is designed, which is very similar to CMA 2-2 but has 50% less complexity. There is one limitation on this cost function method, i.e. the source I-phase and Q-phase signal must be statistically independent to each other [12]. Latest approach is to estimate phase by using characteristic function. This proposed method is independent of noise distribution added to rotated signal. Firstly, gain was estimated then this gain is multiplied to receive signal and compensating its effect and now it is possible to estimate phase offset. We use characteristics function and its estimate (Empirical characteristics function-ECF), in order to perform phase estimation. It is assumed that the received signal is already equalized and frequency synchronized and timing recovery is already done [13].
From [13], the received signal given by

$$Y(k) = GX(k)e^{j\theta} + N(k) \quad (7)$$

Where, G is overall gain seen by symbol, Y(k) is samples of equalized signal at sample rate, θ is unknown phase shift that is to be estimated, X(k) is complex transmitted signal , $N(k)$ is complex noise where its real and imaginary part has zero mean and their PDF is symmetrical. Complex transmitted signals are independent and identically distributed (IID) it means that each random variable has the same probability distribution as the others and all are mutually independent.

Estimated gain formula

$$G = \sqrt{\frac{E\{|Y(k)|^2\} - E\{|N(k)|^2\}}{E\{|X(k)|^2\}}} \quad (8)$$

Noise energy is much less than the signal energy, G estimated through the following:

$$G = \sqrt{\frac{E\{|Y(k)|^2\}}{E\{|X(k)|^2\}}} \quad (9)$$

Characteristic function (CF) i.e. the fourier transform of PDF of real part of received signal Y_r is given by [12]:

$$Y_r = a(k)cos\theta - b(k)\sin(\theta) + N_r \quad (10)$$

$$\emptyset_{Y_r}(\omega) = \left(\frac{2}{M}\right)^2 \left[\sum_{m=1}^{\frac{M}{2}} e^{j\omega a\,(m)cos\theta} \sum_{m=1}^{\frac{M}{2}} e^{-j\omega a\,(m)sin\theta}\right] \emptyset_{u_.}(\omega) \quad (11)$$

In order to estimate unknown phase, Empirical characteristic function (ECF) based method is use on above equation.

III-PROBLEM FORMULATION

In this paper, a systematic overview of various techniques presented. First and second moments of the samples (such as the power spectrum and autocorrelation functions) contain no phase information hence for phase estimation of QAM communication system initially higher order statistics (HOS) based technique are used in which gain control was required and knowledge of transmitted data was essential. Modification over following problems was performed by various scientists. For better efficiency, technology shifts from data aided to non-data aided method. Phase estimation become very difficult task as the constellation size increases. Channel noises introduce difficulties and error in estimated phase. So the work can be extended for 128-QAM or for other large size constellations, in the presence of other types of noise.

REFERENCES

[1] Wayne Tomasi, " *Electronics communication systems Fundamentals through Advanced*" Fifth Edition.

[2] L. Chen, H. Kusaka, and M. Kominami, "*Blind phase recovery in QAM communication systems using higher order statistics*" IEEE Signal Process. Lett. vol. 3, no. 5, pp. 147–149, May 1996.

[3] C. N. Georghiades, "*Blind carrier phase acquisition for QAM constellations*" IEEE Trans. Commun., vol. COM-45, pp. 1477–1486, Nov. 1997.

[4] K.V. Cartwright, "*Blind phase recovery in general QAM communication systems using alternative higher order statistics*" IEEE Signal Process. Lett., vol. 6, no. 12, pp. 327–329, Dec. 1999.

[5] M. Moeneclaey and G. de Jonge, "*ML-oriented NDA carrier synchronization for general rotationally symmetric signal constellations*" IEEE Trans. Commun., vol. 42, pp. 2531–2533, Aug. 1994.

[6] K. V. Cartwright, "*Fourth power phase estimation with alternative two dimensional odd- bit constellations*" IEEE Commun. Lett., vol. 4, pp. 199–201, June 2000.

[7] K. V. Cartwright, "*Blind phase recovery in cross QAM communication systems with eighth-order statistics*" IEEE Signal Process. Lett., vol. 8, no. 12, pp. 304–306, Dec. 2001.

[8] Feng Rice, Bill Cowley, Bill Moran, and Mark Rice, "Cramér–*Rao Lower Bounds for QAM Phase and Frequency Estimation*", IEEE Transactions on Communications, vol. 49, no.9, September 2001

[9] G.panci*,P.campisi**,S.Colonnese*,G.Scarano* "*Blind Phase Recovery for QAM Constellations*". IEEE signal processiong, vol.53, no.4 april 2005.

[10] Marcos Alvarez-Diaz and Roberto Lopez-Valcarce, "*Diamond contour-based phase recovery for (cross)-QAM constellation*" IEEE ©2005

[11] K.V.Cartwright,J.Kaminsky,"*Blind Phase Recovery in Cross QAM Communication Systems with the Reduced-Constellation Eighth- Order Estimator (RCEOE)*".IEEE Globecom 2005.

[12] Z.Zhang, K.Takaya, D.E.Dodds, "*A cost function for simultaneous blind equalization and phase recovery of QAM signals*", CCECE / CCGEI, Saskatoon, May 2005

[13] Ehsan Hassani Sadi, Hamidreza Amindavar, "*Blind phase recovery in QAM communication systems using characteristics function*". ICASSP 2011

