

Modified QAM Modem for Data Transmission at 9.6 Kb/s Over ADPCM Link

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Abstract—This paper presents new modified QAM modem that operates at data rate of 9.6kb/s to be transmitted over Adaptive Differential Pulse Code Modulation (ADPCM). The purpose of this modified QAM modem is to reduce the nonlinear distortion introduced by ADPCM. The performance of ADPCM is studied considering the standard QAM modem and modified QAM modem. The simulation results show that the performance of ADPCM with modified QAM is better than its performance with standard QAM modem.

keywords --QAM modem, ADPCM

1. Importance of Study

To efficiently and economically use, not only digital links of large capacity but also those of small capacity in international communication network, it had been planned to introduce 32 kb/s ADPCM coding technology maintaining a quality comparable to that of 64 kb/s PCM. Furthermore, ADPCM can be easily and efficiently incorporated together with Digital Speech Interpolation in Digital Circuit Multiplication Equipment (DCME), which had been scheduled to be installed in optical submarine cable systems and international satellite communication systems. In addition, superior performance, economy, and application flexibility of ADPCM relative to other bandwidth reduction techniques were the prime reasons for its selection.

2. Statement of Problem

A recommended definition of ADPCM algorithm was published by International Telephone & Telegraph Consultative Committee [CCITT, the new name is International Telecommunication Union (ITU)] as Recommendation G.721 [5].

It was recognized at study group XVIII meeting [5] that voiceband data performance at 9.6 kb/s would not be acceptable with standard 32 kb/s ADPCM because ADPCM adds severe nonlinear distortion to the voiceband data signal with speed greater than 4.8 kb/s. Thus, the interest of many research workers has been directed towards the ADPCM codec capable of providing better performance for speech and voiceband data signal at speed greater than 4.8 kb/s.

3. Methodology of Solution

Exhaustive work had been done to accommodate high speed voiceband data signal either by modifying the algorithm of ADPCM [2],[3],[4], [6], [7], [8], [9], [10], [11], [12], [13] or by modifying the model of data transmission[1],[3]. One way to modify the model of data transmission is to use different constellations of Quadrature Amplitude Modulation (QAM) signal. This idea was firstly studied by AL-Rawi in [1],[3] to improve the performance of ADPCM.

4. Objectives

The main objective of this paper is to modify the model of data transmission at data rate of 9.6 kb/s by modifying the standard QAM modem in order to reduce the distortion of ADPCM

5. Structure of Standard Adpcm

The algorithm of 32 kb/s ADPCM which is described here is as in CCITT G.726 [6]. Fig. 1 shows simplified block diagram of ADPCM codec. Two major components form the algorithm: an adaptive quantizer and an adaptive predictor. The relation between the encoder and the decoder is also depicted. The difference between them is that the encoder has adaptive quantizer(Q) and inverse adaptive quantizer(Q⁻¹), while, the decoder has inverse adaptive quantizer only. The decoder is simply a subset of the encoder and transmits r(n) as its output instead of c(n). The adaptive predictor, which is composed of two poles and six zeros, computes an input signal estimate $\hat{s}(n)$ which is subtracted from input signal s(n) resulting in a difference signal d(n). The adaptive quantizer codes d(n) into 4-bit codeword c(n) which is sent over the transmission facility. At the receiving end, an ADPCM decoder uses c(n) to attempt to reconstruct the original signal s(n). Actually, only r(n) can be reconstructed which is related to the original input signal s(n) by

$$r(n) = s(n) + e(n) \quad (1)$$

where

$$e(n) = dq(n) - d(n) = r(n) - s(n) \quad (2)$$

is the error introduced by the quantizer, and dq(n) is the output of inverse adaptive quantizer

A typical measure of the ADPCM performance is given by signal-to-noise ratio (SNR)

$$SNR = \frac{E[S^2(n)]}{E[e^2(n)]} = \frac{\sigma_s^2}{\sigma_e^2} \quad (3)$$

where E denotes expectation, σ_s^2 is the power (or variance) of input signal, & σ_e^2 is the power (or variance) of the error signal.

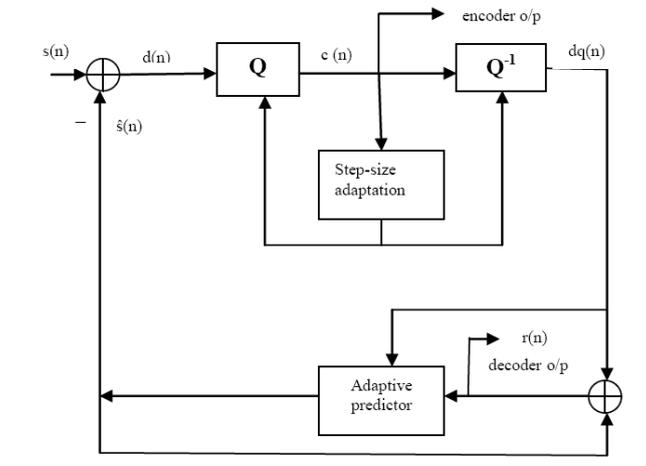


Figure 1. ADPCM Codec

6. Standard and Modified Qam Modems

The standard QAM modem operates at symbol rate of 2400 baud with each symbol is represented by four bits giving data rate of 2400x4=9.6 kb/s. The number of points in M-ary QAM constellation is equal to 2⁴=16 points. The design of QAM constellation plays important role in reducing the effect of channel noise [14], also in reducing the distortion of ADPCM[1]. Some of constellations which are considered here are shown in Fig.2, for 16-point, rectangular, (5,11), (4,12), & (8,8) circular

The modified QAM modem operates at symbol rate of 3200 baud (instead of 2400) with each symbol is represented by three bits (instead of four) giving data rate of 3200x3=9.6kb/s, with 2³=8-point constellation. Fig.3 shows some of 8-point constellations, rectangular, (1,7), & (4,4).

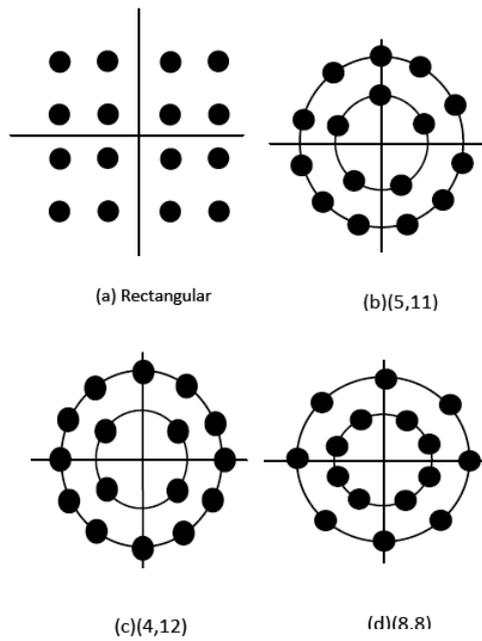


Figure 2. 16-ary QAM constellations

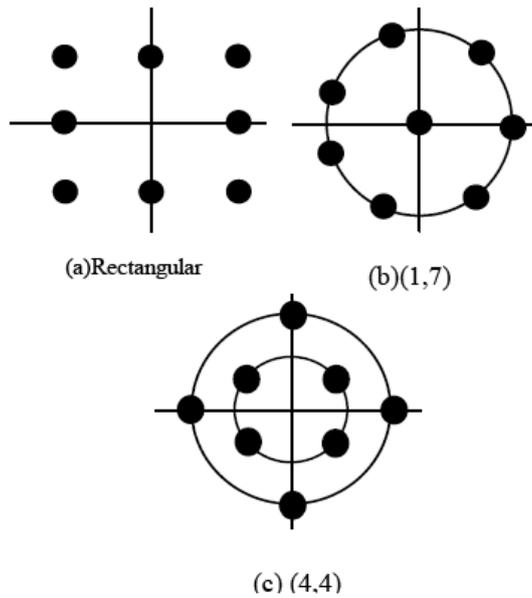


Figure 3. 8-ary QAM constellations

7. Computer Simulation Tests

A series of computer simulation tests have been carried out on ADPCM codec using standard and modified QAM modem signals at 9.6kb/s with constellations shown in Figs.2&3. The performance of ADPCM is measured by calculating SNR in equation 3.

Table 1 shows the results of testing ADPCM. For standard modem, the performance of ADPCM with circular constellation is better than rectangular by approximately 1dB. For modified modem, the performance of ADPCM with (1,7) circular constellation is better than rectangular and (4,4) by approximately 0.5dB.

The comparison between standard an modified modems shows that the performance of ADPCM with modified modem is better than standard modem by approximately 2dB.

8. Summary and Conclusion

Modified QAM modem operates at data rate of 9.6kb/s has been developed in order to reduce the nonlinear distortion of ADPCM. The simulation results show that the performance of ADPCM with modified

QAM modem is better than standard QAM modem. Also, the performance with circular constellation is better than rectangular one.

TABLE I. PERFORMANCE OF ADPCM

SNR (dB)	Standard QAM				Modified QAM		
	Rect	(5,11)	(4,12)	(8,8)	Rect	(1,7)	(4,4)
	22.9	23.9	23.6	23.7	25.2	25.7	25.3

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