Data Transmission at 9.6kb/s Over 16kb/s ADPCM System

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Abstract: This paper studies the performance of 16kb/s ADPCM system using QAM signal at data rate of 9.6kb/s. Two models of QAM signals are used, the first model operates at symbol rate of 2400 baud with each symbol is represented by 4-bit, while, the second model operates at symbol rate of 3200 baud with each symbol is represented by 3-bit. Different constellations related to these models are used. The simulation results show that the performance of ADPCM using the second model of QAM signal is better than that using the first model of QAM signal. Also, the performance of ADPCM with circular constellation is better than that with rectangular constellation.

Keywords — 16kb/s ADPCM, QAM modem.

I. INTRODUCTION

With the increase in demand for efficient use of digital communication channel, various types of highly effective speech coding methods have been developed[1-7]. As one of these coding methods is international standard Adaptive Differential Pulse Code Modulation (ADPCM)[1]. The superior performance, economy and application flexibility of ADPCM relative to other bandwidth reduction techniques were the prime reasons for its selection.

The specification of ADPCM opens the door to a host of applications in telecommunication networks[8-14]. These applications can be divided into three categories: telephone company use, end customer applications, and new service offerings.

The main problem of ADPCM is that it adds severe nonlinear distortion to the voiceband data signal at high data rate. This problem can be solved either by modifying the algorithm of ADPCM[15-21], or by modifying the model of data transmission system[22-24].

II. STRUCTURE OF ADPCM

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 2-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

\[
 r(n) = s(n) + e(n)
\]

where

\[
e(n) = dq(n) - d(n) = r(n) - s(n)
\]

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

![Figure 1. ADPCM Codec](image-url)

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

\[
 SNR = \frac{E[s(n)^2]}{E[e^2(n)]} = \frac{\sigma_s^2}{\sigma_e^2}
\]
where $E$ denotes expectation, $\sigma_s^2$ is the power (or variance) of input signal, and $\sigma_e^2$ is the power (or variance) of the error signal.

### III. MODEL OF QAM MODEM

The first model of QAM modem named modem-I operates at symbol rate of 2400 baud with each symbol is represented by 4-bit (trellis coding is excluded) giving data rate of $2400 \times 4 = 9.6 \text{kb/s}$. The number of points in M-ary QAM constellation is equal to $24=16$-point. The design of QAM constellation plays important role in reducing the effect of channel noise [25], also, in reducing the distortion of ADPCM[22]. Some of constellations which are considered here are shown in Figure 2, for 16-point, rectangular, (5,11), (4,12), (8,8) circular.

The second model of QAM modem named modem-II operates at symbol rate of 3200 baud with each symbol is represented by 3-bit (trellis coding is excluded) giving data rate of $3200 \times 3 = 9.6 \text{kb/s}$, with 23=8-point constellation. Fig.3 shows some of 8-point constellations, rectangular, (1,7), and (4,4) circular.

### IV. COMPUTER SIMULATION TEST

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

Table 1 shows the results of testing ADPCM using modem-I. It seems that the performance of ADPCM with circular constellation is better than that with rectangular one by approximately 0.6dB.

Table 2 shows the results of testing ADPCM using modem-II. It seems that the performance of ADPCM with circular constellation is better than that with rectangular by approximately 0.3dB.

The comparison between the two modems shows that the performance of ADPCM with modem-II is better than that with modem-I by approximately 1.9dB.

<table>
<thead>
<tr>
<th>ADPCM</th>
<th>Modem-I</th>
<th>Modem-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR(dB)</td>
<td>Rect (5,11)</td>
<td>(4,12)</td>
</tr>
<tr>
<td>15.6</td>
<td>16.3</td>
<td>16.1</td>
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<table>
<thead>
<tr>
<th>ADPCM</th>
<th>Modem-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR(dB)</td>
<td>Rect (1,7)</td>
</tr>
<tr>
<td>17.5</td>
<td>17.8</td>
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</tbody>
</table>

### V. CONCLUSION

The performance of 16kb/s ADPCM system has been studied using two models of QAM signal at data rate of 9.6kb/s. The simulation results show that the performance of ADPCM with modem-II is better than that with modem-I. Also, the performance of ADPCM with circular constellation is better than that with rectangular constellation.

### REFERENCES

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