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Performance Optimization of DPCM System

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Abstract: Digital Communication systems make the process feasible for sustaining large amount of noise data and avoid distortions mainly generated through various techniques. However, a common problem with commonly used techniques, such as Pulse Coded Modulation (PCM) and Linear Delta Modulation (LDM), is that they negatively affect the communication process by causing quantization error, slope overload distortion, and granular noise. This paper describes the DPCM technique which solves the quantization error faced by the PCM. The performance optimization has been achieved using optimization tool of MATLAB.

Keywords: Differential Pulse Coded Modulation, quantization error, optimization error, PCM.

I. INTRODUCTION

Digital communications is the transfer of data over a point to-point or even point-to-multipoint communication channel, examples of which are copper wires, optical fibers, and wireless communications media. The data is represented as an electromagnetic signal, such as an electrical voltage, radiowaves, or micro waves [1].

While analog communications is the transfer of continuously varying information signal, digital communications is the transfer of discrete messages. The messages are either represented by means of line codes, or by limited set of continuously varying form using the digital modulation methods [2].

II. BACKROUND INFORMATION

Differential **p**ulse **c**ode **m**odulation (DPCM) is mainly a procedure of converting analog to digital signal in which analog signal is sampled and then difference between actual sample value and its predicted value (predicted value is based on previous sample or samples) is quantized and then encoded forming digital value.DPCM code words represent differences between samples unlike PCM where code words represented a sample value.

The performance of a PCM system is influenced by two major sources of noise, namely the channel noise which is introduced anywhere between the transmitter and the receiver; and the quantization noise which is introduced in the transmitter and is carried all the way to the receiver output. This noise is signal dependent in the sense that it disappears when the message signal is switched off [3].

Instead of taking a difference relative to the previous input sample, a difference relative to the output of a local model of the decoder process is taken. The difference can be quantized, securing a good way to incorporate a controlled loss in the encoding. Thus, the DPCM system reduces the error generated by the quantization process (known as the "quantization error") at the transmitter of the PCM system. The DPCM transmitter is similar to the PCM transmitter, but it has a prediction filter for prediction of the future values of the signal consequently, eliminating the quantization error.

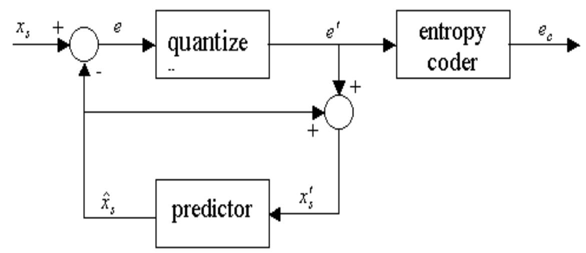

Fig 1. DPCM encoder (transmitter)

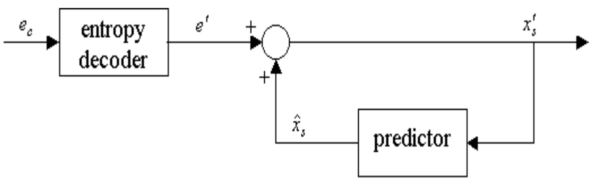

Fig 2. DPCM decoder (receiver)

Fig.1 and Fig.2 show the block diagrams for DPCM transmitter and receiver respectively where the used symbols have the following meaning:

x_s - sampled values of input signal

e - prediction error, difference between actual and predicted value

e' - quantized prediction error

$\hat{x}_s$ - predicted value

x'_s - reconstructed value of sampled signal

e_c - value after DPCM coding (input value for DPCM decoding)

The predicted value is formed using prediction factors and previous samples, usually linear prediction is used, so predicted value can be given as a weighed linear combination of p previous samples using $\{a_i\}$, weighting factors:

$$\hat{x}_s = \sum_{i=0}^{p-1} a_i \cdot x_s(i)$$

Difference signal is then:

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$$e = x_s - \hat{x}_s = x_s - \sum_{i=0}^{p-1} a_i \cdot x_s(i)$$

We choose weighting factors in a order to minimize the prediction error, this leads us to minimization of quantization noise (better signal-to-noise ratio).

Two methods of improving the performance of DPCM systems have been studied: the introduction of delays using incremental tree coding techniques and the design of nonuniform quantizers based upon optimization theory[4].

Differential pulse-coded modulation (DPCM) encoding of Gaussian autoregressive (AR) sequences is considered. It is pointed out that DPCM is rate-distortion inefficient at low bit rates. Simple filtering modifications are proposed and incorporated into DPCM[5].

By modifying the existing rate-distortion models, an improved empirical rate-distortion model with more flexibility is proposed to explain the experimental observations[6].

A two-stage DPCM coding scheme for wireless sensor networks has been presented. The scheme consists of temporal and spatial stages that compress data[7].

A new method of predictor design using only positive coefficients has been proposed. The drastic improvement in the dynamic features has been reported using this technique[8].

III. RESULTS AND DISCUSSION

The design of a DPCM system consists of optimizing the predictor and the quantizer components. Because the inclusion of the quantizer in the prediction loop results in a complex dependency between the prediction error and the quantization error, a joint optimization should ideally be performed. However, to avoid the complexity of modeling such interactions, the two components are usually optimized separatedly.

Fig.3 shows the DPCM encoded and recovered signals with the corresponding error plot with the arbitrarily chosen quantization levels. The coefficient of first order prediction filter has been arbitrarily chosen to be 1.

The mean square error (MSE) comes out to be 0.0362 in this case and the recovered signals has severe distortion.

The impact of optimizing the quantization levels is noticeable in Fig.4 where the mean square error of 0.0362 is reduced to 0.0015 and therefore the quality of the recovered signal has got improved..

The initial and optimized quantization levels are specified in table 1 with corresponding mean square error. The DPCM optimization has been carried out using optimization tool of MATLAB.

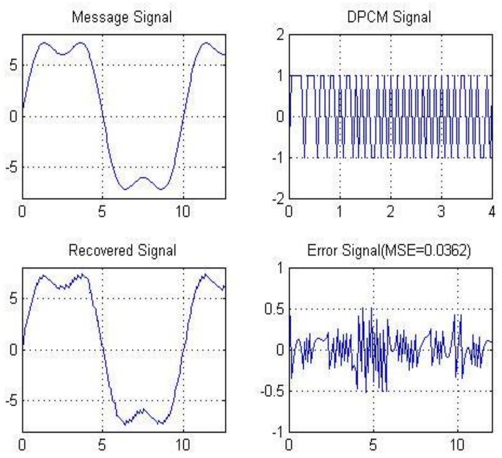

Fig.3 DPCM performance with initial parameters

Table 1. Initial and quantized parameters

Quantization levels	**Value**
Initial Qlevels	[-1.2866, -1.8995, -1.6887, -1.1478, -0.0976, 0.3976, 1.2992, 1.7385, 1.9200, 1.3003]
Optimized Qlevels-1	[-0.7479, -0.9304, -0.7811, -0.4356, -0.0067, -0.4270, 0.7734, 0.9565, 1.0313, 0.8131]
Optimized Qlevels-2	[-0.7043, -0.8101, -0.6781, -0.4356, -0.0067, 0.4270, 0.6967, 0.8390, 0.9393, 0.7732]
Optimized Qlevels-3	[-0.5342, -0.4501, -0.3324, -0.1969, -0.0660, 0.0627, 0.2114, 0.3465, 0.4609, 0.5369]

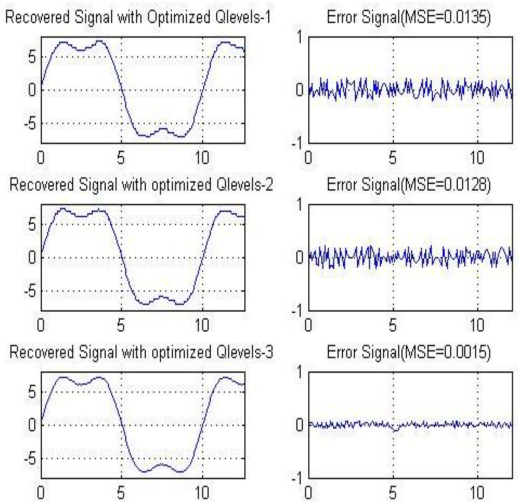

Fig.4 DPCM performance with optimized parameters

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IV. CONCLUSION

After optimization of quantization levels a significant improvement in the performance of the DPCM system has been observed with an appreciable reduction in the mean square error. The optimization algorithm of MATLAB can be run several times until the least amount of distortion is observed in the recovered signal. So we conclude that selection of quantization levels is a critical parameter as far as the performance of a DPCM system is concerned.

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