A MULTIPULSE CODING METHOD FOR BOTH SPEECH AND DATA TRANSMISSION.

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The aim of this study was to analyze the possibility of representing data sequences by means of a multipulse coding description. Indeed, this problem could be relevant in communication systems in which it is necessary to use the same coding techniques for speech and data transmission.

For this purpose, a new multipulse coding method, in which the amplitudes of the pulses were non-linearly quantized, was analyzed. In the tradeout between number of pulses and number of amplitudes quantization levels, this method allowed the use of many pulses and few quantization levels. This feature appears to be important for representing non-speech signals such as data sequences. The case of a maximum bit rate of 14.8 kbits/s was analyzed and the results obtained by applying the method to speech signals showed that comparable synthesized waveforms could be obtained by using 30 pulses and 3 bits for the amplitudes linearly quantized levels, or 34 pulses with 2 bits for the amplitudes non-linearly quantized levels (μ law). Careful examination of the synthesized waveforms showed that non-linear quantization allowed a better reconstruction of speech segments characterized by fast transitions, such as segments at the boundaries between consonants and vowels.

This method was then applied to the case of data sequences characterized by a bit rate of 1000 bits/s. In particular, the cases of DCPSK (Differentially Coherent Phase Shift Keying) and of FSK (Frequency Shift Keying) modulated signals were analyzed. The evaluation of the results will be given in terms of the opening of the eye diagrams and of the probability of error. It will be shown that multipulse methods can be used with sufficient confidence for data coding, and that better results can be obtained with DCPSK modulated signals.

A multipulse coding method for both speech and data transmission

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Abstract- A multipulse coding method, in which the amplitudes of the pulses were non-linearly quantized, was applied to data sequences coding. The non linear quantization appears to be important for representing non-speech signals such as data sequences, as it allows the use of many pulses and few quantization levels. The method was used for coding speech signals at a maximum bit rate of 14.8 kbits/s, and data sequences which were either frequency (FSK) or phase (DCPSK) modulated and which were characterized by a bit rate of 1000 bits/s. Results were very satisfactory for the representation of speech and DCPSK modulated data sequences.

I. Introduction

In recent studies, the advantage of using a non linear quantization rule for amplitudes pulse coding in multipulse systems was investigated (Di Benedetto, 1987, 1988). Results showed that, given a maximum bit rate of 14.8 kbits/s, it was possible to obtain a very satisfactory representation of the original speech if 30 pulses were considered in the multipulse sequence, the amplitudes of which were quantized with 3 bits. Similar results could be obtained with 34 pulses and 2 bits, if a μ-law quantization rule was applied to the amplitudes pulse coding. Detailed examination of the original and synthesized waveforms showed that excellent approximations to the original waveforms could be obtained, using a non linear quantization rule. In particular, segments characterized by fast transitions (for example segments corresponding to the stop consonants burst and release of burst) could be very precisely represented if a μ-law was applied, while the use of a linear quantization rule led to unsatisfactory results in these segments.

In the present study, the possibility of representing by this method non speech signals such as data sequences was analyzed. The method was applied to data sequences characterized by a bit rate of 1000 bits/s. In particular, the cases of phase modulated sequences, in which the differences between the phase deviations in two successive symbol time intervals were transmitted (DCPSK), and of frequency modulated sequences (FSK) will be described in the present paper. The results will be evaluated on the basis of the opening of the eye diagram and of the probability of error. It will be shown that multipulse methods with non linear quantization of the pulses amplitudes can be used with sufficient confidence for data coding, and that better results can be obtained with DCPSK modulated signals.

II Experimentation

II.1 Evaluation criteria of the results

The probability of error was computed in order to have an indication on the quality of the transmission system. In addition, the eye diagram could give an indication on the amplitude and time margins for the evaluation of the sampling instants.

In the computation of the probability of error one should refer to a transmission system as the one schematized in Fig.1. Note that such a system is numeric in each segment, excluding the first and last segments (from the combo to the modem and vice versa). These segments are very short and it is reasonable to suppose that no significant noise is added to the signal.

The contribution of the intersymbol interference, η, gives rise to a scattering around the transmitted values, as one can verify on the eye diagram. Under the hypothesis that the transmitted symbols were statistically independent and that η were characterized by a gaussian distribution, it is possible to give an approximate expression of the probability of error, P_e. The hypothesis of a gaussian distribution is reasonable, since the several factors which contribute to the error are all of small entity and on the same order of magnitude. If one indicates by $\sigma_\eta{}^2$ the variance of η, and supposing that the data are normalized between -1 and 1 with respect to the signal values in the sampling instants, one has:

$$P_e \cong 1/2 \, \mathrm{erfc}\{z\} \qquad (1)$$

with

$$z=[\sqrt{2}\,\sigma_\eta\,(L-1)]^{-1} \qquad (2)$$

where L is the number of levels (dimension of the alphabet of the transmission coder). To have an indication on P_e, σ_η must be first estimated, and then z calculated on the basis of equation (2). The z value is then used to calculate P_e on the basis of Table I or of Fig.2, which show the relation between P_e and z (expressed in dB). The evaluation of the variance $\sigma_\eta{}^2$ can be obtained by computing the errors (differences between the transmitted and the received values) for a sufficient large number of data sequences. It is obvious that this value is significant only in the cases in which the eye diagram is open.

II.2 DCPSK modulated sequences

Two types of multipulse excitations were considered: 34 pulses with 2 bits for the amplitudes description, and 30 pulses with 3 bits. The amplitudes of the pulses were quantized using a μ law with μ=2.5. This value of μ was chosen on the basis of what obtained with speech signals (Di Benedetto, 1988). Data sequences of 256 symbols were considered. The transmission coder alphabet consisted of two values. The roll-off value of the pulse shaping filter (raised cosine filter), α, was initially equal to 0.5. The effects of a variation of α on the P_e were also examined. The 3 dB bandwidth of the receiving filter (7 poles-Butterworth) was $2f_b$, where f_b is the symbol rate. Finally, we considered a multipulse algorithm which allows the 'segment boundaries corrections' (Di Benedetto, Mandarini and Viola, 1985).

Figure 3 shows the eye diagrams for various transmitted sequences, with the 34-2 combination. Note that the eyes are open. The computation of σ_η led to probabilities of error in the range of 10^{-7}, as shown in Fig.4. The σ_η values obtained for various sequences were similar; this finding reinforces the hypothesis on η.

Figure 5 shows the eye diagrams for various transmitted sequences, with the 30-3 combination (all the other parameter values were the same as in the previous case). The comparison between the results of Figs. 3 and 4 shows that the results obtained with the 30 pulses-3 bits combination were more satisfactory. In this case, the probability of error was in the range of 10^{-9}, as shown on Fig.6.

Finally the influence of the roll-off of the raised cosine filter was analyzed. Figure 7 shows the eye diagrams in the case of the 30-3 combination and $\alpha=1$. The probability of error was in this case in the range of 10^{-13}. With $\alpha=0.75$ the probability of error was in the range of 10^{-9}, similar to what was obtained with $\alpha=0.5$. A variation of α from 0.5 to 1 led to more satisfactory P_e values (10^{-8}) also in the case of 34 pulses-2 bits.

II.3 FSK modulated sequences

In the case of FSK modulated sequences, we considered the same parameters values as those described for DCPSK modulated sequences. In particular, the raised cosine roll-off value was initially 0.5. The modulation index was 0.66.

In the case of frequency modulated sequences, the case of 34 pulses and 2 bits led to unsatisfactory results (the eye diagram was closed), as shown in Fig.8.

Figure 9 shows that also for the 30-3 combination the results were not satisfactory. The results obtained with $\alpha=1$ were slightly better, as shown in Fig.9. However, the P_e values were not satisfactory (in the range of 10^{-4}). Better results were obtained with $\alpha=0.75$, but the probability of error was still unacceptable (in the range of 10^{-4}).

III Conclusion

In this study, we examined the results obtained by the application of a multipulse method to the representation of data sequences. On the basis of the results obtained on speech signals, we observed that good combinations of number of pulses and number of bits for the pulse amplitudes representation were 30 pulses-3 bits or 34 pulses-2 bits. The pulse amplitudes were non linearly quantized by a μ-law with $\mu=2.5$, when the maximum bit rate was 14.8 kbits/s.

The results obtained with DCPSK modulated sequences using the 30-3 and 34-2 combinations were satisfactory. The probability of error was acceptable for various roll-off values.

The results obtained with FSK modulated sequences were not satisfactory. The eye diagram was most often closed, and in the cases of open eye diagrams, the probability of error was too high.

One should note that in the computation of the multipulse sequence, the distance between the original and synthetic signals was weighted in order to take into account some masking properties of the peripheral auditory system. The weighting filter parameters depend upon the value of a parameter (parameter γ) which was optimized on the basis of speech signals. In the application of the multipulse methos'to both speech and data coding, the effect of changes of the γ parameter should be investigated.

References

Di Benedetto, M.G., Mandarini, P. and Viola, R. (1985) "On critical aspects of parameters evaluation in multi-pulse LPC speech systems", Proceedings of MELECON '85, Mediterranean Electrotechnical Conference, Madrid, pp.115-118.

Di Benedetto, M.G. (1987) "Riduzione della ridondanza del segnale vocale per applicazioni via satellite" rapporto Selenia Spazio, n° 2.

Di Benedetto, M.G. (1988) "Non linear quantization rule for amplitudes pulse coding in multipulse speech systems" Proceedings of the 7th FASE Symposium, Edinburgh, pp.755-761.

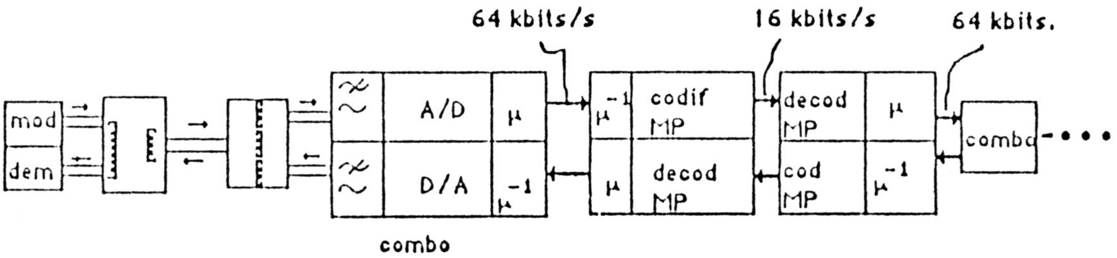

Figure 1 Data transmission system

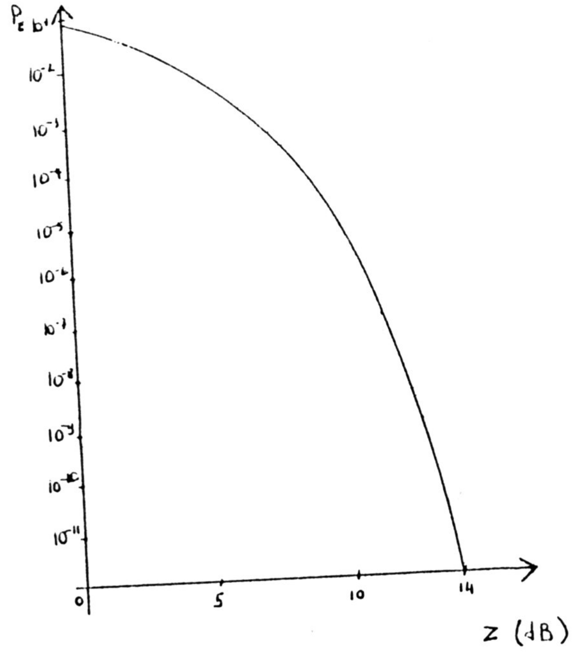

Figure 2 Relation between the probability of error P_e and z, expressed in dB (equation 2 in the text).

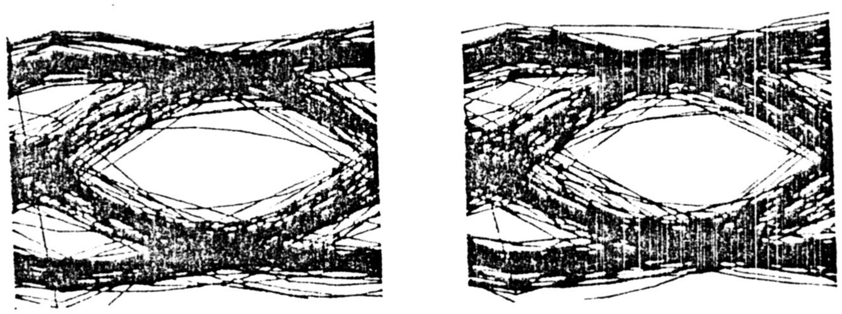

Figure 3 Eye diagrams obtained with various DCPSK modulated data sequences, with the combination 34 pulses and 2 bits, and α=0.5 raised cosine filter.

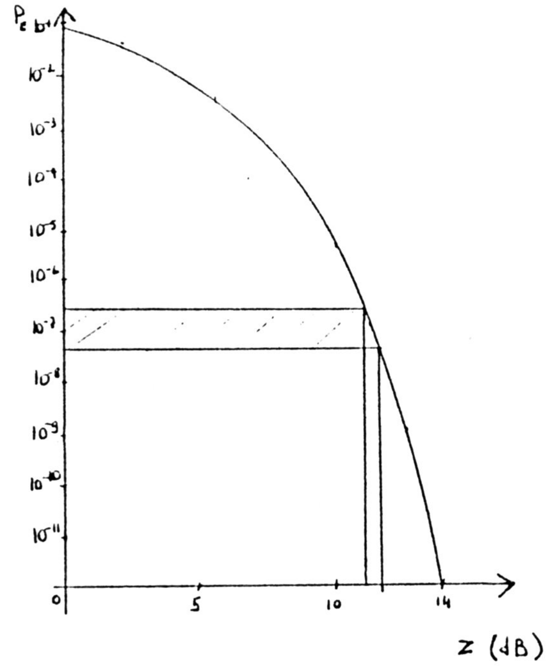

Figure 4 Probability of error, P_e, obtained with the 34 pulses-2 bits combination, and α=0.5 raised cosine filter (case of DCPSK modulated sequences).

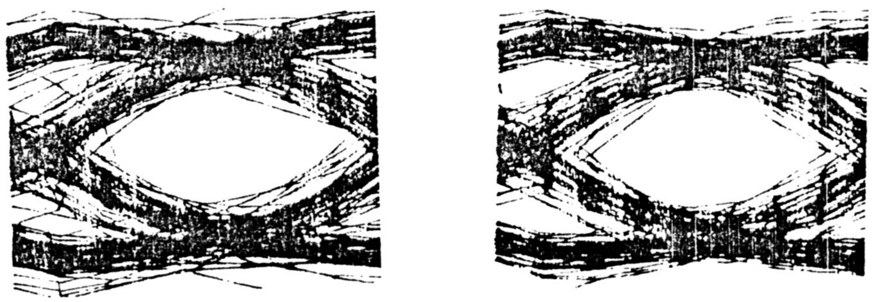

Figure 5 Eye diagrams obtained with various DCPSK modulated data sequences, with the combination 30 pulses and 3 bits, and α=0.5 raised cosine filter.

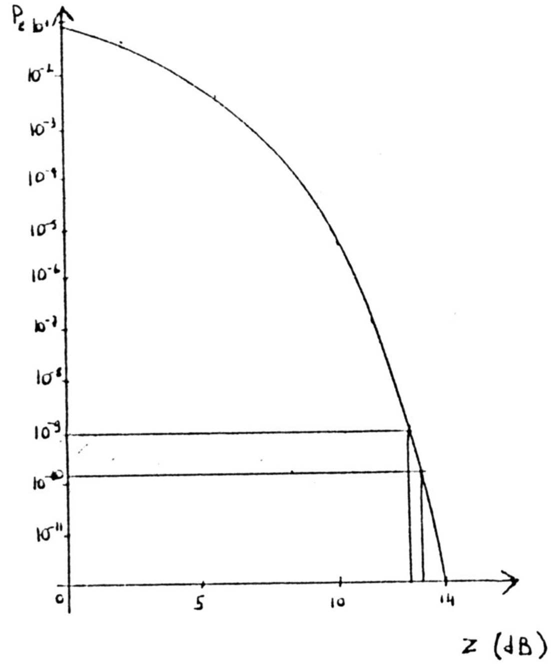

Figure 6 Probability of error, P_e, obtained with the 30 pulses-3 bits combination, and α=0.5 raised cosine filter, for DCPSK modulated sequences.

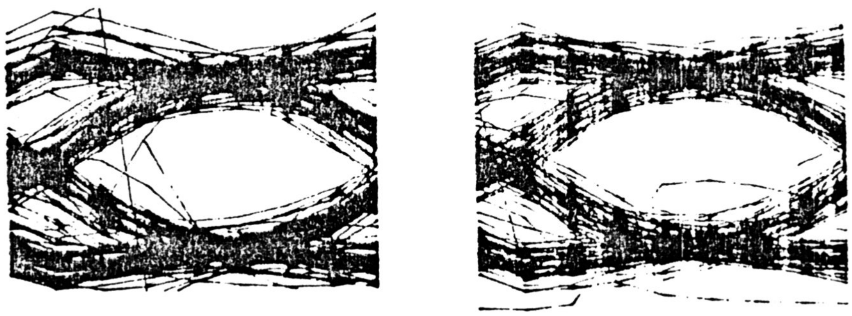

Figure 7 Eye diagrams obtained with various DCPSK modulated data sequences, with the combination 30 pulses and 3bits, and α=1 raised cosine filter.

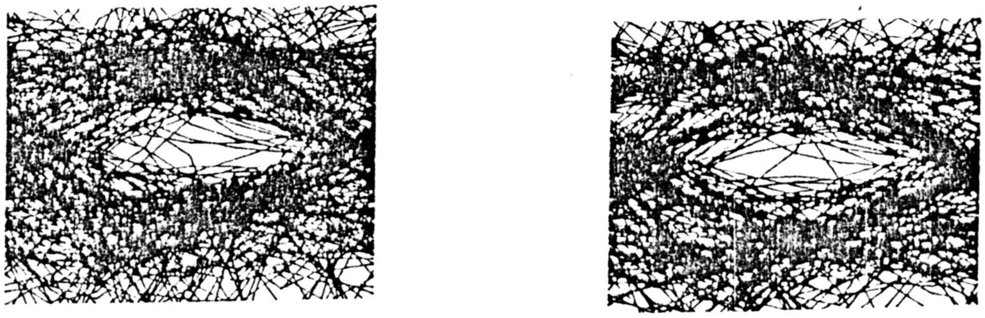

Figure 8 Eye diagrams obtained with various FSK modulated data sequences, with the combination 34 pulses and 2 bits, and α=0.5 raised cosine filter.

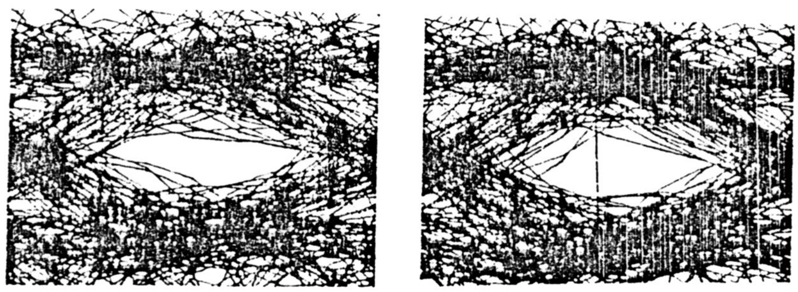

Figure 9 Eye diagrams obtained with various FSK modulated data sequences, with the combination 30 pulses and 3 bits, and α=0.5 raised cosine filter.

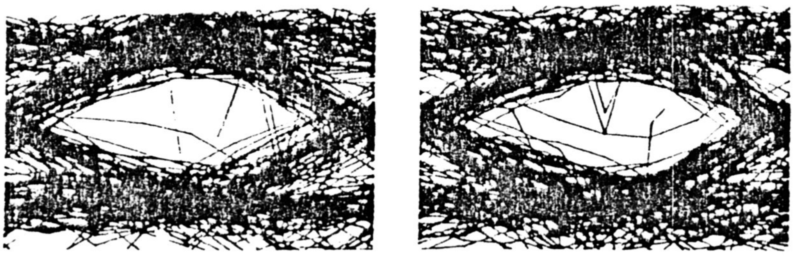

Figure 10 Eye diagrams obtained with various FSK modulated data sequences, with the combination 30 pulses and 3 bits, and $\alpha=1$ raised cosine filter.

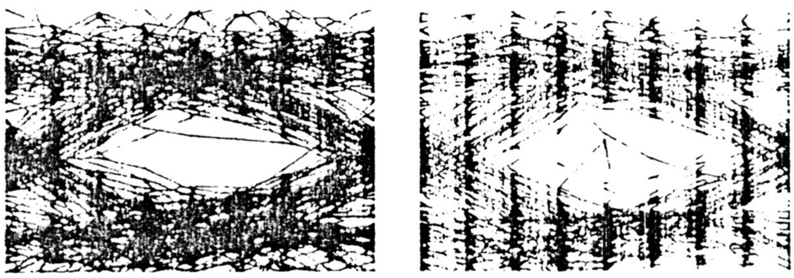

Figure 11 Eye diagrams obtained with various FSK modulated data sequences, with the combination 30 pulses and 3 bits, and $\alpha=0.75$ raised cosine filter.

x	x(dB)	1/2 erfc(x)
1.0	0	$7.8\ 10^{-2}$
1.2	1.58	$4.5\ 10^{-2}$
1.4	2.92	$2.4\ 10^{-2}$
1.6	4.08	$1.2\ 10^{-2}$
1.8	5.11	$5.5\ 10^{-3}$
2.0	6.02	$2.3\ 10^{-3}$
2.2	6.85	$9.3\ 10^{-4}$
2.4	7.60	$3.4\ 10^{-4}$
2.6	8.30	$1.2\ 10^{-4}$
2.8	8.94	$3.7\ 10^{-5}$
3.0	9.54	$1.1\ 10^{-5}$
3.2	10.1	$3.0\ 10^{-6}$
3.4	10.6	$7.6\ 10^{-7}$
3.6	11.1	$1.8\ 10^{-7}$
3.8	11.6	$3.8\ 10^{-8}$
4.0	12.0	$7.7\ 10^{-9}$
4.2	12.5	$1.4\ 10^{-9}$
4.4	12.9	$2.4\ 10^{-10}$
4.6	13.3	$4.0\ 10^{-11}$
4.8	13.6	$5.7\ 10^{-12}$
5.0	14.0	$7.7\ 10^{-13}$

Table I