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Method of Soft-Decision Decoding of Block Codes

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Abstract—A method of soft-decision decoding of a block code was considered as a solution of the problem of estimating "soft" values of information symbols by the maximum-likelihood method. Estimation of values of information symbols was conducted under conditions where levels of continuous output signals of a discriminator (demodulator) were subjected to an appropriate interpretation with due regard for the coding rule.

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One of the directions for enhancing the efficiency of coding systems with correction of errors involves application of decoders of the type "soft input—soft output". The use of statistical characteristics of continuous output signals produced by a demodulator (discriminator) of the received elementary signals corresponding to code symbols "0" and "1" makes it possible to estimate the equiprobable information symbols by the criterion of maximum a posteriori probability [1, 2]. However, such solution of the soft-decision decoding problem was obtained only for the case of Gaussian noises, when the random value of intensity z of the demodulator output signal is characterized by the conditional probability densities

$$g_0(z) = g(z/\text{"0"}) = k\exp[-(z-m)^2/2\sigma_z^2], \quad g_1(z) = g(z/\text{"1"}) = k\exp[-(z+m)^2/2\sigma_z^2];$$

by their ratio $\pi(z) = g_0(z)/g_1(z) = \exp[2mz/\sigma_z^2]$ or the logarithm of the ratio

$$l(z) = \ln[\pi(z)] = 2mz/\sigma_z^2, \tag{1}$$

that is a linear function of variable z only in the given case.

For independent equiprobable information binary symbols x_i, x_j, $i \neq j$, the logarithm of ratio of probabilities $l(x_i \oplus x_j)$ of binary sums can be expressed in terms of logarithms of probability ratios $l(x_i) = l_i$, $l(x_j) = l_j$ of components in the following form [1, 2]

$$l(x_i \oplus x_j) = \ln\frac{1+\exp(l_i + l_j)}{\exp(l_i)+\exp(l_j)}. \tag{2}$$

With due regard for the recurrent properties of the last ratio, one can obtain the known analytical expression of the relationship of ratio logarithm $l(z_n)$ of the coded symbol z_n on the basis of the known operator of transforming a set of information symbols $[x_m]$, $m = 1,..., M$ into coded symbols $[z_n]$, $n = 1, \ldots, N$. For example, for a system of coding transformations of information vector $X = [x_1, x_2, x_3]$:

$$z_1 = x_1;\ z_2 = x_2;\ z_3 = x_3;\ z_4 = x_1 \otimes x_2;$$

$$z_5 = x_1 \otimes x_3;\ z_6 = x_2 \otimes x_3;\ z_7 = x_1 \oplus x_2 \oplus x_3;$$

we can write the equations relating the logarithms of probability ratios $l(z_j)$, $j = 1,\ldots,7$ in the form:

$$l(z_1) = l(x_1) = l_1,\ \ l(z_2) = l(x_2) = l_2;\ \ l(z_3) = l(x_3) = l_3;$$