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SPECIFICATIONS OF AN INFORMATION PROCESSING INVARIANT SYSTEM IN CONDITIONS OF NONCOHERENT RECEPTION AND INACCURATE DETERMINATION OF THRESHOLDS

An information processing invariant system based on a linear detector in conditions of inaccurate determination of thresholds is considered. Quantitative estimation of noise immunity of such a system with its further comparison with noise immunity of an ordinary binary system with non-coherent reception is carried out.

Keywords: invariant system, noise immunity.

The main requirement to an information processing system is undistorted transmission through communication channels with variable parameters.

There are methods which are reduced to using of ARA, diversed reception, adaptive methods with a training signal, systems with feedback.

These methods have both positive and negative characteristics. One of the drawbacks of the methods mentioned above is a difficulty in realization of transmission algorithms of signals with multilevel amplitude modulation.

In the given paper the algorithm of multilevel amplitude modulated signals transmission through the channels with variable parameters is synthesized and quantitative estimation of the noise immunity in conditions of non-coherent reception is carried out.

There is a communication channel restricted by the frequencies f_{low} и f_{high}. The state of the communication channel is defined by the stationary interval inside which the influence of multiplicative noise is described by the stability of the transmission coefficient $k(t)$ on a certain frequency.

The algorithm of reception is defined by the carrying frequency given as an average frequency of the channel, the amplitude of which is modulated by rectangular impulses.

It is required to determine the technical characteristics of an invariant transmission system in conditions of imprecise definition of thresholds.

Each transmitted block will contain the informative part and the sequence of training signals S_{PILOT}.

On the receiving side the training signals are averaged and used for modulation of the informative part of the block.

At the same time due to the changing of communication channel parameters the information and training signals are interfered with the adaptive noise.

To decrease the influence of adaptive noise of the communication channel the operation of averaging of the training signals in each block is used [1].

Let us carry out the analysis of noise immunity of the invariant system in fig. 1, where two processing channels are used.

In the first channel, consisting of a synchronous detector (SD) and the first solving device (SD1) the estimation of the channel transmission coefficient and dispersion of normal noise is carried out. Later these data are used for calculating the threshold in conditions of invariants demodulation.

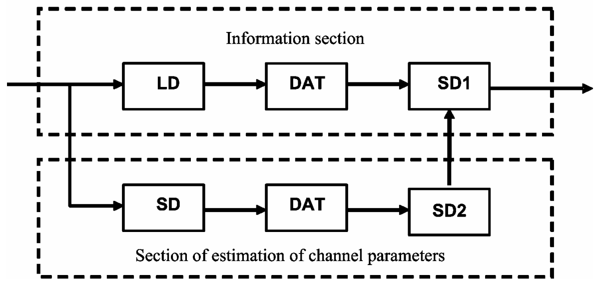

Fig. 1. Extended structural scheme of an invariant system: LD is a linear detector; DAT is a digital – analogue transducer; SD1 is a solving device 1; SD is a synchronous detector; SD2 is a solving device 2

In the second channel a non-coherent system with a linear detector (LD) and the second solving device (SD2) are used. In this channel reception signals are really demodulated.

Let us estimate the quantitative indicators of the method offered.

The principle of information section operation consists in the separation of the reception signals envelope together with the normal noise with the help of LD. The result of transformation into DAT further on is recorded in SD1.

In SD1 the decision in favour of one or another invariant is made.

As it is known [2], in the process of LD using the displacement of mathematic expectation appears. Mathematic expectation is calculated by the following formula [2]:

$$m_R = \sigma\sqrt{\frac{\pi}{2}}\left\{ I_0\left(\frac{\alpha^2}{4\sigma^2}\right) + \frac{\alpha^2}{2\sigma^2} \times \times \left[I_0\left(\frac{\alpha^2}{4\sigma^2}\right) + I_1\left(\frac{\alpha^2}{4\sigma^2}\right)\right]\right\} e^{-\frac{\alpha^2}{4\sigma^2}}, \quad (1)$$

where m_R is the quantity of mathematic expectation; σ^2 is dispersion component of normal noise; I_0 and I_1 are modified Bessel functions of zero and first order; $\alpha = k \cdot \mathrm{INV}_l$, where k is a coefficient of transmission of the channel; INV_l is l transmitted invariant.

The quantity of dispersion on the output of LD is calculated by the following formula [2]:

$$\sigma_R^2 = m_2 - m_R^2 = 2\sigma^2 + \alpha^2 - m_R^2 . \qquad (2)$$

The variables in (2) are described above.

To decide in favour of one or another invariant it is necessary to know the values of thresholds for each pair of invariants.

To estimate thresholds it is necessary to calculate m_R and σ^2_R.

It can be done with the help of section of channel parameters estimation (fig. 1) where calculation of quantities k and σ^2 is made.

Joint operation of the information section and the section of channel parameters estimation consists in reception and recording of values of amplitude modulated informative and training signals in SD1 and SD2 by a non-coherent receiver and calculating of invariant estimation on their basis.

On the basis of the latter and the calculated thresholds a decision in favour of one or another invariant is made.

Let us calculate the probability of erroneous reception in case of multilevel invariant amplitude modulated transmission of signals. The well-known approach is used to do this [3]:

$$P_{tr} = P_1 \int_0^{z_p} W_2(z)\,dz + P_2 \int_{z_p}^{\infty} W_1(z)\,dz , \qquad (3)$$

where P_{tr} is the probability of transition of the first invariant into the second one and vice versa; P_1 is the probability of appearing of the first invariant; P_2 is the probability of appearing of the second invariant; the first integral is the probability of appearing of the second invariant, when the first one is sent; the second integral is the probability of appearing of the first invariant, when the second one is sent; z_P is a threshold value necessary to calculate P_{tr} with known P_1 and P_2.

The quantity z_P is defined with the help of the best bias estimation by minimizing P_{tr} by z_P. With unknown P_1 and P_2 let us choose $P_1 = P_2 = 0.5$.

As we can see from the expression (3), it is necessary to know the analytical expression $W_1(z)$ and $W_2(z)$.

For coherent reception the calculation of quantities $W_1(z)$ and $W_2(z)$ is known and is shown in [1]. The same approach can also be used in case of non-coherent reception.

Thus the quantity of estimation of the invariant in such a system is calculated as follows:

$$\mathrm{INV}_l^* = \frac{\sum_{i=1}^{N}\left(k \cdot \mathrm{INV}_l + \xi(i)\right)}{\frac{1}{L}\sum_{m=1}^{L}\sum_{j=1}^{N}\left(k \cdot S_{PILOT} + \eta(m,j)\right)} S_{PILOT} ,$$

where INV_l is l transmitted invariant; $\xi(i)$ is i value of Relay noise; k is the coefficient of communication channel transmission; in the denominator: S_{PILOT} is the value of the training signal; $\eta(m, j)$ is j value of Relay noise in m realization of signal S_{PILOT}; N is the number of readings taken by the envelope INV_l or S_{PILOT}; L is the number of training signals.

Without loss of generality let us take $S_{PILOT} = 1$, as $S_{PILOT} > 0$, and we can divide the values of invariants INV_l and root-mean-square deviation into S_{PILOT}.

When $S_{PILOT} = 1$ we obtain the following analytical expression:

$$\mathrm{INV}_l^* = \frac{\sum_{i=1}^{N}\left(k \cdot \mathrm{INV}_l + \xi(i)\right)}{\frac{1}{L}\sum_{m=1}^{L}\sum_{j=1}^{N}\left(k + \eta(m,j)\right)} . \qquad (4)$$

To calculate P_{tr} it is necessary to know mathematic expectations and dispersion of the numerator and the denominator of the expression (4).

To calculate it let us use the following approach.

Mathematic expectation of the numerator (4) will be:

$$m_{num} = m_R \cdot N . \qquad (5)$$

Dispersion of the numerator (4) will be:

$$D_{num} = N \cdot \sigma_R^2 , \qquad (6)$$

where m_R and σ^2_R are calculated in accordance with the expressions (1) и (2). Mathematic expectation of the denominator (4) after transformation will be as follows:

$$m_{den} = m_{R2} \cdot N , \qquad (7)$$

where m_{R2} is calculated in accordance with (1) by $\alpha = k$, as $S_{PILOT} = 1$ is used instead of INV_l.

Dispersion of the denominator (4) will be:

$$D_{den} = \frac{N \cdot \sigma_{R2}^2}{L} , \qquad (8)$$

where σ^2_{R2} is calculated in accordance with (2) by $\alpha = k$, where m_{R2} is used instead of m_R.

Then the expression of density of the probability of the estimation of the invariant will be [4]:

$$W(z) = \int_{-\infty}^{\infty} \frac{1}{2\pi\sigma_1\sigma_2} e^{-\frac{(zx-m_1)^2}{2\sigma_1^2}} e^{-\frac{(x-m_2)^2}{2\sigma_2^2}} |x|\,dx , \qquad (9)$$

where $\sigma_1 = \sqrt{D_{num}}$; $\sigma_2 = \sqrt{D_{den}}$; $m_1 = m_{num}$; $m_2 = m_{den}$.

The calculation of P_{tr} is carried out quantitatively by approximation of the formula (9).

In the systems with AM and non-coherent reception the analogue of the probability of the pairwise transition is the probability of error Per, which is calculated by the know formulas [3].

The probability of the pairwise transition and the probability of error are calculated for the similar h – noise-to-signal ratio which is calculated by the formula $h = k \cdot \mathrm{INV}_1 / \sigma_R$.

Threshold z_P are calculated by minimization of P_{tr} in formula (3). For $k = 1$ and $\mathrm{INV}_1 = 1$, $\mathrm{INV}_2 = 2, 3, 4, 5, 6$ the calculations result in z_P = 1,23; 1,49; 1,77; 2,07; 2,36.

For $k = 0{,}7$ and $\mathrm{INV}_1 = 1$, $\mathrm{INV}_2 = 2, 3, 4, 5, 6$ the calculations result in z_P = 1,14; 1,30; 1,50; 1,68; 1,92.

The results of modulation are shown in fig. 2 and fig. 3, from which we can see that the peculiarity of any invariant system based on the principle of invariant relative amplitude modulation is that amplitude modulated signals formed by INV_l and S_{PILOT} are transmitted through the channel.

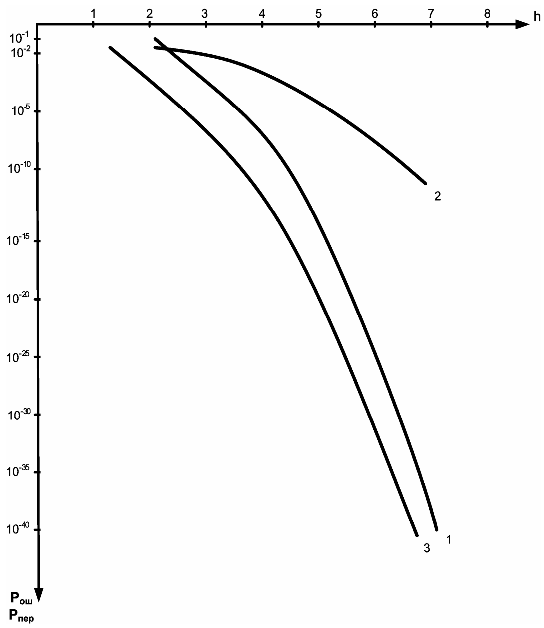

Fig. 2. Results of modulation:
1 – the probability of pairwise transition of one invariant into another under the following given conditions: $k = 1$; $\mathrm{INV}_1 = 1$; $\mathrm{INV}_2 = 2, 3, \ldots, 6$ and non-coherent reception; 2 – the probability of error in classical amplitude modulation and non-coherent reception; 3 – the probability of the pairwise transition of one invariant into another under the following given conditions: $k = 1$; $\mathrm{INV}_1 = 1$; $\mathrm{INV}_2 = 2, 3, \ldots, 11$ and coherent reception

As a rule the transmission of these signals on the basis of classical algorithms provides low noise immunity of information processing [3].

Only after processing of these signals in accordance with the quotient algorithm using expression (4), we obtain the invariant estimation which is really a number but not a signal.

As we can see from fig. 2 and fig. 3 the probability of the pairwise transition of one invariant into another in conditions of great noise-to-signal ratio is defined by the values (10^{-30}–10^{-40}). In recalculation of the shown above quantities the probability of erroneous reception of a single symbol in classical systems is within the limits (10^{-6}–10^{-10}).

However, in real situations it is impossible to determine the value of the transfer constant of communication channel accurately. The consequence of this would be inaccurate definition of the thresholds. The summand of the denominator X_j in formula (4) of evaluation of the invariant ISPR can be represented as:

$$X_j = \frac{1}{L}\sum_{m=1}^{L}\left(k + \eta(m, j)\right), \quad (10)$$

where L is the number of averages; k is thetransfer constant of communication channel; $\eta(m, j)$ is j-th reading of additive noise in the m-th realization of the training signal.

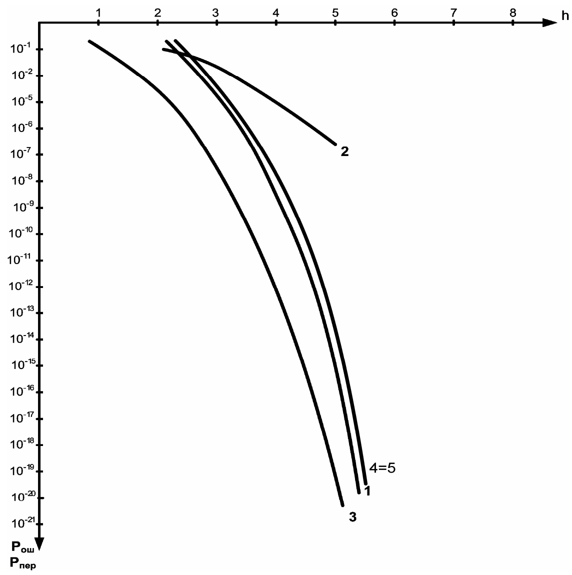

Fig. 3. Results of modulation:
1 – the probability of the pairwise transition of one invariant into another under the following given conditions: $k = 0{,}7$; $\mathrm{INV}_1 = 1$; $\mathrm{INV}_2 = 2, 3, \ldots, 6$ and non-coherent reception; 2 – the probability of error in classical amplitude modulation and non-coherent reception; 3 – the probability of the pairwise transition of one invariant into another under the following;given conditions: $k = 0{,}7$; $\mathrm{INV}_1 = 1$; $\mathrm{INV}_2 = 2, 3, \ldots, 11$ and coherent reception; 4 – the probability of pairwise transition at $k = 0{,}7$, and thresholds, calculated with k_{-}; 5 – the probability of pairwise transition at $k = 0{,}7$, and thresholds, calculated with k_{+}

Then expected X_j is equal to:

$$EX_j = E\left(k + \eta(m, j)\right) = m(k). \quad (11)$$

In addition, we have

$$\overline{X} = \frac{1}{N}\sum_{j=1}^{N} X_j = m(\hat{k}), \quad (12)$$

$$\hat{k} = g(\overline{X}), \quad (13)$$

where $\hat{k}$ is the evaluation of the transfer constant of communication channel; g is the inverse of the function m;

$$D\hat{k} \approx \left(g'(m(k))\right)^2 \frac{\sigma^2}{NL} \quad (14)$$

(according to the theorem on asymptotic normality),

$$m(k) = X, \quad (15)$$

$$k = g(X), \quad (16)$$

$$g'(X) = \frac{1}{\left(m(k)\right)'} = \frac{1}{m'(k)} = \frac{1}{m'\left(g(X)\right)}, \quad (17)$$

$$m(k) = \sigma\sqrt{\frac{\pi}{2}}\, e^{-\frac{k^2}{2\sigma^2}} \sum_{i=0}^{\infty} \frac{(2i+1)!!}{(i!)^2\, 4^i}\left(\frac{k}{\sigma}\right)^{2i}. \quad (18)$$

Then

$$m'(k) = \sigma\sqrt{\frac{\pi}{2}}\left(-\frac{k}{\sigma^2}e^{-\frac{k^2}{2\sigma^2}}\sum_{i=0}^{\infty}\frac{(2i+1)!!}{(i!)^2\,4^i}\left(\frac{k}{\sigma}\right)^{2i} + e^{-\frac{k^2}{2\sigma^2}}\sum_{i=0}^{\infty}\frac{(2i+1)!!}{(i!)^2\,4^i}\frac{2i\cdot k^{2i-1}}{\sigma^{2i}}\right), \quad (19)$$

$$D\hat{k} = \frac{\sigma^2}{(m'(k))^2\,N\cdot L}, \quad (20)$$

$$k_- = k - 3\sqrt{D\hat{k}}, \quad (21)$$

$$k_+ = k + 3\sqrt{D\hat{k}}. \quad (22)$$

Fig. 3 shows the curves 4 and 5 corresponding to the curves of noise immunity at k_- and k_+, respectively. In this case $D\hat{k} = 1.2\cdot 10^{-19}$, k_- = $6.99999988\cdot 10^{-1}$ and k_+ = $6{,}99999989\cdot 10^{-1}$. As it is evident from these curves, a decrease in immunity ISPR is observed.

The invariant non-coherent system of information transmission is offered and its qualitative characteristics in conditions of inaccurate definition of thresholds are defined.

The developed method can find application in the systems of information processing.

In the author's opinion it is necessary to compare the noise immunity of the investigated invariant system with the noise immunity of similar invariant systems. That will be done in the subsequent papers.

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MAGNETOELECTRIC EFFECT INDUCED BY ORBITAL ORDERING OF ELECTRONS

Relationship between orbital order and the formation of the spontaneous magnetic moment, lattice constant, correlation function of orbital and spin moments between nearest neighbors have been investigated in terms of the continuous Potts model for set of electron-phonon parameters and spin-phonon interactions. A change in the permittivity and orbital correlation functions in the external magnetic field has been found.

Keywords: permittivity, magnetoelectric effect, electron-lattice interaction, orbital and spin moment.

The study of multiferroics with the coexistence of at least two of the three order parameters (magnetic, electric, and crystallographic) [1] is an urgent problem, for it describes the possibility of controlling the magnetic properties of a material by means of an electric-field and, vice versa, magnetic-field modulation of electric properties. In the future, multiferroics may find wide technical application in sensors and recording devices, reading and storing information. While the spintronic devices transform information by changing the magnetization to electric voltage; in multiferroics the correlation between the magnetic and electric subsystems manifests itself in the magnetoelectric effect [2; 3].

The $Co_xMn_{1-x}S$ solid solutions can be attributed to the multiferroic class [4]. In the temperature ranges of $T \approx$ 110–120 K and $T \approx$ 230–260 K, the correlation between the magnetic and electric subsystems has been found [5]. The presence of this correlation is confirmed by sharp rise of the magnetization and the maximum in the relative variation of permittivity, measured in the external magnetic field and without it at a lowering temperature [6].

Electron density redistribution inside a 3d-shell arising from electron transitions from e_g to t_{2g} levels; or due to the different electro negativities of cobalt and manganese ions can lead to changes the orbital occupancy at the t_{2g} shell of Mn ions.

An important feature is that magnetic exchange interaction depends on orbital occupancy. This means that even the sign could change. Therefore, it is possible that magnetic correlation at normal can be very different from that in the ordered phase, when the orbital order is accompanied by magnetic transition. The variation of the orbital occupancy may be caused shift in polarizability and in spin state of cation.

The aim of this study is to investigate the physical properties of the $Co_xMn_{1-x}S$ solid solutions typical of multiferroics, induced by spin-charge ordering, and to establish the interrelation between the magnetic, electric, and elastic subsystems.