METHOD FOR CONTROLLING STATE CHANNEL WIRELESS NETWORKS UNDER A PRIORI UNCERTAINTY

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***Abstract**: A method of monitoring the state of the radio channel using statistical information of the turbo decoder, the use of which in the adaptive system will allow carrying out its restructuring under varying random actions.*

***Keywords:** information technologies, a priori uncertainty, wireless networks, turbo codes.*

***ACM Classification Keywords**: H.4 Information system applications, H.4.3 Communications Applications, G.1.6 Optimization, I.6 Simulation and modeling, K.6.4 System management*

Introduction

Promising direction of development in the field of telecommunications is to develop a software defined radio (SDR), principle of which is based on the hardware and software implementation [Maier, 2005]. There are currently plans to design means having an open architecture construction: media themselves can produce some manufacturers, and the functions and modes of operation will determine the third-party software. Analysis of possible guidelines for constructing these wireless facilities shows [Uhm, 2006] that these tools you plan to use spread spectrum techniques and effective signal adaptive signal-code structures based on the use of turbo codes. The use of turbo codes (TC) as a correction because the noise immunity characteristics of close to the theoretical values [Berrou, 1993].

Due to increased demand for quality voice and data wireless channels it is necessary to build wireless networking equipment, parameters and structure of the physical layer which would vary with changes in the characteristics of the signal propagation medium under the action of powerful noises. This can be achieved by using SDR to permit dynamic change of its parameters or structures depending on the analysis of the information transmission channel. Influence of powerful interference gives rise to uncertainty in the decision-making process in the processing of the transmitted information sequence. There is need to assess the uncertainty (risk) and to develop an adaptive system that will adaptively change its parameters.

The aim is to develop a method for monitoring the state of the channel wireless networks under a priori uncertainty.

Description the problem of parametric adaptation of the wireless networks

Formulate the problem of parametric adaptation of the wireless networks (wireless system), which will act as the object of adaptation. The wireless system will have a number of adapted parameters by which can be controlled by her work: $P = (p_1, p_2, ..., p_n)$.

Wireless system to work affected by the environment, having exposure parameters $Z = (z_1, z_2, ..., z_n)$. Influence of environment on the control object can be characterized by using the estimated parameters $E = (e_1, e_2, ..., e_n)$, which will be a function of the parameters and the parameters exposure parameters:

$$E = f(Z, P).$$

The purpose of adaptation defines requirements that will be imposed on the parameters which define the efficiency of the system. Such requirements are specified as constraints on the values that can take the estimated parameters Y of the adaptive system. Constraints on the values of the estimated parameters may be stored either as equalities $G(E)=0$ or inequalities $H(E)\geq 0$ as. Target species such restrictions define the scope of admissible controls that will be a finite set:

$$S:\begin{cases} G(E)=0 \\ H(E)\geq 0 \end{cases}.$$

In the process of the adaptive system must satisfy the condition $E\in S$ that guarantees the application of the process control system only allowed configurations (control solution).

Besides the restrictions that define the domain S, in the adaptive system can be set to minimize the condition $Q(E)\rightarrow \min$ which would provide the best method of finding the management of the system using a variety of management solutions S:

$$Q(E)\rightarrow \min,\ P\in S.$$

Graphically, this approach to management constraints shown on the Figure 1.

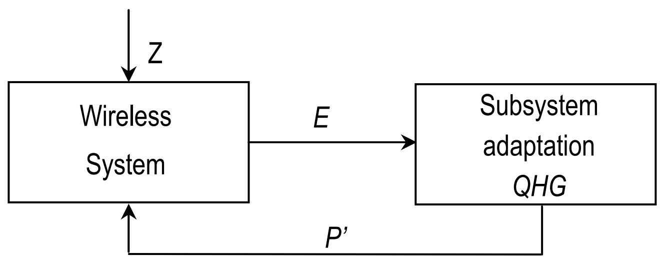

Figure 1. Control system with constraints

Availability minimization conditions in the future will allow talking about more effective or less effective process control, i.e. allowing quantifying the effectiveness of a strategy of adaptation.

The process of adaptive management system will be a series of changes over time adapted system parameters P:

$$P_0\rightarrow P_1\rightarrow P_2\rightarrow \ldots \rightarrow P_N.$$

Algorithm for finding the optimal solutions will bind successive solutions to be obtained in the management of: $P_N=f(P_{N-1})$, where f – algorithm (strategy) management determines the transition from the state P_{N-1} as to P_N.

In order to determine the set of parameters adapted TC, which may change during the session, and to further understand the method of obtaining the estimated parameter for wireless networks with TC.

Description of the principle of turbo coding-decoding

Consider the block diagram of the encoder and decoder TC. Figures 2 and 3 are block diagrams of the encoder and decoder TC (one iteration) that were prepared by parallel connection of two component encoders and decoders, respectively. As the component codes have been applied recursive systematic convolution codes (RSCC) [Qi, 1999].

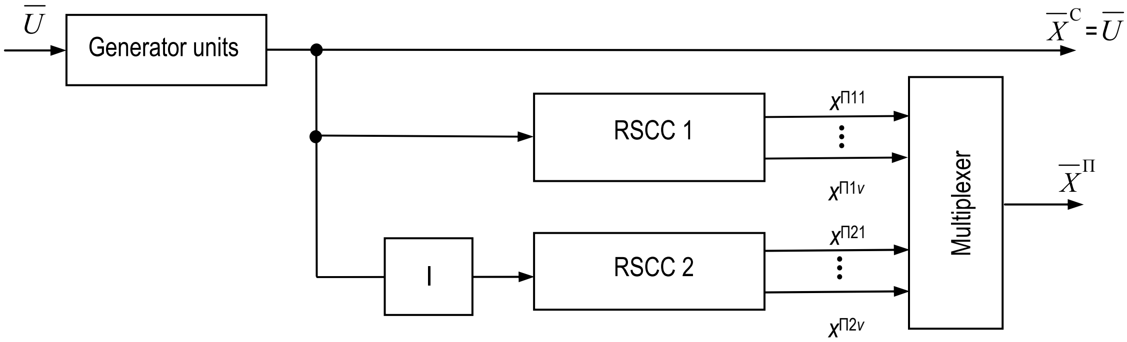

Figure 2. Block diagram of the two-component encoder TC

Information sequence $\overline{U}$ divided into blocks of length *N* symbols $\overline{U} = (u_1; u_2; u_3 \ldots u_t \ldots u_N)$, where *t* – current index, *N* - the size of the information unit. Further, it enters the systemic output of the encoder, as well as two parallel RSCC, wherein the second through interleaving block (I). It is assumed that the encoder circuit TC RSCC uses a rate 1 / n of the form: $(1, g_1 / g_0, \ldots, g_{n-1} / g_0)$, where g_0 – polynomial generator feedback, and $g_1, \ldots, g_{n-1}$ – polynomial generators of direct links. In the structure of the codec can be used pseudo, S-random, block, diagonal and others interleaving the block types [Robertson, 2006].

The sequence at the encoder output has the form of TC: $\overline{Y} = (\overline{Y}^{C}, \overline{Y}^{П})$. Where $\overline{Y}^{C} = \overline{U}$ – systematic encoder output, and $\overline{Y}^{П} = (\overline{Y}^{П1}, \overline{Y}^{П2})$ – verification TC output of the encoder. Herewith $\overline{Y}^{П1} = (\overline{Y}^{П11}, \ldots, \overline{Y}^{П1v})$ – output of the first screening RSCC, $\overline{Y}^{П2} = (\overline{Y}^{П21}, \ldots, \overline{Y}^{П2v})$ – output of the second test RSCC, *v* - the total number of parity of each encoder RSCC TC. A multiplexer is required for adjusting the encoding rate in accordance with a puncturing matrix [Robertson, 2006].

TC decoder is composed of two decoders, the two interleaving blocks (I) and two blocks of deinterleaving (D) [Robertson, 2006]. Each decoder uses «soft» input and a «soft» output (SISO (soft input-soft output)).

At the decoders 1 and 2 (fig. 3) supplied sequentially $\overline{X}^1 = (L_c \overline{X}^{C1}, L_c \overline{X}^{П1}) = (L_c x_t^{C1}, L_c x_t^{П11}, \ldots, L_c x_t^{П1v})$ – the first decoder, where $\overline{X}^{П1} = (\overline{X}^{П11}, \ldots, \overline{X}^{П1v})$, respectively $\overline{X}^2 = (L_c \overline{X}^{C2}, L_c \overline{X}^{П2}) = (L_c x_t^{C2}, L_c x_t^{П21}, \ldots, L_c x_t^{П2v})$ – for another decoder, where $\overline{X}^{П2} = (\overline{X}^{П21}, \ldots, \overline{X}^{П2v})$. $\overline{X}^{C1} = \overline{X}^{C}$, $\overline{X}^{C2}$ – systematic sequence of characters after applying an appropriate interleaving operation. $\overline{X}^{П1}, \overline{X}^{П2}$ – sequence of parity, v - the number of polynomial generators of direct links RSCC, L_c – parameter channel “reliability” [Khan, 2000].

Each decoder computes the likelihood function $L^1(y_t^{C}), L^2(y_t^{C})$, then – “external” information: $L_e^1(y_t^{C}), L_e^2(y_t^{C})$, using basic decoding algorithms TC [Khan, 2000]. The output of the block move «external» information used by the first decoder as a priori second decoder – $L_a^2(y_t^{C})$. “External” information given iteration of the second decoder after deinterleaving operations (D) is used as a priori for the first decoder next iteration.

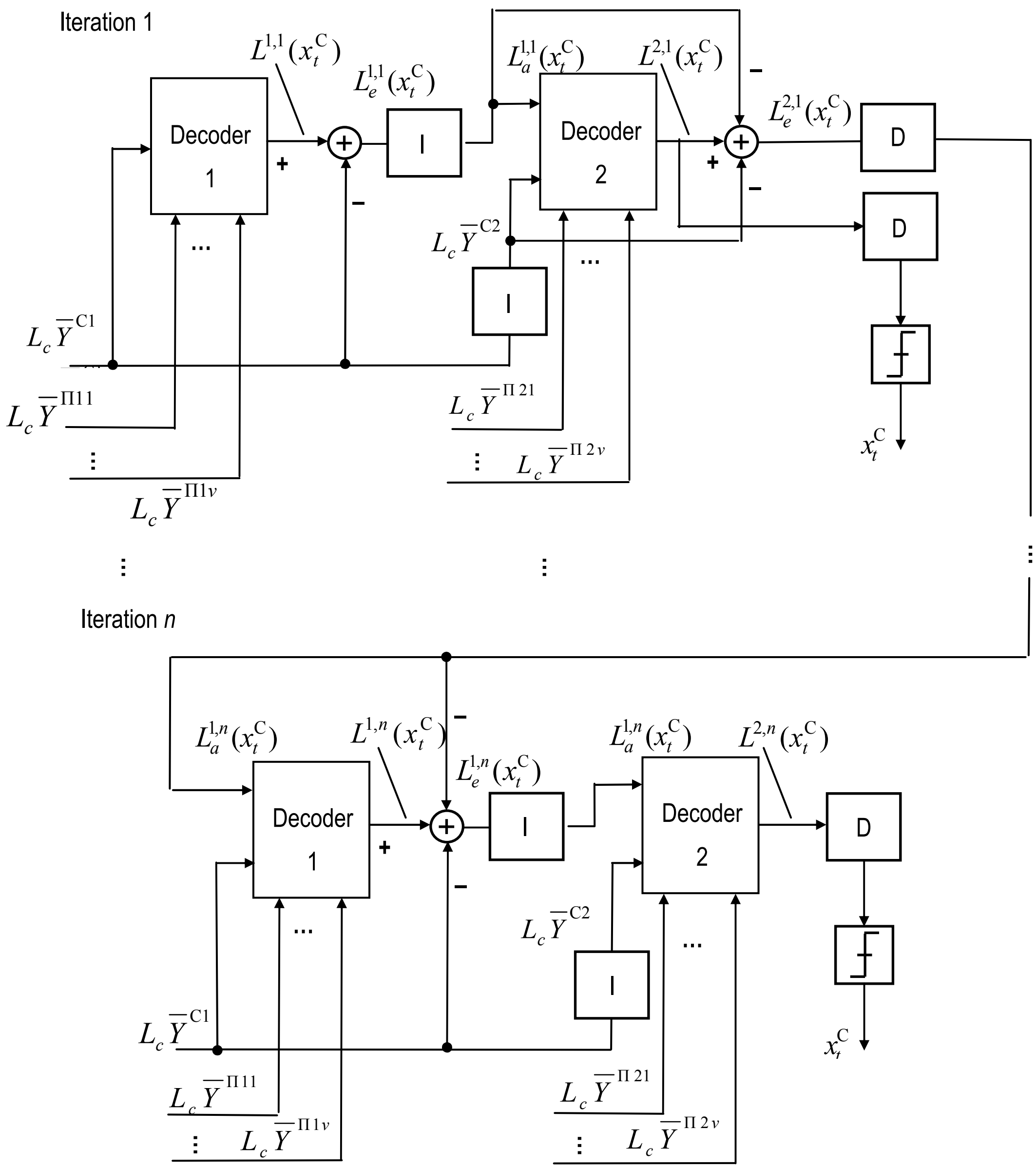

Figure 3. Block diagram of the two-component decoder TC

Descriptions of controlling state channel wireless networks under a priori uncertainty

Condition monitoring system (receipt of estimated parameters), it can be done in several ways:

– Directly estimating parameter signal-to-noise ratio ( ) by analysis of variance channel samples taken;

– To carry out an indirect assessment of the impact analysis results by channel decoding process.

Assessing the impact of the channel (receiving perturbation parameters Z) can occur by analysis of variance channel samples taken. According to the obtained numerical value of the dispersion parameter assessment. After information processing at the decoder is completed, the channel information will be updated (decoder performs correction of information bits) which gives the possibility to specify a value for subsequent sequential decoder, etc.

As a method of evaluation of the second type (getting the estimated parameter E – estimation subsystem decode) the following approach, suitable for iterative decoding process. To recover the information sequence TC decoder uses an iterative decoding. The process of iterative decoding is a sequential processing data according to the channel information a priori. Thus, the output of each serial decoder is a function of the values of channel data and a priori information:

$$y^C = f(L_C \overline{X}, L_a),$$

where L_a – priori information about the value of information bits obtained in the previous step decoding, $L_C \overline{X}$ – decision value of the information bits based on the received channel data. The first argument of this function for each decoder will remain constant, and the second will vary from one to another sequential decoder.

The unit value of the information bits will fit positive statistic $L^i(x_t^C)$, $i \in \overline{1,D}$, $t \in \overline{1,N}$, and zero – negative, where *D* – total number of decoders that are involved in the iterative decoding process. Changing the sign of a priori information in the transition to aposteriori $L_e^i(x_t^C)$ will be a prerequisite for changing decisions regarding the value of the information bit.

If in the process of decoding the number of sign changes $L_a^i(x_t^C) \to L_e^i(x_t^C)$ is zero, it can be argued that the tough decisions about the decoded bits. After each subsequent decoder value of the likelihood function of the transmitted bits will decrease (if it was transmitted bits “0”) or increase (if it was transmitted bits “1”). A situation may arise in the case of large values of the noise variance in the channel that in the process of decoding the number of sign changes $L_a^i(x_t^C) \to L_e^i(x_t^C)$ after the procedures of iterative decoding of all the decoders D is not equal to zero, resulting in an uncertainty about the value of the transmitted bits. This results in a decoding error probability of 0.5. Thus, there are four events.

Event 1 - A_1. Number of sign changes $L_a^i(x_t^C) \to L_e^i(x_t^C)$, $i \in \overline{1,D}$ in the process of iterative decoding after the *i*-th decoder is equal to zero. Made a tough decision that was handed bit $x_t^C = 0$.

Event 2 - A_2. Number of sign changes $L_a^i(x_t^C) \to L_e^i(x_t^C)$, $i \in \overline{1,D}$ in the process of iterative decoding after the *i*-th decoder is equal to zero. Made a tough decision that was handed bit $x_t^C = 0$.

Event 3 - A_3. Number of sign changes $L_a^i(x_t^C) \to L_e^i(x_t^C)$, $i \in \overline{1,D}$ in the process of iterative decoding after the *i*-th decoder is equal to zero. Made a tough decision that was handed bit $x_t^C = 1$.

Event 4 - A_4. Number of sign changes $L_a^i(x_t^C) \to L_e^i(x_t^C)$, $i \in \overline{1,D}$ in the process of iterative decoding after the *i*-th decoder is equal to zero. Made a tough decision that was handed bit $x_t^C = 0$.

Probability $P(A_1)$ and $P(A_2)$ will be the greater, and the likelihood $P(A_3)$ and $P(A_4)$ the smaller, the smaller the dispersion channel interference. With increasing values of noise variance in the channel $P(A_1)$ and $P(A_2)$ will reduce the likelihood probability $P(A_3)$ and $P(A_4)$ increase.

Given the above, we obtain a quantitative characterization of the state channel, using an estimate of uncertainty decoding. Obviously, the decoding ambiguity will be greater, the greater the value of noise variance, and the smaller, the smaller the value of noise variance in the channel. Status information transmission channel is characterized by a signal-to-noise ratio (the ratio of signal energy to the total noise power spectral density – Eb/GΣ) in the channel.

Obtain a quantitative estimate of the uncertainty from the change of sign in the iterative decoding process.

For this we use the following algorithm.

– Formation matrix *LA* size $D \times N$.

$$LA = \begin{bmatrix} L_a^1(x_1^{\mathrm{C}}) & L_a^1(x_2^{\mathrm{C}}) & \dots & L_a^1(x_N^{\mathrm{C}}) \\ L_a^2(x_1^{\mathrm{C}}) & L_a^2(x_2^{\mathrm{C}}) & \dots & L_a^2(x_N^{\mathrm{C}}) \\ \vdots & \vdots & \vdots & \vdots \\ L_a^D(x_1^{\mathrm{C}}) & L_a^D(x_2^{\mathrm{C}}) & \dots & L_a^D(x_N^{\mathrm{C}}) \end{bmatrix}. \quad (1)$$

– Payment $L^i(x_1^{\mathrm{C}})$, $i \in \overline{1,D}$, $t \in \overline{1,N}$ all the decoder and for all bit blocks *N*.

– Formation matrix *L* size $D \times N$.

$$L = \begin{bmatrix} L^1(x_1^{\mathrm{C}}) & L^1(x_2^{\mathrm{C}}) & \dots & L^1(x_N^{\mathrm{C}}) \\ L^2(x_1^{\mathrm{C}}) & L^2(x_2^{\mathrm{C}}) & \dots & L^2(x_N^{\mathrm{C}}) \\ \vdots & \vdots & \vdots & \vdots \\ L^D(x_1^{\mathrm{C}}) & L^D(x_2^{\mathrm{C}}) & \dots & L^D(x_N^{\mathrm{C}}) \end{bmatrix}. \quad (2)$$

– Calculations $L_e^i(x_1^{\mathrm{C}})$, $i \in \overline{1,D}$, $t \in \overline{1,N}$ all the decoder and for all bit blocks *N*.

– Formation matrix *LE* size $D \times N$.

$$LE = \begin{bmatrix} L_e^1(x_1^{\mathrm{C}}) & L_e^1(x_2^{\mathrm{C}}) & \dots & L_e^1(x_N^{\mathrm{C}}) \\ L_e^2(x_1^{\mathrm{C}}) & L_e^2(x_2^{\mathrm{C}}) & \dots & L_e^2(x_N^{\mathrm{C}}) \\ \vdots & \vdots & \vdots & \vdots \\ L_e^D(x_1^{\mathrm{C}}) & L_e^D(x_2^{\mathrm{C}}) & \dots & L_e^D(x_N^{\mathrm{C}}) \end{bmatrix}. \quad (3)$$

– Formation matrix L^* size $D \times N$, using (1), (3).

$$L^* = \begin{bmatrix} L_a^1(x_1^{\mathrm{C}})L_e^1(x_1^{\mathrm{C}}) & L_a^1(x_2^{\mathrm{C}})L_e^1(x_2^{\mathrm{C}}) & \dots & L_a^1(x_N^{\mathrm{C}})L_e^1(x_N^{\mathrm{C}}) \\ L_a^2(x_1^{\mathrm{C}})L_e^2(x_1^{\mathrm{C}}) & L_a^2(x_2^{\mathrm{C}})L_e^2(x_2^{\mathrm{C}}) & \dots & L_a^2(x_N^{\mathrm{C}})L_e^2(x_N^{\mathrm{C}}) \\ \vdots & \vdots & \vdots & \vdots \\ L_a^D(x_1^{\mathrm{C}})L_e^D(x_1^{\mathrm{C}}) & L_a^D(x_2^{\mathrm{C}})L_e^D(x_2^{\mathrm{C}}) & \dots & L_a^D(x_N^{\mathrm{C}})L_e^D(x_N^{\mathrm{C}}) \end{bmatrix}. \quad (4)$$

7. Looping: if $L_a^i(x_t^{\mathrm{C}})L_e^i(x_t^{\mathrm{C}}) < 1$, то $C_L = C_L + 1$.

Number of sign changes on the *i*-th sequential decoder *j*-th iteration of decoding – C_{Lij}. The value will be calculated as the total number of sign changes in the transitions $L_a^i(x_t^{\mathrm{C}}) \to L_e^i(x_t^{\mathrm{C}})$ for all N information bits processed by the *i*-th decoder *j*-th iteration of the TC.

In the simulation result found that in the processing unit bit length information N value C_L can take values ranging from 0 to $N/2$. Exception to the rule is the first decoder. Its value is always taken equal C_L value due to the fact that prior to the decoding procedure value L_a for all data bits is zero, i.e. not taken any positive or negative value.

As previously noted, an iterative decoding process in which an improvement of the result. For the value C_L of improvements in performance will be shown that the sequence of values C_L is conditionally decreasing nearby. “Conditional” because, in general, the numerical sequence is decreasing, but her next item may not always be less than the previous one.

If the value C_L of acquired value of zero, then we can say that at this decoder for each data bit clear decision, otherwise – a decision on the value of some bits is still pending, but it can be made to the following consecutive decoders.

Uncertainty decoding the entire subsystem is denoted as F . This value can be defined as the sum of the $L_a^i(x_t^C)L_e^i(x_t^C) < 1$ all serial decoders:

$$F = \sum_{j=1}^{I} \sum_{i=1}^{2} C_{Lij} \ , \tag{5}$$

where *I* – number of decoding iterations.

Value F characterizes the plausibility of data obtained by decoding block. The smaller the numerical value, the more reliable data block has been decoded. In the robot subsystem decoding are two extreme cases.

1. The transmission channel is not affected by interference or the influence of the transmitted information so small as to be negligible.

2. The transmission channel affects the transmitted information so that decoding becomes impossible to correct. In the first case, the value will make its smallest value is numerically equal to the number of transmitted information bits: $F^{(-)} = N$.

This situation corresponds to the case when the sequence has been successfully adopted decoded at the first decoder, the first sequential iteration.

In the second case, the value will take its maximum value which can be calculated as follows:

$$F^{(+)} = \frac{N}{2}(2I+1).$$

Parameter value for the actual process of iterative decoding will take values in the range between the two limits: $F^{(-)} \le F \le F^{(+)}$. Assessment of the proposed values for the analysis should be carried out as follows. First, the value C_L of analyzes on the final decoder. If it is below a certain, predetermined maximum level, the decoding process is considered completed successfully. Second, obtained in this case, the values can be compared with similar values for the decoding process is successfully completed. Higher quality wills this process, the value for which you will be less.

In practice it is more convenient to use a value F^* which is calculated as follows:

$$F^* = \frac{F - F^{(-)}}{F^{(+)} - F^{(-)}} \cdot 100\% = \frac{F - N}{N(I - 0{,}5)} \cdot 100\% \ . \tag{6}$$

For the quantity value F^* of 100% corresponds to the absolute inefficiencies and 0% - absolute effectiveness during processing subsystem decoding the information block.

Obtain the value F^* of value for each individual decoding iteration. Assessment of the uncertainty decoding the first iteration is denoted as F_1 . This value can be defined as the sum of the $L_a^i(x_t^C)L_e^i(x_t^C) < 1$ two sequential decoder:

$$F_1 = \sum_{i=1}^{2} C_{Li1} . \quad (7)$$

Let $F_1' = F_1$ – the number of sign changes $L_a^i(x_t^C) \to L_e^i(x_t^C)$ on the 1st iteration $F_2' = F_1 + F_2$ - the number of sign changes $L_a^i(x_t^C) \to L_e^i(x_t^C)$ on the 2nd iteration – decoding iteration 1.

Estimation of uncertainty decoding for the second iteration is calculated:

$$F_2 = 2(F_1 - N)N/3 + 2F_2N/3 . \quad (8)$$

To simplify (8), we introduce a replacement $m = (F_1 - N)/(N(I_1 - 0{,}5))$, as a result of the expression (8) will have the form:

$$F_2 = m/3 + 2F_2N/3 . \quad (9)$$

Estimation of uncertainty for the third iteration of decoding is determined according to the following relationship:

$$F_3 = 2(F_1 - N)N/5 + 2F_2N/5 + 2F_3N/5 . \quad (10)$$

Or after simplification:

$$F_3 = m/5 + 2F_2N/5 + 2F_3N/5 . \quad (11)$$

Similarly, for the fourth iteration:

$$F_4 = m/7 + 2F_2N/7 + 2F_3N/7 + 2F_4N/7 . \quad (12)$$

Analyzing (9), (11), (12), you can see some dependence and obtain a formula for estimating uncertainty for any decoding iteration:

$$F_J = \frac{m}{2I_j - 1} + \sum_{i=2}^{J} \frac{2F_i}{(2I_J - 1)N} . \quad (13)$$

Specificity object adaptation (wireless system TC) will be adapted to determine the parameters by changing which progress can be adaptive management. Such adjustment parameters include:

- Polynomial generators RSCC;
- The length of the input data block;
- The type of unit permutation;
- Coding rate;
- Matrix perforations;
- The number of decoding iterations;
- Decoding algorithm.

Analysis of simulation results

Figure 4 shows a graph of estimating uncertainty F_J of SNR E_b / G_0 for different decoding iterations, the resulting simulation. Unused turbo code with regular interleaver, the decoding algorithm Map, the number of bits in the block $N = 1000$. Figure 5 shows the same relationship, but a turbo code used in a pseudo-random interleaver.

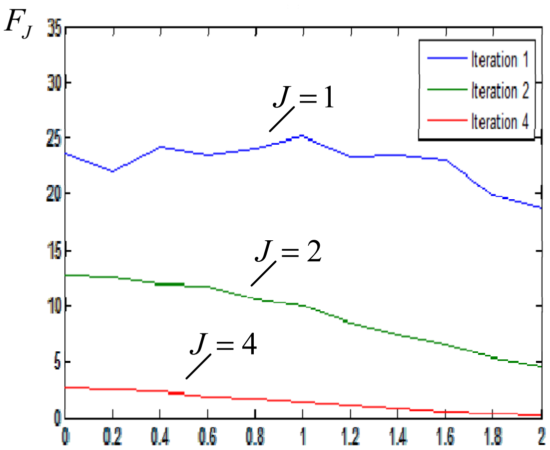

Fig. 4. Estimating uncertainty F_J of SNR E_b/G_0 for different decoding iterations

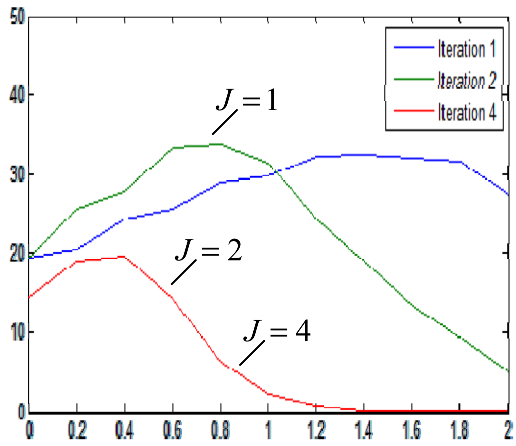

Fig. 5. Estimating uncertainty F_J of SNR E_b/G_0 for different decoding iterations

Conclusion

This paper presents a method of monitoring the state of the radio channel using statistical information of the turbo decoder, the use of which in the adaptive system will allow carrying out its restructuring under varying random actions.

For further development of an adaptive system with turbo codes is necessary to analyze a fixed set of system configurations that will occur between switching and develop a strategy for adaptive behavior in the state space.

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