ISSN 0735-2727, Radioelectronics and Communications Systems, 2017, Vol. 60, No. 1, pp. 18–27. © Allerton Press, Inc., 2017.
Original Russian Text © S.V. Zaitsev, V.V. Kazymyr, 2017, published in Izvestiya Vysshikh Uchebnykh Zavedenii, Radioelektronika, 2017, Vol. 60, No. 1, pp. 25–36.

Structural Adaptation of the Turbo Code Coder and Decoder for Generating the Transmission Repeat Request under Conditions of Uncertainty

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Received in final form August 7, 2016

Abstract—The paper deals with the issue of enhancing the performance efficiency of wireless networks built by using the with automatic repeat request scheme for retransmission. The proposed method is based on adaptive change of polynomials of recursive systematic convolutional codes forming a part of turbo codes and aimed at enhancing their correcting properties at the expense of increasing the code limitation at each data block retransmission for the set coding rate. In this case, the decoding algorithm of turbo codes is modified in respect of using the introduced additional a priori information during the calculation of logarithmic ratios of likelihood functions or log-likelihood ratios (LLR) for each component decoder obtained during the earlier repeat requests for retransmission. The results of simulation modeling showed that the application of this technique made it possible to obtain the energy gain in coding and enhance the data transmission accuracy as compared to the fourth generation mobile communication system, such as 4G LTE-Advanced.

DOI: 10.3103/S0735272717010034

INTRODUCTION

Correcting codes with variable redundancy are applied in many wireless telecommunication systems with feedback [1–3]. The specified codes were initially called rate-compatible repetition convolutional (RCRC) codes [4] and rate-compatible punctured convolutional (RCPC) codes [5, 6]. The codes using a priori known inserted bits in the code word structure were proposed as an The coding rate that affects correcting capabilities of codes with variable redundancy is adapted depending on the state of the data transmission channel for ensuring the set characteristics of data transmission accuracy. To this end, standard IEEE 802.16e (WiMAX) [1] and standard IEEE 802.11n (WLAN) [2] employ low-density parity-check (LDPC) ensembles of codes [8–11], while system UMTS LTE [3] utilizes the turbo code [12, 13].

ANALYSIS OF STUDIES AND PUBLICATIONS

The standard automatic repeat request (ARQ) scheme implies that the cyclic redundancy check (CRC) bits are added to the transmitting frame, and the error detection at the receiving side takes place by using CRC. If the CRC code detects an error in the received frame, the retransmission of this frame takes place due to a repeat request from the receiver. The corresponding message is transmitted via a feedback link; in this case, the error-free reception of frame is designated as Acknowledge (ACK), while the reception with error is designated as Negative Acknowledge (NACK).

HARQ (Hybrid ARQ) schemes [14–16] combine a noise-immune code (e.g., turbo code) with standard ARQ code. Additional application of noise-immune code with variable redundancy in HARQ schemes makes it possible to enhance the data transmission accuracy and reduce the number of repeat requests for transmission thus resulting in a reduced delay of the received data processing.

There are three basic types of HARQ schemes:

1. HARQ type-1 [15]. Each coded frame of data is retransmitted when the CRC code detects an error in the received data block at the receiving side. Frames containing errors are discarded and not used in the receiver. In this case, the number of retransmissions does not exceed the set number.

2. HARQ type-II [14]. Unlike HARQ type-1, in this case the redundancy of data frame increases with each successive retransmission request. Redundant information is combined in the receiver prior to channel

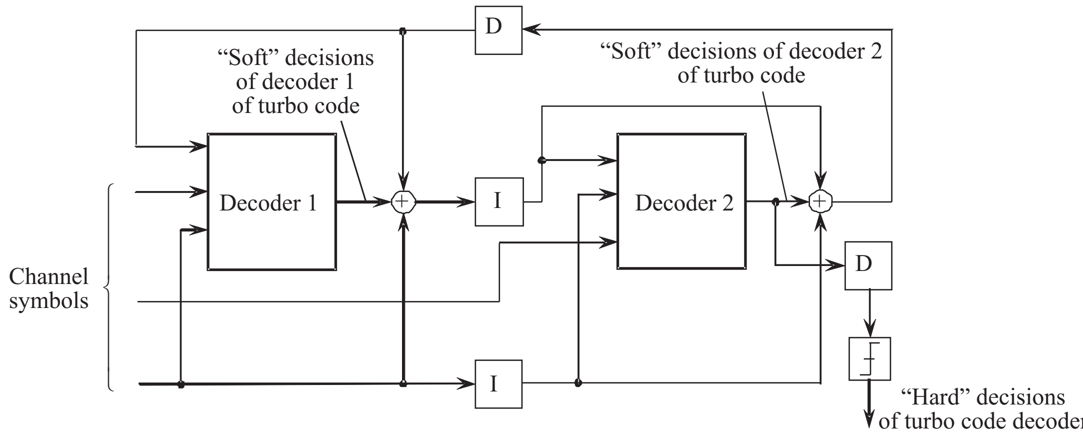

Fig. 1.

decoding and is used for enhancing the reliability of decision making in the process of data bit decoding. This scheme is called HARQ with increasing redundancy.

3. HARQ type-III [16]. This scheme combines HARQ type-1 and HARQ type-II. Each coded data frame contains the "weighted" redundancy that is determined depending on the current signal-to-noise ratio in the channel and is combined in the receiver prior to channel decoding.

At present, the variable-redundancy codes are applied in hybrid automatic repeat request schemes (HARQ type II and HARQ type III) [14], where a receiver can generate automatic repeat request for a certain data block. For example, the mobile communication system LTE employs the HARQ type-II scheme. The coding rate varies in a wide range [17]. The application of turbo code in combination with ARQ schemes is shown in [18, 19]. These papers employ also the CRC code for error detection in received combinations, while the HARQ scheme provides only for the regulation of the coding rate.

A disadvantage of HARQ schemes implies that these schemes ignore the possibility of enhancing the specified index of data transmission accuracy at the expense of additional adaptive complication of the coder and decoder structure for variable-redundancy schemes that does not require an introduction of additional redundancy. In addition, the specified systems do not involve the possibility of their effective operation under conditions of exposure to deliberate interferences. Such interferences can materially affect the data transmission accuracy that leads to the emergence of uncertainty in decision-making. In this case, it is possible to simultaneously use the schemes of adaptation with variable redundancy and the change of the coder and decoder structure of noise-immune code, e.g., turbo code.

PROBLEM STATEMENT

The purpose of this study is to develop a structural adaptation method for the turbo code coder and decoder of wireless data transmission system aimed at generating a hybrid automatic repeat request of transmission based on the control of channel quality state in terms of indirect indicators and adaptive increase of the code limitation length of recursive systematic convolutional codes forming a part of turbo codes for the purpose of enhancing their correcting properties during the data block retransmission. In this case, the employed decoding algorithm is modified regarding the use of introduced additional a priori information in calculating the log-likelihood ratios (LLR) of each component decoder with due regard for the decoding results obtained during the previous retransmission requests.

MAIN BODY

The principle of the structural adaptation method for the turbo code coder and decoder aimed at ensuring the specified indices of data transmission accuracy consists in the change of polynomials of recursive systematic convolutional codes of turbo codes and trellis diagram of states in decoding the information sequence with due regard for additional a priori information at each successive retransmission of data block. The existing methods of data retransmission using the variable redundancy codes for enhancing the data transmission accuracy do not involve the variation of code polynomials.

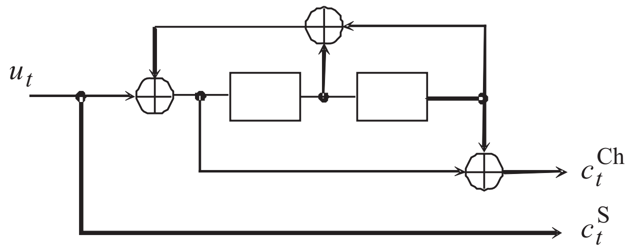

Fig. 2.

The high efficiency of turbo codes largely depends on principles of generating code combinations and probabilistic decoding algorithms developed for them that take into account both a posteriori and a priori information for enhancing the reliability of decoding. The correcting capacity of code is based on performing several stages of decoding or decoding iterations. The specified property is used as a basis for building algorithms of turbo code decoding aimed at enhancing the decoding reliability when a posteriori information of turbo code decoder after the operation of interleaving or deinterleaving is used as a priori information for the next decoder.

Figure 1 presents a functional block-diagram of turbo code decoder consisting of two elementary decoders, each of which performs the decoding of information generated by an appropriate component recursive systematic convolutional code (RSCC) and also two deinterleavers. The interleavers are similar to those used in the coder.

Each turbo code decoder calculates LLR for transmitted data bits presented in the form of "soft" decisions. In this case, the absolute value of obtained quantity is proportional to likelihood (reliability) of transmitted bit, while the sign corresponds to the value of symbol: minus and plus correspond to zero and unity, respectively.

LLR for each transmitted bit obtained by component decoder of turbo code in the process of decoding are transposed or detransposed (depending on the decoder used) that results in the reduction of correlation links between information and check symbols and also in the increase of turbo code correcting properties.

A scheme of recursive systematic convolutional code (1, 5/7) with code limitation $K = 3$ is shown in Fig. 2. The structure of this code has the form: $(1, g_1 / g_0)$, where g_0 is the feedback polynomial, g_1 is the feedforward polynomial.

Each RSCC performs the coding of information sequence over its trellis diagram, the structure of which depends on polynomial generators. As the order of polynomial increases, the size of trellis diagram also increases in accordance with law 2^M, where M is the number of memory cells of RSCC, $M + 1 = K$, where K is the code limitation of RSCC. In this case, the algorithm of turbo code decoding becomes more complicated, and the correcting capacity of the code is enhanced.

Information bit u_t, $t \in \overline{1, N}$ of the block having size N is applied to the RSCC input at instant time t. RSCC of turbo code depending on the value of input bit generates systematic c_t^{S} and check c_t^{Ch} bits, $t \in \overline{1, N}$, c_t^{S}, $c_t^{\mathrm{Ch}} \in (0,1)$. The implementation of phase modulation procedure of 2PSK signal implies the need of transforming systematic c_t^{S} and check c_t^{Ch} bits into systematic x_t^{S} and check x_t^{Ch} symbols, $t \in \overline{1, N}$, $x_t^{\mathrm{S}}, x_t^{\mathrm{Ch}} \in (-1,1)$. The code word of turbo code is formed by the parallel connection of two RSCC separated by interleaver [12]. As a result of turbo coding, each systematic bit c_t^{S} corresponds to two check bits c_t^{Ch1} and c_t^{Ch2} that are next transformed into symbols $x_t^{\mathrm{S}}, x_t^{\mathrm{Ch1}}, x_t^{\mathrm{Ch2}} \in (-1,1)$.

Transmitted symbols in the communication channel are exposed to noises and deliberate interferences that can be presented as a white Gaussian noise in the limited frequency band. Hence, the systematic and check symbols at the output of the discrete-continuous channel will be random quantities distributed according to the normal distribution law:

$$y_t^{\mathrm{S}} = x_t^{\mathrm{S}} + n_t^{*},$$

$$y_t^{\mathrm{Ch1}} = x_t^{\mathrm{Ch1}} + n_t^{**},$$

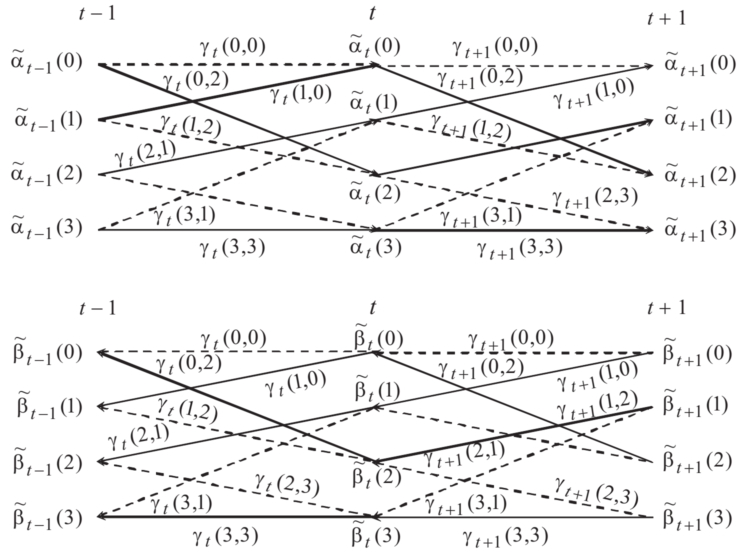

Fig. 3.

$$y_t^{\mathrm{Ch2}} = x_t^{\mathrm{Ch2}} + n_t^{***},$$

where n_t^{*}, n_t^{**}, n_t^{***}, $t \in \overline{1,N}$ are samples of the white Gaussian noise. Systematic and check symbols y_t^{S}, y_t^{Ch1}, y_t^{Ch2}, $t \in \overline{1,N}$ from the channel output are fed to the input of turbo code decoder.

Decoding of turbo codes is performed by using the algorithm of decoding in terms of maximum a posteriori probability (MAP) that performs the calculation of a posteriori probability of each decoded symbol minimizing the error probability of information symbol (bit) [20, 21]. Decoding of turbo codes proceeds over the same trellis diagram, according to which operates each RSCC of turbo code.

Trellis diagrams for other RSCC, for example, code (1, 39/33) or (1, 47/43) can be obtained in a similar way. In this case, the number of RSCC states will increase to 2^M, where M is the number of RSCC memory cells. The number of diagrams is equal to the number of bits in the block of size N. In this case, the decoding of each bit involves the need of calculating the forward $\tilde{\alpha}_{t-1}(s')$, backward $\tilde{\beta}_t(s)$ and transition recursions $\gamma_t(s',s)$, $t \in \overline{1,N}$, and also LLR for transmitted bit $L(u_k)$.

As an example, Fig. 3 shows the MAP decoding algorithm of two turbo code bits for RSCC having the form (1, 5/7). The decoding proceeds in two directions: the forward and transition recursions are calculated from the beginning to the end of block for each state of turbo code, while the calculation of backward recursions proceeds from the end to the beginning of block using the transition recursions obtained during the first direction of calculations.

The implementation of automatic repeat request of transmission involves the change of RSCC polynomials, generation of appropriate trellis diagram of states, and the calculation of appropriate recursions and likelihood functions. Let us consider these calculations in a detail.

LLR for transmitted bit $L(u_t)$ depends on the channel information $L_{\mathrm{c}}(y_t)$, a priori information about transmitted bit $L_{\mathrm{a}}(x_t)$ and a posteriori LLR generated directly by the decoder proper $L_{\mathrm{d}}(x_t)$. Therefore, in decoding bit y_t for performing calculations by the first decoder at decoding iteration j, $j \in \overline{1,I}$, where I is the total number of decoding iterations, LLR expression can be written as follows [20]:

$$L^{1,j}(x_t) = \log \frac{\sum\limits_{\substack{(s',s)\\ u_t=1}} \tilde{\alpha}_{t-1}^{(1)}(s')\,\tilde{\beta}_t^{(1)}(s)\,\gamma_t^{(1)}(s',s)}{\sum\limits_{\substack{(s',s)\\ u_t=0}} \tilde{\alpha}_{t-1}^{(1)}(s')\,\tilde{\beta}_t^{(1)}(s)\,\gamma_t^{(1)}(s',s)} = L_{\mathrm{c}}^{1,j}(y_t) + L_{\mathrm{a}}^{1,j}(x_t) + L_{\mathrm{d}}^{1,j}(x_t), \quad (1)$$

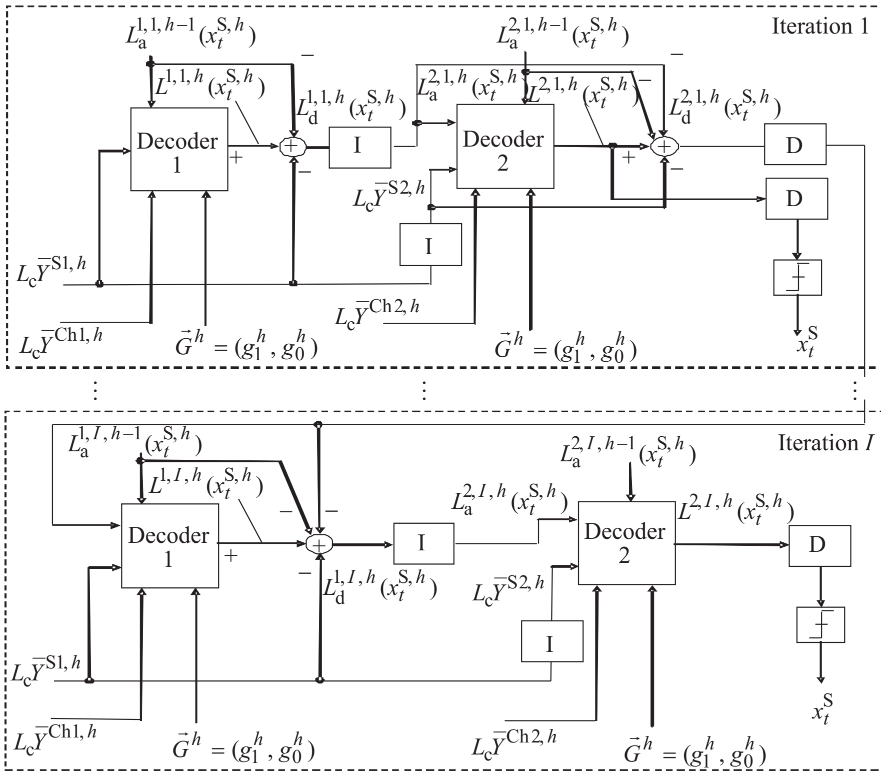

Fig. 4.

where $L_{\mathrm{c}}^{1,j}(y_t)$ is the channel information, $L_{\mathrm{d}}^{1,i}(x_t)$ is a posteriori LLR of data bit x_t, $\widetilde{\alpha}_{t-1}^{(1)}(s')$ is the normalized value of forward recursion $\alpha_{t-1}^{(1)}(s')$, $\widetilde{\beta}_t^{(1)}(s)$ is the normalized value of backward recursion $\beta_t^{(1)}(s)$.

Correspondingly, for the second decoder we obtain:

$$L^{2,j}(x_t) = \log \frac{\sum\limits_{\substack{(s',s)\\ u_t=1}} \widetilde{\alpha}_{t-1}^{(2)}(s')\widetilde{\beta}_t^{(2)}(s)\gamma_t^{(2)}(s',s)}{\sum\limits_{\substack{(s',s)\\ u_t=0}} \widetilde{\alpha}_{t-1}^{(2)}(s')\widetilde{\beta}_t^{(2)}(s)\gamma_t^{(2)}(s',s)} = L_{\mathrm{c}}^{2,j}(y_t) + L_{\mathrm{a}}^{2,j}(x_t) + L_{\mathrm{d}}^{2,j}(x_t). \tag{2}$$

Next, we calculate a posteriori LLR of data bit x_t generated by the decoder proper:

$$L_{\mathrm{d}}^{1,j}(x_t) = L^{1,j}(x_t) - L_{\mathrm{c}}^{1,j}(y_t) - L_{\mathrm{a}}^{1,j}(x_t). \tag{3}$$

After interleaver I, a posteriori LLR $L_{\mathrm{d}}^{1,i}(x_t)$ is transformed into a priori LLR $L_{\mathrm{a}}^{2,j}(x_t)$: $L_{\mathrm{a}}^{2,j}(x_t) = f_1(L_{\mathrm{d}}^{1,j}(x_t))$, where $f_1(\cdot)$ is the function performing the interleaving operation; the transformed LLR is fed to decoder 2. Decoder 2 performs similar calculations for obtaining quantity $L_{\mathrm{d}}^{2,j}(x_t)$:

$$L_{\mathrm{d}}^{2,j}(x_t) = L^{2,j}(x_t) - L_{\mathrm{c}}^{2,j}(y_t) - L_{\mathrm{a}}^{2,j}(x_t). \tag{4}$$

After performing the deinterleaving operation D: $L_a^{1,j+1}(x_t) = f_2(L_d^{2,j}(x_t))$, where $f_2(\cdot)$ is the function performing the deinterleaving operation, quantity $L_a^{1,j+1}(x_t)$ can be used as an a priori one for decoder 1 of iteration $j + 1$. Next, it is necessary to carry out calculations similar to expressions (1) and (2). After performing all iterations of decoding, "hard" decisions are made regarding the transmitted bit: $\tilde{u}_t = \text{sign}[L(u_t)]$. The modified decoder diagram of turbo code is shown in Fig. 4.

The process of structural adaptation of turbo code coder and decoder for generating the automatic repeat request of data retransmission under conditions of uncertainty can be presented in the form of algorithm 1.

Algorithm 1 (the *i*th decoder of the *j*th iteration is considered).

Step 1. Input of the initial data:

– the number of the automatic repeat requests of transmission h, $h \in \overline{1,H}$;

– parameters of the turbo code coder $\{I, N, P, K, \vec{G}, R\}$, where I is the number of iterations of turbo code decoding, N is the size of data block in bits, P is the type of interleaver, K is the number of component coders (decoders), $\vec{G}^H = (g_1^0, g_0^0, g_1^1, g_0^1, \ldots, g_1^H, g_0^H)$ is the vector of polynomials of turbo code coder that will be selected during the subsequent retransmission requests, the description of which together with functional block diagrams is presented above; R is the turbo code coding rate.

Step 2. The parameter of automatic repeat requests of retransmission is assigned the value $h = 1$ required for tracking the number of requests.

Step 3. Calculation of LLR of data bit x_t, $t \in \overline{1,N}$ by the *i*th decoder, $i \in \overline{1,2}$ of the *j*th decoding iteration, $j \in \overline{1,I}$ for all bits of block having length N of decoder 1 and 2 of decoding iterations $j \in \overline{1,I}$, where I is the total number of decoding iterations:

$$L^{i,j,h}(x_t) = \log \frac{\sum\limits_{\substack{(s',s)\\u_t=1}} \tilde{\alpha}_{t-1}^{(i)}(s')\tilde{\beta}_t^{(i)}(s)\gamma_t^{(i)}(s',s)}{\sum\limits_{\substack{(s',s)\\u_t=0}} \tilde{\alpha}_{t-1}^{(i)}(s')\tilde{\beta}_t^{(i)}(s)\gamma_t^{(i)}(s',s)}$$

$$= \log \frac{\sum\limits_{\substack{(s',s)\\u_t=1}} \tilde{\alpha}_{t-1}^{(i)}(s')\tilde{\beta}_t^{(i)}(s)\exp\left[\frac{1}{2}\left(x_t^{\mathrm{S},h}(L_a^{i,j,h}(x_t^{\mathrm{S},h}) + L_c y_t^{\mathrm{S},h}) + L_c y_t^{\mathrm{Ch}i,h} x_t^{\mathrm{Ch}i,h}\right)\right]}{\sum\limits_{\substack{(s',s)\\u_t=0}} \tilde{\alpha}_{t-1}^{(i)}(s')\tilde{\beta}_t^{(i)}(s)\exp\left[\frac{1}{2}\left(x_t^{\mathrm{S},h}(L_a^{i,j,h}(x_t^{\mathrm{S},h}) + L_c y_t^{\mathrm{S},h}) + L_c y_t^{\mathrm{Ch}i,h} x_t^{\mathrm{Ch}i,h}\right)\right]}$$

$$= L_c^{i,j,h}(y_t) + L_a^{i,j,h}(x_t) + L_d^{i,j,h}(x_t). \quad (5)$$

Step 4. Calculation of a posteriori LLR of data bit x_t, $t \in \overline{1,N}$ by the *i*th decoder, $i \in \overline{1,2}$ of the *j*th decoding iteration, $j \in \overline{1,I}$ for all bits of block having length N of decoder 1 and 2 of decoding iterations $j \in \overline{1,I}$:

$$L_d^{i,j,h}(x_t) = L^{i,j,h}(x_t) - L_c^{i,j,h}(y_t) - L_a^{i,j,h}(x_t). \quad (6)$$

Step 5. After completion of all decoding iterations, "strict" estimates are made regarding the decoded bits. If $h = H$, a jump is made to step 12.

Step 6. Error presence check in the received block by using the CRC-decoder.

Step 7. If errors exist in the received block of length N, signal HARQ is generated that is transmitted to the decoder for modifying the decoding algorithm, it is transmitted via feedback channel for data block retransmission and change of RSCC polynomials, and finally the jump to step 8 is executed. If no errors exist, the algorithm jumps to step 12.

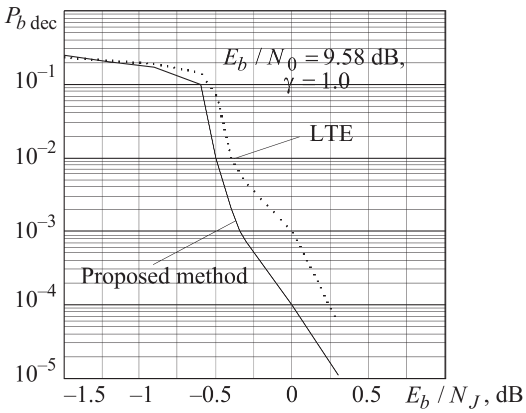

Fig. 5.

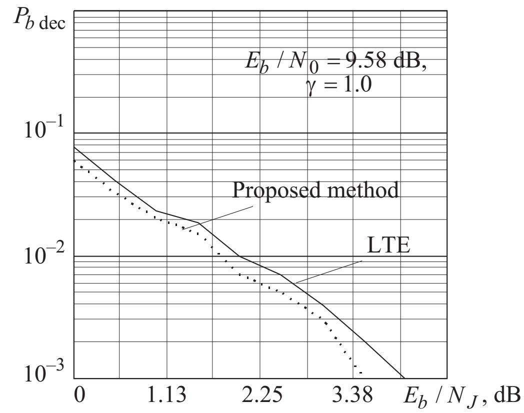

Fig. 6.

Step 8. The parameter of automatic backward transmission requests is assigned the value $h = h + 1$. If $h < H$, the jump is executed to step 9, otherwise—to step 5.

Step 9. Generation of the vector of new polynomials of RSCC $\vec{G}^h = (g_1^h, g_0^h)$ and change of the decoder structure with due regard for changes of RSCC trellis diagram.

Step 10. Calculation of LLR of data bit x_t, $t \in \overline{1, N}$ by the ith decoder for all bits of block having length N of decoder 1 and decoder 2 for decoding iterations $j \in \overline{1, I}$ with due regard for the change of the decoder structure depending on selected polynomials $\vec{G}^h = (g_1^h, g_0^h)$ and additional a priori information. The additional a priori information takes into account the results of decoding of data bit x_t, $t \in \overline{1, N}$ of previous request $h-1$ obtained by using the state diagram that is described by polynomials $\vec{G}^{h-1} = (g_1^{h-1}, g_0^{h-1})$:

$$L^{i,j,h}(x_t) = \log \frac{\sum\limits_{\substack{(s',s)\\u_t=1}} \tilde{\alpha}_{t-1}^{(i)}(s')\,\tilde{\beta}_t^{(i)}(s)\gamma_t^{(i)}(s',s)}{\sum\limits_{\substack{(s',s)\\u_t=0}} \tilde{\alpha}_{t-1}^{(i)}(s')\,\tilde{\beta}_t^{(i)}(s)\gamma_t^{(i)}(s',s)}$$

$$= \log \frac{\sum\limits_{\substack{(s',s)\\u_t=1}} \tilde{\alpha}_{t-1}^{(i)}(s')\,\tilde{\beta}_t^{(i)}(s)\exp\left[\frac{1}{2}\left(x_t^{\mathrm{S},h}(L_\mathrm{a}^{i,j,h}(x_t^{\mathrm{S},h}) + L_\mathrm{a}^{i,j,h-1}(x_t^{\mathrm{S},h-1}) + L_\mathrm{c}^{i,j,h} y_t^{\mathrm{S},h}) + L_\mathrm{c}^{i,j,h} y_t^{\mathrm{Ch}i} x_t^{\mathrm{Ch}i}\right)\right]}{\sum\limits_{\substack{(s',s)\\u_t=0}} \tilde{\alpha}_{t-1}^{(i)}(s')\,\tilde{\beta}_t^{(i)}(s)\exp\left[\frac{1}{2}\left(x_t^{\mathrm{S},h}(L_\mathrm{a}^{i,j,h}(x_t^{\mathrm{S},h}) + L_\mathrm{a}^{i,j,h-1}(x_t^{\mathrm{S},h-1}) + L_\mathrm{c}^{i,j,h-1} y_t^{\mathrm{S},h}) + L_\mathrm{c}^{i,j,h} y_t^{\mathrm{Ch}i} x_t^{\mathrm{Ch}i}\right)\right]}$$

$$= L_\mathrm{c}^{i,j,h}(y_t^{\mathrm{S},h}) + L_\mathrm{a}^{i,j,h}(x_t^{\mathrm{S},h}) + L_\mathrm{a}^{i,j,h-1}(x_t^{\mathrm{S},h-1}) + L_\mathrm{d}^{i,j,h}(x_t^{\mathrm{S},h}). \quad (7)$$

Step 11. Calculation of a posteriori LLR of data bit x_t, $t \in \overline{1, N}$ by the ith decoder for all bits of block having length N of decoder 1 and decoder 2 for decoding iterations $j \in \overline{1, I}$ with due regard for the change of the decoder structure depending on selected polynomials $\vec{G}^h = (g_1^h, g_0^h)$ and additional a priori information. The additional a priori information, similar to step 10, takes into account the results of decoding of data bit x_t, $t \in \overline{1, N}$ of previous request $h-1$ obtained by using the state diagram that is described by polynomials $\vec{G}^{h-1} = (g_1^{h-1}, g_0^{h-1})$:

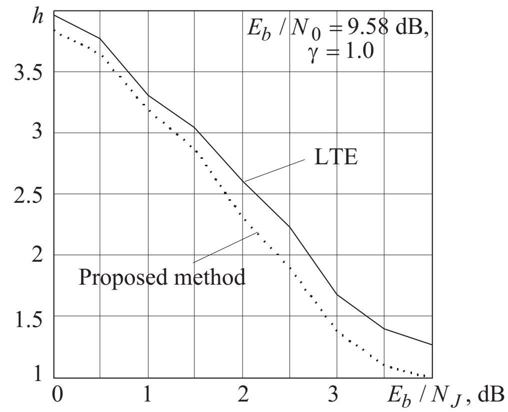

Fig. 7.

$$L_{\mathrm{d}}^{i,j,h}(x_t^{\mathrm{S},h}) = L^{i,j,h}(x_t^{\mathrm{S},h}) - L_{\mathrm{c}}^{i,j,h}(y_t^{\mathrm{S},h}) - L_{\mathrm{a}}^{i,j,h}(x_t^{\mathrm{S},h}) - L_{\mathrm{a}}^{i,j,h-1}(x_t^{\mathrm{S},h-1}). \quad (8)$$

Jump to step 5.

Step 12. Transfer of the decoded block to data recipient.

The estimation of the characteristics of data transmission accuracy by using the proposed method of structural adaptation of turbo code coder and decoder was performed by the simulation modeling method. The fourth generation mobile communication standard 4G LTE-Advanced was selected as an analog for comparing the proposed results.

Figures 5 and 6 show the results of simulation modeling that display the plots of the relationship of the average decoding bit error probability $P_{b\,\mathrm{dec}}$ as a function of signal-to-interference ratio E_b / N_J without applying the structural adaptation (similar to standard LTE) and with application of the structural adaptation of turbo code coder and decoder. In this case, the signal-to-noise ratio was selected equal to $E_b / N_0 = 9.58$ dB, where E_b is the energy of bit, N_0 is the spectral power density of white Gaussian noise, N_J is the spectral power density of deliberate interference presented in the form of spectrum-limited white Gaussian noise. The selected values of confidence were $\alpha = 0.95$ and $t_\alpha = 0.95$ (argument of the Laplace function), and the value of relative accuracy was $d = 0.1$. The number of bits in transmitted (received) block was selected equal to $N = 6{,}144$ for a pseudo-random interleaver (Fig. 5) and $N = 169$ for a regular interleaver (Fig. 6).

The plots of the relationship of the number of automatic repeat requests of transmission h as a function of the signal-to-interference ratio with and without application of the structural adaptation of turbo code coder and decoder are shown in Fig. 7. In this case, the parameters of turbo code coder and decoder are similar to those used in obtaining graphical relationships in Fig. 5.

The simulation was performed for a data transmission system with turbo codes operating under conditions of exposure to white Gaussian noise with spectral power density N_0 and the noise barrage jamming with spectral power density N_J. The interference bandwidth ratio was chosen to be $\gamma = 1.0$. We used the coder and decoder of the turbo code similar to one used in mobile communication standard LTE (long term evolution): with two component coders, pseudo-random interleaver and deinterleaver, the number of bits in transmitted (received) block amounted to $N = 6{,}144$, the decoding algorithm was MAP, the coding rate of turbo code was $R = 1/3$, and the number of decoding iterations was $I = 8$. The number of retransmissions was selected to be equal to $H = 4$.

For the first transmission of block, as a turbo code RSCC we used a code similar to standard LTE described by polynomial (1, 13/11). When the repeat request was received, RSCC polynomials became more complicated and changed in the following way: (1, 39/33), (1, 47/43), (1, 57/53). For comparison, polynomials in the LTE standard are not changed. In addition, we carried out the simulation for the above specified parameters of turbo code, but for the number of bits in transmitted (received) block $N = 169$ and the use of a regular interleaver.

The results of simulation modeling indicate (Figs. 5 and 6) that the application of the structural adaptation of turbo code coder and decoder of data transmission system for generating hybrid automatic repeat request of transmission under conditions of deliberate interferences makes it possible to enhance the data transmission accuracy, obtain the energy gain in signal-to-interference ratios and reduce the number of automatic repeat requests of data block transmission.

CONCLUSIONS

The paper proposes a new technique of structural adaptation of turbo code coder and decoder of wireless data transmission system for generating hybrid automatic repeat request of transmission under conditions of uncertainty in making decisions. This uncertainty is caused by the exposure of transmitted information sequence to high-power deliberate interferences.

Unlike the known results, in case of retransmission request, in addition to variation of the coding rate, the length of code limitation of component codes is increased that contributes to enhancing the data transmission accuracy without reducing (affecting) the channel throughput. In this case, the employed decoding algorithm is modified with due regard for additional a priori information. The method makes it possible to reduce the correlation between check symbols that results in decrease of uncertainty during turbo code decoding.

The simulation modeling results for the data transmission system operating under conditions of exposure to deliberate interferences showed that the use of structural adaptation of turbo code coder and decoder for generating the hybrid automatic data transmission repeat request made it possible to enhance the data transmission accuracy and reduce the number of errors by a factor of 10, obtain the energy gain in signal-to-interference ratios of 0.35 dB, and decrease the number of automatic data block retransmission requests by 7.5%.

Directions of further of investigations include the use of adaptive selection of the size of transmitted data block and the type of interleaver during the structural adaptation of turbo code coder and decoder for generating the hybrid automatic transmission repeat request.

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