DECODING ALGORITHM FOR THE BOWES-CHAUDHURY-HAKWENGHAM (BCH) CODE TO PROVIDE INCREASED IMMUNITY IN THE DVB-T2 STANDARD DIGITAL TELEVISION SYSTEM

A.B. Jabborov.
Tashkent State Technical University, 100095, Tashkent city, Republic of Uzbekistan

Abstract. *In this paper, a decoding algorithm for the Bowes-Chowdhury-Hawkvingham code has been developed to provide an increase in noise immunity in a digital television system of the DVB-T2 standard. Decoding stages are described taking into account the choice of communication channel: Gaussian (AWGN), Rice and Rayleigh..*

Keywords: *Decoding algorithm, Bowes-Chowdhury-Hokvingham code, noise immunity, DVB-T2 standard, primitive Galois field element, error locators, signal/noise, syndrome, bit block.*

Bowes-Chowdhury-Hokvingham (BCH) error-correcting codes is a cyclic multiple error correcting code.

The most popular method used in BCH codes for error correction is the syndromic method. It is based on a one-to-one correspondence between the variety of correctable errors and their many syndromes. The direct path - "syndrome - error" - is implemented in the historically first decoders [1].

To decode BCH codes, in particular, in the time domain, algebraic procedures are used, as a result of which syndromes are found and numbers of erroneous positions are determined by solving the polynomial of error locators using the Chen algorithm [2].

In practice, in a digital television system, Bowes-Chowdhury-Hokvingham codes are used for external coding.

To receive a digital signal of the DVB-T2 standard in terrestrial broadcasting, it is necessary to take into account the receiving channels such as the Gaussian channel (AWGN), Rice and Rayleigh to determine and measure the signal-to-noise ratio C / N.

It can be noted that the channels for receiving digital signals of the DVB-T2 standard are characterized as follows:

1. The Gaussian channel defines and characterizes the ideal reception case.
2. The Rice channel determines and characterizes reception in the presence of impulse noise using a stationary directional antenna (on the roof and at low levels of reflected signals).

3. The Rayleigh channel determines and characterizes the reception of signals indoors and outdoors when using an indoor antenna.

The initial data for the BCH decoding algorithm are: the Gaussian (AWGN), Rice and Rayleigh channel, the adoption of an n-bit code block $\vartheta(x)$ from the channel, the m-bit block representing the coefficients of the generator polynomial of the BCH code g(x) and the array *(n=2^μ-1)* symbols of the field *GF(2^μ)*.

The algorithm for decoding the BCH code is shown in Fig. 1, where e_{n-j}, the j-th coefficient of the error polynomial. Taking into account the fact that there are not always t errors in $\vartheta(x)$, in order to speed up the execution of the BCH code decoding algorithm, it is necessary to identify cases where decoding is carried out with less complexity. The algorithm has the following three stages:

1) No errors - execution of blocks 1-10.12;

2) The presence of a single error - the execution of blocks 1-11,13,14,16,23,24;

3) The presence of more than one error - the execution of blocks 1-11,13-15,17-24.

The syndromic polynomial S(x) is calculated by the formula

$$S(x) = R_{g(x)}[\vartheta(x)] = \sum_{j=0}^{m-1} S_j\, x^j \qquad (1)$$

where S_j is a binary variable (0,1). The division of polynomials with binary coefficients is performed.

Blocks 4-9 are involved in determining S(x). It is assumed that n bits of the code block and m coefficients g(x), excluding g_m, are in memory. First, the channel is selected and set: Gaussian (AWGN), Rice and Rayleigh (block 1), then an array L is formed, consisting of n bits of the code block ϑ(x) (block 2). After the array L is formed, it is shifted to the left by one bit without losing the shifted bit α (block 3) and analyzed for zero α (block 10). If it is equal to one, then summation modulo two of the arrays L and G is performed (block 11). If α is zero, this block is skipped. After k cycles, the calculation of S(x) ends, the remainder of the division is stored in the cells of the array L.

The values of the syndromic polynomial *S(x)* at the points $x = \alpha^j$, $j = 1 \ldots\ldots, 2t$, are called syndromes *Sj*:

$$S_j = S\left(\alpha^j\right) = \sum_{i=0}^{m-1} S_i\, x^{ij} \qquad (2)$$

This mathematical model (2) can be represented as

$$S_j = \left(\ldots.\left(\left(S_{m-1} \cdot \alpha^j \oplus S_{m-2}\right) \cdot \alpha^j \oplus S_{m-3}\right) \cdot \alpha^j \oplus \ldots.\oplus S_1\right) \cdot \alpha^j \oplus S_0 \qquad (3)$$

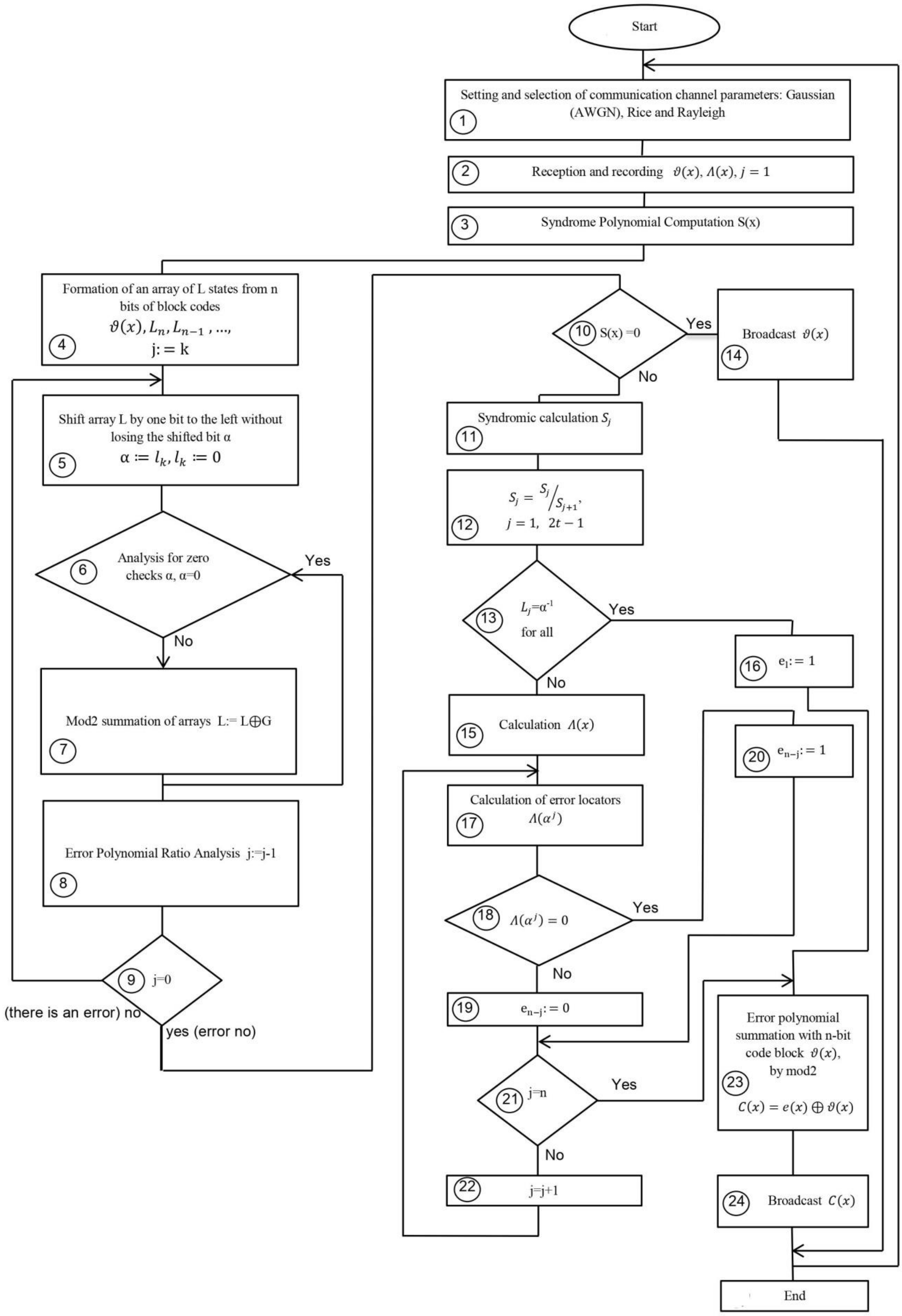
Start
Setting and selection of communication channel parameters: Gaussian (AWGN), Rice and Rayleigh
Reception and recording $\vartheta(x), \Lambda(x), j = 1$
Syndrome Polynomial Computation S(x)
Formation of an array of L states from n bits of block codes $\vartheta(x), L_n, L_{n-1}, \ldots,$ $j := k$
Shift array L by one bit to the left without losing the shifted bit α $\alpha := l_k, l_k := 0$
Analysis for zero checks α, α=0
Yes
No
Mod2 summation of arrays L:= L⊕G
Error Polynomial Ratio Analysis j:=j-1
j=0
(there is an error) no
yes (error no)
S(x) =0
Yes
No
Broadcast $\vartheta(x)$
Syndromic calculation S_j
$S_j = S_j / S_{j+1}$, $j = 1, 2t - 1$
$L_j = \alpha^{-1}$ for all
Yes
No
$e_l := 1$
Calculation $\Lambda(x)$
$e_{n-j} := 1$
Calculation of error locators $\Lambda(\alpha^j)$
$\Lambda(\alpha^j) = 0$
Yes
No
$e_{n-j} := 0$
Error polynomial summation with n-bit code block $\vartheta(x)$, by mod2 $C(x) = e(x) \oplus \vartheta(x)$
j=n
Yes
No
j=j+1
Broadcast $C(x)$
End

Fig.1. Bowes-Chowdhury-Hokvingham (BCH) code decoding algorithm to improve noise immunity

where * is the multiplication in the Galois field $GF(2^{\mu})$; α is a primitive element of the Galois field $GF(2^{\mu})$.

Let us represent this mathematical model as a recursive equation of the type

$$S_N = S_{N-1} \cdot \alpha^j \oplus S_{m-N-1}\ , \qquad (4)$$

$$N=0,1,2,\ldots,m-1;$$

$$S_{-1}=0,\ S_{m-1}= S_j$$

where S_N is a partial sum of terms of formula (3).

The presence of a single error is determined by the existence of such a value of l, in which $S_j / S_{j+1} = \alpha^{j-i}$ for all j , $0 \leq j \leq 2t\text{-}2$. This value of l specifies the position of a single error.

The error locator polynomial coefficients $\Lambda(x)$ are calculated by the algorithm for determining the error locator polynomial from the known syndromes S_j , $j=1,\ldots\ldots,2t$.

$$S_j \oplus \sum_{i=1}^{t} S_{j-1} \Lambda_i = 0\ ,\ j=t+1,\ldots\ldots,\ 2t \qquad (5)$$

To calculate Λ(x), we use the Berlekamp-Massey algorithm. The next step is decoding and calculating the error polynomial e(x):

$$_j = \begin{cases} 1, If\ \Lambda(\alpha^j) = 0 \\ 0,\ b\ \ otherwise \end{cases} \qquad (6)$$

The values of the polynomial $\Lambda(x)$ are calculated for all elements of the field $GF(2^{\mu})$; this procedure is known as Chen's procedure.

The last stage of decoding the BCH code is error correction by modulo two summation of the error polynomial and the code word.

$$\vartheta'(x) = \vartheta(x) \oplus e(x) \qquad (7)$$

This completes the decoding stage and again with the selection and installation of the communication channel, it will be possible to decode the acceptance of a digital binary signal to ensure noise-immune reception of signals.

The results show that such a code provides protection of information from errors, correction of errors of large multiplicity, and the less likely it is to interfere with the communication channel, the less will be the erroneous reception of binary symbols. The required efficiency, in this case, is achieved through the use of feedback.

With the introduction of this BCH code decoding algorithm in a DVB-T2 digital television system, the noise immunity of the optimal reception of digital television signals increases. When achieving the same BER values in the DVB-T and DVB-T2 standards, using a new unique error-correcting coding in the DVB-T2 standard: BCH, the gain in the signal-to-noise ratio can average 3-5 dB. The developed decoding algorithm with the choice of communication channel: Gaussian (AWGN), Rice and Rayleigh, can practically be used to study and analyze the increase in noise immunity in a digital television system of the DVB-T2 standard.

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