Modified Min Sum Algorithm for Next Generation Satellite Broadcasting System: ABS-S

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***Abstract*—The Advanced Broadcasting System for Satellite (ABS - S) is a new satellite TV and sound broadcasting system. In comparison to Digital Video Broadcasting (DVB - S2) it offers same performance but with lower complexity for future satellite digital broadcasting. The system are employed with Low-Density Parity-Check (LDPC) codes which offers channel capacity close to the shannon's limit with iterative probabilistic decoding algorithm. For decoding with LDPC codes, sum product and min sum algorithms are used. This paper presents and overview of ABS - S system and a *modified min sum algorithm* (MMS) for decoding. The proposed algorithm is based on computation of sub - minimum value and a correction factor $\hat{\gamma}$ which is based on minimum and sub - minimum value of extrinsic information. We achieved improvement of BER performance with short block length LDPC by applying correction factor $\hat{\gamma}$ to messages sent from check node to bit node. Simulation results shows that the modified min sum algorithm performs better as compared to the MS algorithm and Sum Product (SP) algorithm with a reasonable complexity.**

***Keywords* - ABS-S, Digital Video Broadcasting (DVB-S2), Low-Density Parity-Check (LDPC) codes, Min-sum algorithm, Modified min-sum algorithms.**

I. Introduction

DIGITAL satellite transmission system was first Proposed by European Telecommunications Standards Institute (ETSI) under there DVB project in 1993 [8]. It is initial standard for satellite delivery of digital television, data services (DVB-S), digital satellite news gathering (DSNG). The system used a serial concatenation of an outer reed solomon code and an inner variable rate convolution code. To meet the increases in demand for larger capacity and innovative services in satellite broadcast, a new standard called as DVB-S2 was enacted [8]. DVB-S2 has been designed for different types of applications such as broadcast services for SDTV and HDTV, interactive services including internet access for consumer applications and the professional applications encompassing digital TV contribution and news gathering, data content distribution and internet trunking.

The DVB-S2 standard was based around three major concepts of best transmission performance, total flexibility, and reasonable receiver complexity. The LDPC is the key subsystem in channel coding mainly responsible for the significant improvement in satellite link performance in the presence of noise and interference. To achieve the best BER performance DVB-S2 adopted serial concatenation of an outer BCH code and inner LDPC code with higher modulation scheme (QPSK, 8PSK, 16APSK and 32APSK). Without any concatenated code with block length shorter than 64800 bits, LDPC code in DVB - S2 produces BER performance poor than the required performance of 10^{-7} in digital video broadcasting [5].

In the recent years academy of broadcasting science, SARFT has proposed next generation satellite TV broadcasting system (ABS-S) [4]. It is a low cost system using short block length with optimized frame structure. This system does not use BCH code & thus results in reduce complexity. It has been claimed in the literature that ABS-S is capable of supporting interactive services in consumer IRD, personal computers and other interactive satellite communication devices. The high level function blocks for the ABS - S transmission system are shown in figure 1.

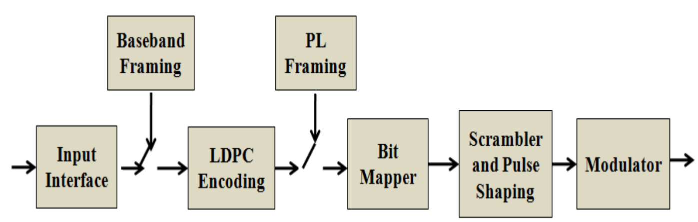

Fig. 1. Functional block diagram of the ABS - S transmission system

The transmission system is defined as a series of functional blocks. It takes the transport stream or generic packet data as input and formatted them into Forward Error Correction (FEC) blocks. The LDPC code is used to encode each block into coded blocks, codeword. After that synchronization words and other necessary overheads are inserted. The pulse-shaping is than achieved using a filter which remove aliasing effect. The signal is up-converted in to a desired radio frequency [2]. The main purpose of Error Correcting Code (ECC) design is to construct LDPC codes with a reduction in transmission power consumption and to lower the error to provide satisfactory services.

A. LDPC code in DVB-S2 and ABS-S

With a reasonable complexity in comparison to the LDPC codes in the DVB-S2 standard, the family of LDPC codes in ABS-S has several advantages. First, without any concatenated codes, it is possible to reach 10^{-7} BER which is required for digital video broadcasting system with reduced complexity dramatically [3]. Second, LDPC code in ABS-S uses shorter block length 15360, in contrast to block length of 64800 used in DVB-S2 system. In general, from application point of view shorter block length is more preferable as compared to long length because of hardware implementation. Third, LDPC code in ABS-S support variable code rates with QPSK/ 8PSK/ 16APSK/ 32APSK modulation for different applications and different mode adaptation like Adaptive Coding Modulation (ACM), Variable Coding Modulation (VCM), Constant Coding Modulation (CCM) [4].

II. LDPC DECODING IN ABS-S

The min-sum product process is almost completely determined by the magnitude and sign of the minimum value [1] [6]. The MS algorithm suffers from performance degradation in terms of bit error rate due to this minimum value. In this section we propose an algorithm based on sub - minimum value which has its effect on decoding performance. First we describe the process for computing the correction factor followed by developing an algorithm applying the proposed correction factor as used in ABS-S system.

A. Computation of Correction factor

Each iteration of our the proposed algorithm consists of two phases

1) Updating sub - minimum value and compute correction factor
2) Update bit node

We intend to take the sub - minimum value into consideration and find correction factor $\hat{\gamma}$ which is related to decoding process. The process of computing correction factor is as follows. Let $m1$, $m2$ denote the minimum and sub - minimum value of $\mid M_{j,i'} \mid$ respectively. Using property of $\phi(x) = -log[tanh(x/2)]$ [9], for $x > 0$, where the smaller x has larger value of $\phi(x)$. We can make an approximation that

$$\phi\left(\sum_{i\neq i'} \phi(\mid M_{j,i'} \mid_{min_{i\neq i'}})\right) = \phi[\phi(m1) + \phi(m2)] \qquad (1)$$

also assume that

$$\phi[\phi(m1) + \phi(m2)] = \hat{\gamma} \;\; m1 \qquad (2)$$

On solving, we get correction factor in terms of $m1$ and $m2$

$$\hat{\gamma} = \frac{1}{m1} log\left[\frac{1 + e^{(m1+m2)}}{e^{m1} + e^{m2}}\right] \qquad (3)$$

Figure 2 shows correction factor $(\hat{\gamma})$ changes slightly as minimum value $(m1)$ changes. It also shows that along with the increasing $m2$, correction factor $(\hat{\gamma})$ also increasing and converges from 0 to 1. As a result the curves with different $m1$ value are very close to each other. According to the above analysis, it seems that the sub - minimum value among the extrinsic messages from the variable nodes plays an important role in the valuation of the correction factor $(\hat{\gamma})$. By allowing the factor to change at each iteration in view of the sub-minimum value, the MMS algorithm can improve the BER performance. An algorithm for ABS-S system based on correction factor $\hat{\gamma}$ is presented below.

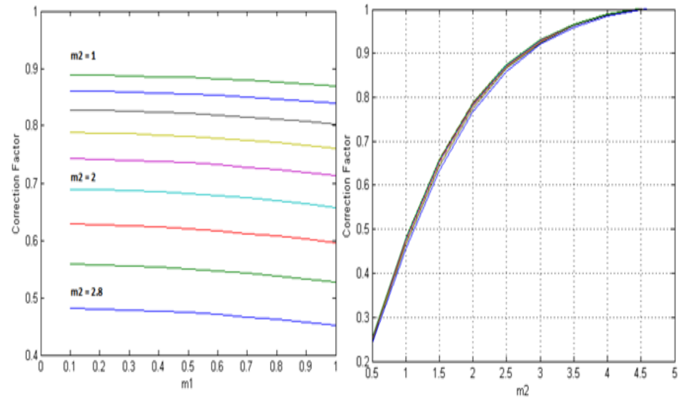

Fig. 2. Relation between correction factor and $m1$, $m2$

B. Algorithm for ABS-S system

The notations used in the proposed algorithm are defined as follows.

- λ_n = LLR of priori message probabilities.
- $C_{m,n}$ = Messages sent from the bit node *n* to the check node *m*.
- $\alpha_{m,n}$ = Messages sent from check node *m* to bit node *n*.
- $\hat{\gamma}$ = Correction factor.
- $m1, m2$ = minimum and sub - minimum value respectively.

Initialization :
Compute the log likelihood ratio λ_n for each bit nodes *(n=1,2,...,N)* using received data by channel.
Set $C_{m,n} = \lambda_n$ for each *(m,n)* with satisfying $H_{m,n}$ = 2.

Phase 1 : Check message
Calculate LLR message form connected check node *m* to bit node *n* using equation

$$\begin{aligned}(\alpha_{m,n})_{MS} &= \left(\prod_{n\neq n'} sign(C_{m,n'})\right) min_{n\neq n'} \mid C_{m,n'} \mid \\ (\alpha_{m,n})_{MMS} &= \hat{\gamma}\;(\alpha_{m,n})_{MS} \qquad (4)\end{aligned}$$

$$where \quad \hat{\gamma} = \frac{1}{m1} log\left[\frac{1 + e^{(m1+m2)}}{e^{m1} + e^{m2}}\right] \qquad (5)$$

Phase 2 : Bit message
Updated bit node can be calculated using

$$L(q) = \lambda_n + \sum_{m\in C_n} (\alpha_{m,n})_{MMS} \qquad (6)$$

Decision :
Compute tentative LDPC codeword $y_n \simeq$ sign [L(q)]

$$y_n = \begin{cases} 0 & \text{if sign [L(q)] = 1;} \\ 1 & \text{if sign [L(q)] = -1.} \end{cases}$$

Termination :
Repeat this procedure until $H \cdot (y_1, y_2 .... y_n)^T = 0$ or maximum number of iteration otherwise go to Phase 1 and continue with iteration.

III. Performance Evaluation and Numerical Results

In this section we analyze simulation results of proposed MMS decoding algorithm and present a comparison DVB-S2, ABS-S, Proposed ABS-S also we analyzed the computational complexity of the proposed algorithm and compared it with that of sum product and min sum decoding algorithm.

A. BER Performance

Figure 3 shows the BER performances of (500, 250) LDPC codes with code rate - 1/2 and compare sum product, min sum product, modified MS algorithm with correction factor = 0.95. Moreover, modulations by BPSK and transmissions over an AWGN channel are assumed, and the maximum number of iterations is set to 50. Results shows that modified min sum algorithm offers $3.457 * 10^{-5}$ BER at 3 dB which is better as compared to sum product and min-sum algorithm.

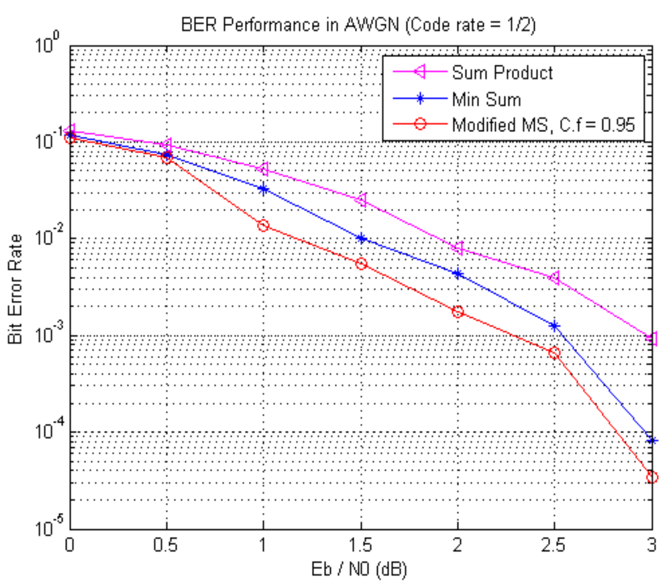

Fig. 3. Comparison of SP, Min Sum, Modified MS algorithm

Figure 4 shows the BER performance of LDPC code in DVB-S2 and ABS-S. For simulation purpose we set normal codeword length 64800 for DVB-S2, 15360 for ABS-S with code rate 1/2 and set base matrix which is an identity matrix whose size is 32 × 32. Without any concatenated codes and with much shorter codeword length, the LDPC codes in ABS-S provides BER lower than 10^{-7}. Results shows that the ABS-S has shown almost the same BER performance as that of commercial DVB-S2 system, meanwhile, the complexity of the ABS-S system is much lower than that of the DVB-S2 system. It shows that the proposed method not only offers a better performance but also achieves a lower error floor in the high E_b/N_0 region.

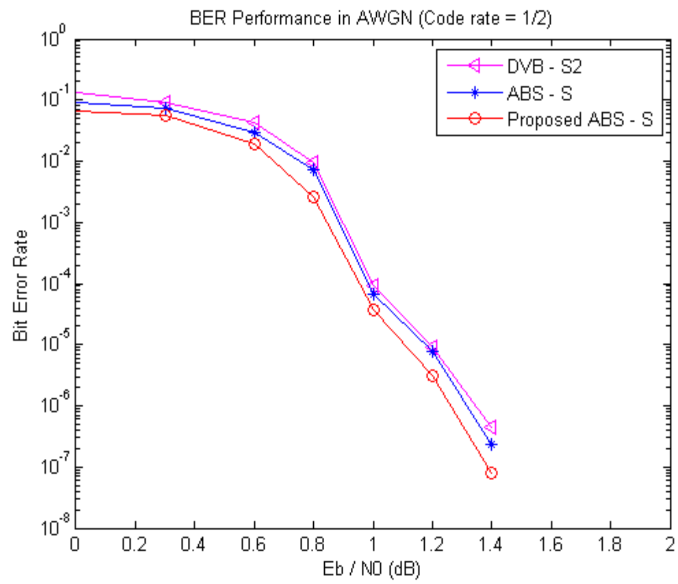

Fig. 4. Comparison of DVB - S2 and ABS - S and Proposed system

B. Computational Complexity

The computational complexity depends on the number of operations involved in decoding a single information bit. It obviously is a function of the average number of iterations. The average complexity of the decoding process is hence the product of two factors:

- The number of operations per node,
- The average number of iterations

Sum product algorithm require multiplications and divisions to update the check nodes. In contrast, min sum and proposed min sum algorithm requires additions and subtractions instead of multiplications and divisions for the check node updates [7]. In general, in terms of hardware complexity and delay, both multiplication and division are much more complicated and require more time than addition and subtraction. Table I shows comparison complexity of different decoding algorithms. The results shows that proposed algorithm reduces the computational complexity as compared to the existing SP algorithms and gives almost the same complexity as that of min sum algorithm. But BER performance of the proposed MMS algorithm as better than MS algorithm with same computational complexity.

Where α = Represents the number of bit nodes connected to the single check node

TABLE I
COMPARISON OF COMPUTATIONAL COMPLEXITY

Factor	SP algorithm	Min Sum	Modified Min Sum
$tanh$ and $tanh^{-1}$ function	2 Quantization Table	1 Quantization Table	1 Quantization Table, 1 Correction factor table
Multiplication	α-1	0	0
Division	α	0	0
Addition	0	α-1	α-1
Subtraction	0	α	α

IV. CONCLUSION

In this paper we proposed a modified min sum decoding algorithm for ABS-S. The modification is based on considering the effect of sub minimum value in decoding performance. We suggested a correction factor which when applied to MS algorithm, produced better BER performance, having the computational complexity less than SP algorithm and reasonably same as that of MS algorithm. With our proposed algorithm we achieved 2.32×10^{-7} BER performance at 1.4 dB. It also shows combination of proposed decoding algorithm with short block length LDPC code in next generation satellite broadcasting system ABS-S system offers better interactive services and video broadcasting application.

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