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An Efficient Design for the DVB-S2 Forward Link System Outer Layer Encoding Based on PCC Turbo Coding Across Fading Channel

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ABSTRACT

The most significant challenges wireless broadcasting systems face are channel effects and Inter Symbol Interference (ISI). Many different kinds of channel coding are employed to get around these issues. Digital Video Broadcasting for Satellite Telecommunication Second Generation (DVB-S2) uses a serial concatenation of Bose, Ray-Chaudhuri, and Hocquenghem (BCH) code and Low-Density Parity-Check (LDPC) code as a Forward Error Correction (FEC) for error detection purpose and correction. In this work, a MATLAB code (m-files) is constructed to simulate the standard DVB-S2 Bit-Interleaved Coded Modulation (BICM) system according to the ETSI Technical Report (EN 302 307 1). Then, the traditional design is redesigned with a Parallel Concatenation Convolutional (PCC) Turbo coding in concatenation with LDPC coding to enhance the (FEC). The two approaches have been tested under the official modulation types QPSK, 8PSK, 16APSK, and 32APSK with 2/3, 3/4, 3/5, 4/5, and 5/6 code rates (RC). Over a Rayleigh Fading channel, the two models are compared. The proposed model performed better than the standard model regarding bit error rate (BER) mitigation when operating at varying signal-to-noise ratio (SNR) levels, especially in 8PSK 3/5 MODCODE. The proposed model achieved (2.6272×10^{-3}) BER mitigation value with power gain equal to 4 dB.

Keywords: FEC, BCH, LDPC, PCC Turbo Codec, Code Rate.

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تصميم فعال لترميز الطبقة الخارجية لنظام الارتباط الأمامي الخاص بالبث الفيديوي الفضائي الرقمي (الجيل الثاني) استناداً الى التسلسل المتوازي للترميز التوربايني التلافيفي عبر قناة التلاشي

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الخلاصة

تتمثل أهم التحديات التي تواجه أنظمة البث اللاسلكي في تأثيرات القناة والتداخل بين الرموز (ISI). حيث يتم استخدام العديد من أنواع تشفير القنوات المختلفة للتغلب على هذه المشكلات. يستخدم نظام البث الفيديو الرقمي لاتصالات الأقمار الصناعية من الجيل الثاني (DVB-S2) تسلسلاً لرمز بوس، راي-جودري وهاكوينغهام (BCH) بالتوافق مع رمز التحقق من التكافؤ منخفض الكثافة (LDPC) كطبقة تصحيح للأخطاء الأمامية (FEC) لغرض اكتشاف الأخطاء وتصحيحها. في هذا البحث، قمنا بإنشاء كود ماتلاب (ملفات m) لمحاكاة نظام DVB-S2 المؤمن بترميز (BICM) وفقًا للتقرير الفني (EN 302 307 1) الخاص بالمعهد الأوربي لمعايير الاتصالات (ETSI) وكذلك تم إعادة التصميم التقليدي باستخدام الترميز التوربايني للتسلسل التلافيفي المتوازي (PCC) بالتوافق مع تشفير LDPC لتحسين كفاءة طبقة عمل الـ(FEC). تم اختبار الطريقتين تحت أنواع التضمين الرسمية QPSK و 8PSK و 16APSK و32APSK بمعدلات ترميز 3/2 و3/3 و4/3 و5/3 و5/4 و6/5 ثم تمت مقارنة النموذجين عبر قناة التلاشي رايلي. حقق النموذج المقترح أداءً أفضل من النموذج القياسي فيما يتعلق بتخفيف معدل خطأ البت (BER) عند التشغيل بمستويات متغيرة لنسبة الإشارة إلى الضوضاء (SNR)، خاصةً في حالة الـ(8PSK 3/5 MODCODE) حيث حقق النموذج المقترح (2.6272×10^{-3}) قيمة تخفيف لمعدل خطأ البت مع كسب قدرة يساوي 4 ديسيبل.

الكلمات المفتاحية: تصحيح الأخطاء الأمامية، بوس، راي-جودري وهاكوينغهام، رمز التحقق من التكافؤ منخفض الكثافة، التسلسل المتوازي للترميز التوربايني التلافيقي، معدل الترميز.

1. INTRODUCTION

The DVB Project launched development on DVB-S2 in 2003. After that, in March 2005, ETSI gave its stamp of approval **(Standard, 2014; Benguluri, 2019)**. DVB-S2 uses a concatenation of BCH and LDPC codecs to provide Forward Error Correction. In addition, the standard includes a variety of modulation types and coding speeds. QPSK, 8PSK, 16APSK, and 32APSK are used in DVB-S2 **(Mohammed and Hussein, 2020)**. Based on the current transmission conditions, the DVS-S2 standard employs Adaptive Modulation and Coding (ACM), optimising each user's transmission parameters individually. Adaptive coding and modulation change the modulation type and coding rate for each forward channel frame based on signal propagation circumstances while keeping a constant symbol rate. To apply LDPC to a communication system, the code must match the system's data rate. LDPC codes with varied code-word lengths must accommodate different data speeds in adaptive communication systems. However, the DVS-S2 system's LDPC code is restricted in its use since it employs just two different code-word lengths (16200 and 64800), and each of these requires a different parity check matrix **(Standard, 2014; Seksembayeva, 2021).**

Conducted research on the conveyance of electrocardiograms (ECGs) via multi-path Rayleigh channels and found that MIMO increases performance by 5 dB. ECG transmission is more effective with (DVB S2) than with (DVB -T) in AWGN and fading channels. It is well known that satellite transmissions are more erratic and delayed than terrestrial transmissions. Therefore, if performance loss can be tolerated, the (DVB T) approach can be used for faster ECG transmission **(Alsaadi and Serener, 2017)**. Verilog code and FPGAs were implemented to transmit DVB signals. DVB used interleaver, convolutional, and reed-Solomon coding. Reed-Solomon uses an interleaver with a value of 12, a 1/2 convolutional code, and (204, 188). Code written in Schematic and Verilog was used to program FPGAs. However, using the analysis, FEC design techniques can be selected according to system requirements **(Jain and Singhai, 2017)**.

They explored the outcomes of creating an encoder and a decoder utilizing an FPGA for LDPC codes compliant with DVB-S2. Frame types and coding rates were considered while designing parametrized FEC modules. Performance was enhanced in this study using coder and decoder topologies. **(Zinchenko et al., 2018)** established a novel technique for forecasting Quasi-Cyclic (QC)-LDPC code SNR degradation. The recommended codes are almost full due to limited iterations and a short code word. The proposed (1/2) and (2/3) code rates, according to analysis and BER simulation, are equivalent to the state-of-the-art design and are only 0.39 and 0.37 dB from the Shannon limit under the BI-AWGN channel and 0.60 and 0.65 dB under the BI-Rayleigh channel, respectively. **(Chen et al., 2018)** suggested JDDD, a simultaneous detection, demodulation, and decoding alternative to the LDPC decoder. JDDD is simulated via DVBS2 modulation. JDDD is faster than SPA at decoding LDPC codes. When computing power is enough, JDDD is preferable to a modulated additive white Gaussian noise/ISI channel. The paper contrasts LDPC and JDDD decoders. For lower code-word lengths and fewer resources, the JDDD outperforms the IDD, while longer CWLs favor the IDD with more resources. **(Chan et al., 2019)** recommended increasing DVB bitrates by utilizing polar coding PC with adaptable SCL decoders. It's also feasible to get faster and better services. They first constructed polar codes and a novel mathematical relation to determine the optimal design location. The minimum BER was not far from the enhanced design point. They contrasted throughput, codec delay, and polarly and LDPC BER. Both channel coding techniques have comparable BERs. Compared to LDPC, Polar codes were faster. Lastly, they emphasized how optimising polar codes—like FEC rather than BCH and LDPC codes—can enhance DVB performance. **(El-Abbasy et al., 2021)** suggested that for DVB-S2 systems, LDPC codes based on protograph have low complexity and excellent performance. BICM-ID enhanced the performance of ASK-modulated DVB. Simulation results and PEXIT analysis show that protograph-based LDPC codes perform better than standard DVB-S2 codes at all code rates. The suggested codes produced a 0.2 dB gain in 16-APSK high-rate performance **(Li et al., 2021).** In the presence of nonlinear distortion on a two-link satellite channel, the 2r16APSK modulation, as compared to the 16APSK modulation, was accepted by the DVB-S2 standard using a range of performance criteria. The bit error probability and the constellation figure of merit have been consistent in the case of an undisturbed received signal in a high signal-to-noise ratio regime **(Guimaraes, 2022)**.

The main objective of this work is to improve the Bit Error Ratio (BER) performance of the inherent Outer Layer Encoding OLE for the second-generation Digital Video Broadcasting over Satellite (DVB-S2) link system employing channel coding techniques. The work combines LDPC over Rayleigh Fading Channel with a new FEC Layer frame based on the Parallel Concatenation Convolutional PCC Turbo coding scheme. Lower the signal-to-noise ratio (SNR) levels and decrease the LDPC decoder iterations in the receiver section.

2. CONVENTIONAL DVB-S2 BICM SYSTEM MODEL

Figure 1. illustrates the MATLAB code used to create the Standard Digital Video Broadcasting for satellite communication second generation (DVB-S2) Model. The Binary Data input passes through the BBFrame Buffering, then is coded by the BCH outer encoder and coded for a second time by the LDPC inner encoder. The generator Code-Word interleaved by General Block Interleaver the modulated before traveling to the channel. All these operations represent the transmitter part of the DVB-S2 BICM System **(Standard, 2014; Benguluri, 2019; Salih and Hameed, 2023; Awad et al., 2019)**.

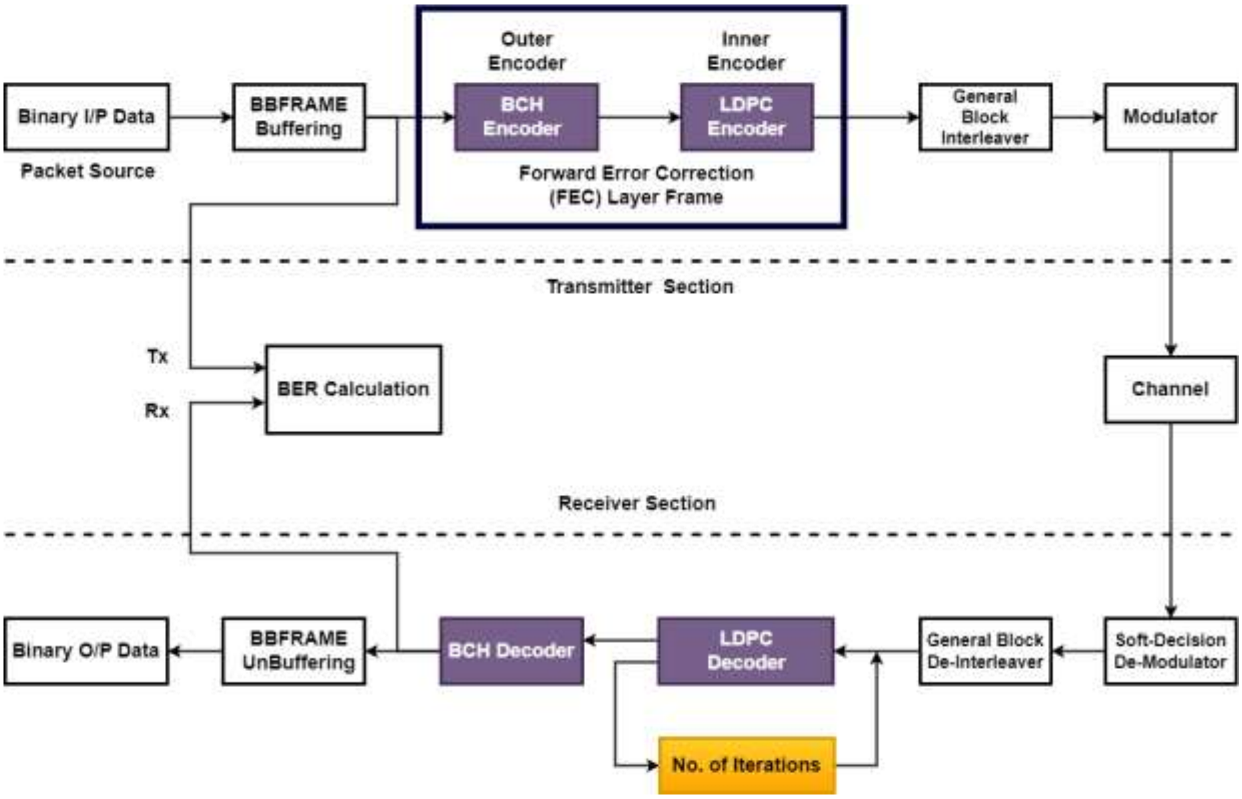

Figure 1. DVB-S2 BICM System Block Diagram

2.1 Bose, Ray-Chaudhuri and Hocquenghem (BCH) Codec

The Bose, Ray-Chaudhuri, and Hocquenghem (BCH) codes are a strong family of cyclic random error correction codes. This category of codes is an extension of the Hamming code for multiple-error correction that is extraordinarily effective **(Kumar and Raju, 2015).** The number of correctable symbol mistakes in a BCH code may be precisely controlled during the design phase of the code. In particular, binary BCH codes may be designed to compensate for multiple-bit faults. The fact that BCH codes are so simple to decode using the algebraic technique of syndrome decoding is still another benefit. This makes creating a decoder for these codes easier by using modest, low-power electrical components **(Bera et al., 2015; Al-Barrak et al., 2017)**.

This investigation used the regular FECFRAME (n_ldpc=64800) from the DVB-S2 standard. Each BBFRAME (Kbch) is given. A (t) error correcting BCH (Nbch, Kbch) code creates an error-protected packet. Polynomial for the (t) error-correcting BCH encoder is generated by multiplying the first (t) polynomials, as required by DVB-S2 **(Salih and AL-Muraab, 2020). Table 1** summarises the relationship between information length k_BCH and block length N_BCH for all standard and short BCH codes described in DVB-S2. All BCH codes in DVB-S2 are essential, with their higher-order bits set to zero and hidden.

Table 1. The lengths and error-correction abilities of BCH codes **(Azarbad and Sali, 2012)**

Data-Word	Bits-Redundant	Code-Word	Errors-Correction
51 648	192	51 840	12
48 408	192	48 600	12
43 040	160	43 200	10
38 688	192	38 880	12
32 208	192	32 400	12

2.2 LDPC Encoding Technique

LDPC, developed by Robert Gallager in 1960, is a forwarding error-correcting code **(Gallager, 1962; Al-Haddad, 2016).** (N, K) notation describes LDPC codes, in which N is the number of code words. K is the information length, and N-K is the number of redundancy bits added to the data block during encoding **(Gagan et al., 2017)**. Every linear block coding has a (G-matrix) encoder and (H-matrix) decoder **(Zikry et al., 2021; Almaamory and Mohammed, 2012)**. Two matrices are linked in LDPC coding. The encoder multiplies the message by G-matrix to obtain N-bits code words **(Enad and Al-Jammas, 2019).**

$$G_{(K*N)} = \left[I_K \,.\, P_{K*(N-K)}\right] \tag{1}$$

From (H) and (G), matrices are derived **(Enad and Al-Jammas, 2019)**

$$H_{(N-K*N)} = \left[P^T . I_{(N-K)}\right] \tag{2}$$

If the codeword is C_wThe decoder syndrome must be zero to be error-free **(Ghouri et al., 2019)**. At the encoder side

$$C_w = K * G \tag{3}$$

and at the decoder side

$$S = C_w * H^T \tag{4}$$

2.3 LDPC Decoding Technique

LDPC code employed iterative decoding (Message Passing Algorithm) on the Tanner graph, where the variable node and check node exchanged messages until the parity check condition [C_w* H^T=0] is satisfied **(Zikry et al., 2021)**. The hard decision (Bit-Flipping) decoding algorithm and soft decision (Sum-Product) decoding algorithm are the two main algorithms for the iterative process of an LDPC decoder. In this investigation, we used the Soft-Decision (Sum-Product) LDPC decoding since it has a higher performance rating than the Hard-Decision (Bit-Flipping) decoding technique **(Bhavsar and Vala, 2014; Jose and Pe, 2015)**. Soft decision algorithms interpret the received bit's probability as the log-likelihood ratio (LLR). (Priori probabilities) are those obtained before the decoder operates, while (posterior probabilities) are those received after the decoder has run **(Sonia and Gupta, 2015)**. Given that (x) is the independent variable, we only need to keep track of one number to represent the probability of x: P(x = 0) from P(x = 1) and vice versa. The log-likelihood ratio is a statistic used to assess the importance of a binary variable Where:

$$LLR(x) = log\left[P_{(x=0)}/P_{(x=1)}\right] \tag{5}$$

3. CHANNEL MODEL

Numerous modes of transmission exist in the actual satellite communication channel. Each route has a propagation delay and attenuation factor **(Manh et al., 2019; Almaamory, 2011)**

$$X(t) = \sum_{i=1}^{N} \alpha_i(t).S[t - \tau_i(t)] \tag{6}$$

where (N) represents the path number and $\alpha_i(t)$ the factor of attenuation on the (i^{th}) paths, whereas $\tau_i(t)$ represent the signal propagation delay on the (i^{th}) paths.

The purpose of this modeling effort is to simulate the use of several propagation channels. One of the distributions that are used the most often is the Rayleigh distribution. The Rayleigh distribution is a statistical model used to describe a fading signal for which there is no dominating line of sight (LoS). The Rayleigh probability density function (pdf) is defined as follows **(Manh et al., 2019):**

$$pdf_{\alpha}(\alpha) = \frac{1}{2\alpha}\exp\left[-\frac{\alpha^2}{2\sigma^2}\right] \qquad ,\alpha \geq 0 \tag{7}$$

Where (α) is the amplitude of the channel fades and (σ^2) is the time-averaged power of the received signal.

In this case, a single-path Rayleigh fading channel is created independent of all other paths. Let's assume the grouped bits of information, or h(n) vector (x), have a length of (L_d). A (L_d)-length channel coefficient vector (h) has real and imaginary parts that are separate complex Gaussian variables with zero mean and 1/2 variance. After element-wise multiplying (x) and (h), AWGN noise is added. The received signal (y) elements are **(Alshammary and Almuraab, 2020).**

$$y(n) = x(n).h(n) + w(n) \tag{8}$$

When a data cell x(n) is broadcast, the receiver section provides the demapper with y(n) and h(n) to calculate the LLR values of the bits in the data cell.

4. TURBO CODER

Concatenated codes like Turbo Code, created by Berrou, Glavieux, and Thitimajshima in 1993, effectively correct some errors **(Berrou et al., 1993)**. Turbo code, or Parallel

Concatenated Codes (PCC), comprises two convolutional codes linked in parallel using an interleaver**.** It is the FEC of choice for various uses, including deep space communications, because of its excellent performance in BER, throughput, and dependability.

Fig. 2 depicts a turbo encoder, which consists of two identical Recursive Systematic Convolutional encoders (RSC) of rate 1/2, coupled in parallel with an interleaver between them, as shown in **Fig. 3.**

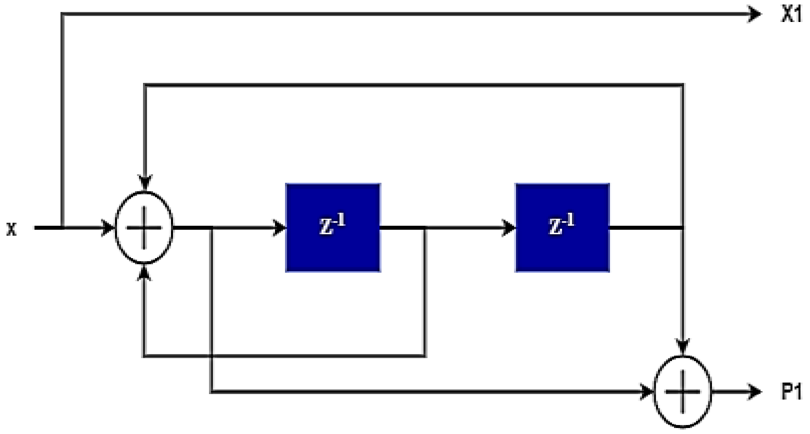

Figure 2. RSC Encoder Structure **(Rao, 2015)**

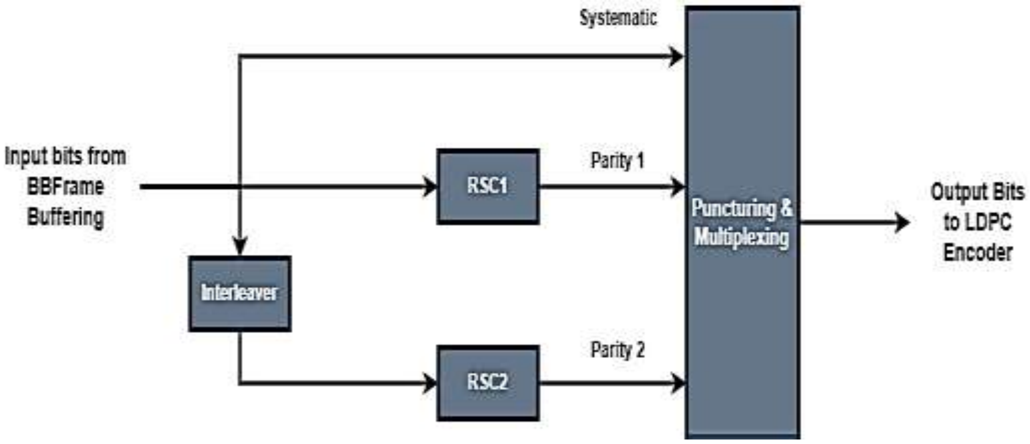

Figure 3. Turbo Encoder structure with puncturing and multiplexing **(Almaamory and Mohammed, 2012)**

The systematic input is fed into the first encoder, while the interleaved systematic vector feeds into the second encoder. Before sending the incoming bit stream to the second RSC encoder, the interleaver randomly rearranges the bits in the incoming bit stream **(Ryan and Lin, 2009)**. The output of this code is the systematic (information vector) and the sum of the results from two rate-splitting-code (RSC) encoders (parity vectors). Performance can be improved in turbo code by using an interleaver to shuffle the bit order, hence raising the minimum distance and decreasing the frequency of burst mistakes. As a final step, a systematic input is combined with the low-weight vector output from RSC1 and the high-weight vector output from RSC2 to form the code-word, which is then transmitted over the channel **(Rao, 2015)**.

5. PCC TURBO DECODER

Two Maximum posterior (MAP) decoders comprise a turbo decoder, as shown in **Fig. 4.** DEC1 decodes RSC1's sequence and DEC2 RSC2's. The output of ENC1 is sent to DEC1 in the form of an estimate of the systematic series (y_k^s) and a parity1 vector (y_{k1}^p). DEC1 outputs extrinsic data EXT1, which represents soft data estimate **(Mohammed, 2010)**. This interleaved information is given to DEC2 together with the interleaved systematic (y_k^s) and parity2 vector (y_{k2}^p) from RSC2. DEC2 creates extrinsic information EXT2, which is de-interleaved and sent back to DEC1 until a preset number of iterations. After a certain number of iterations, DEC2 outputs a $\Lambda(d_k)$, which represents the approximately accurate replica of the data that was conveyed **(Sah, 2017; Kaza and Chakrabarti, 2004).**

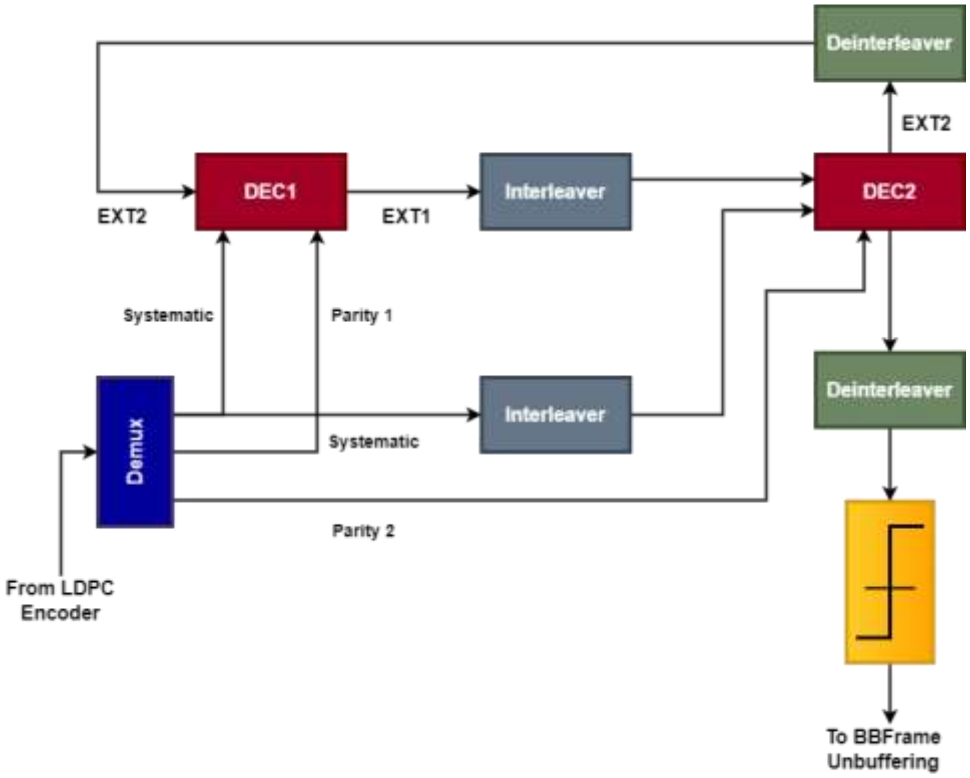

Figure 4. Pattern Diagram of Turbo Decoder

6. SIMULATION RESULTS AND DISCUSSION

The simulation results are presented in this section as a comparative analysis between the original DVB-S2 Forward link model and the modified model, which was developed by replacing the BCH codec with the PCC turbo codec as the outer encoder to enhance the (FEC) frame layer. **Fig. 5** shows the flux diagram for the MATLAB code that was constructed to simulate the modified model.

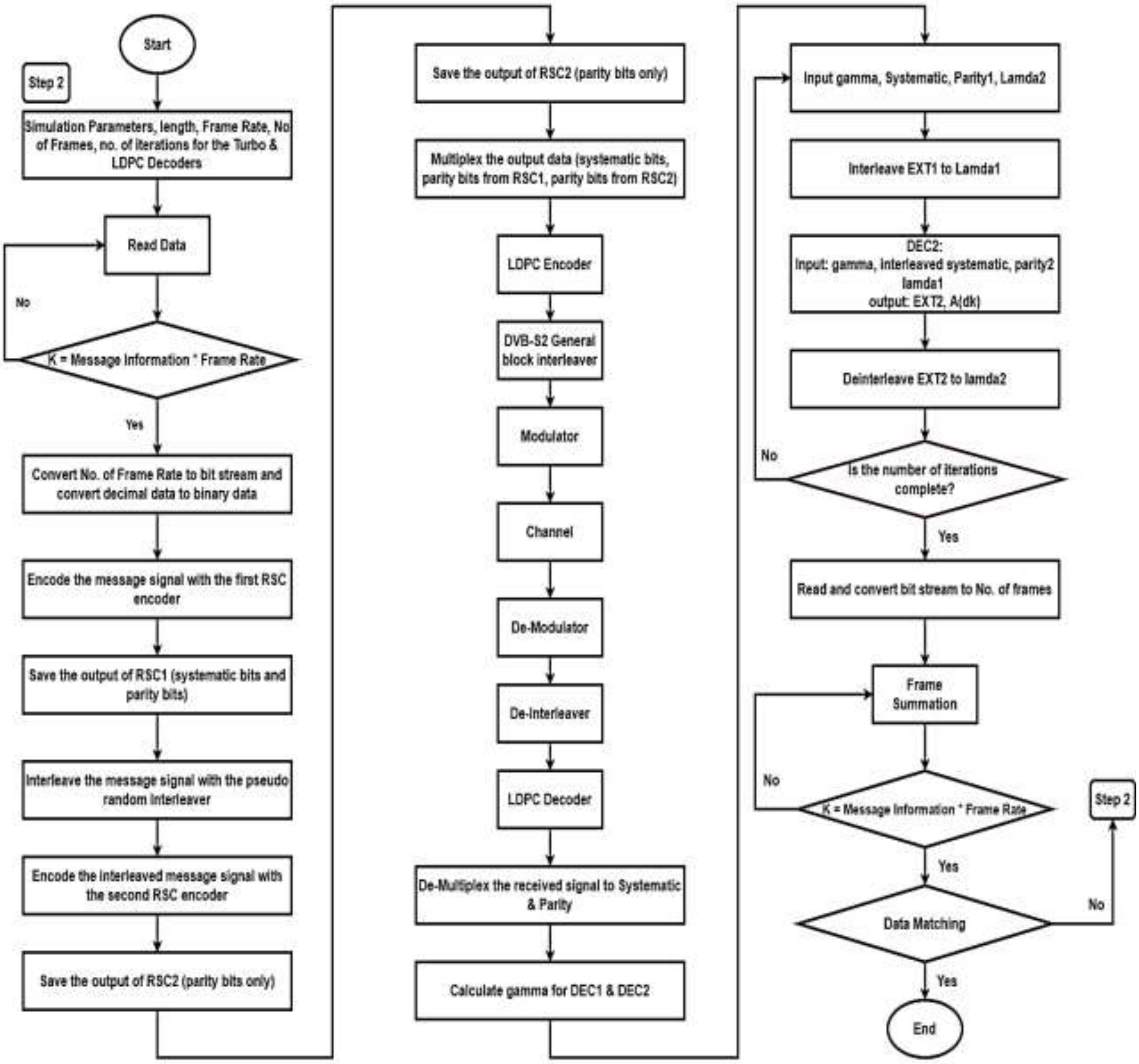

Figure 5. MATLAB Flux Diagram Modified Model

The two approaches were evaluated based on their BER performance in a Rayleigh fading channel with Gaussian noise (AWGN) using the official types of the constellation and coding rate. Various signal-to-noise ratios (SNR) are used at varying levels to achieve the desired outcomes. The important simulation parameters that were taken into consideration for the investigation of this research are shown in **Table 2**.

Table 2 Simulation parameters

Variables	Values
Data Input	Random
BBFrame Buffering & Unbuffering out	43040, 48408, 38688, 51648 and 53840
Code Rate (R_c)	2/3, 3/4, 3/5, 4/5, and 5/6
BCH Encoder & Decoder out	43200, 48600, 38880, 51840 and 54000
Turbo Coding rate (Outer Encoder)	1/3 fixed
Turbo coding technique	PCCC
Turbo Decoding Technique	Log-MAP algorithm
No. of Turbo Decoder iterations	10
LDPC Encoder & Decoder out	64800
No. of LDPC Decoder iterations	10
Interleaver & De-interleaver out	64800
Modulation (Constellation) orders & types	QPSK, 8PSK,16APSK and 32APSK
Channel type	Rayleigh Fading Channel
Noise type	AWGN

The first scenario to test the two models is done with a QPSK constellation and two code rate levels, 2/3 and 3/4, respectively. The results of the tests are presented in **Figs. 6 and 7.**

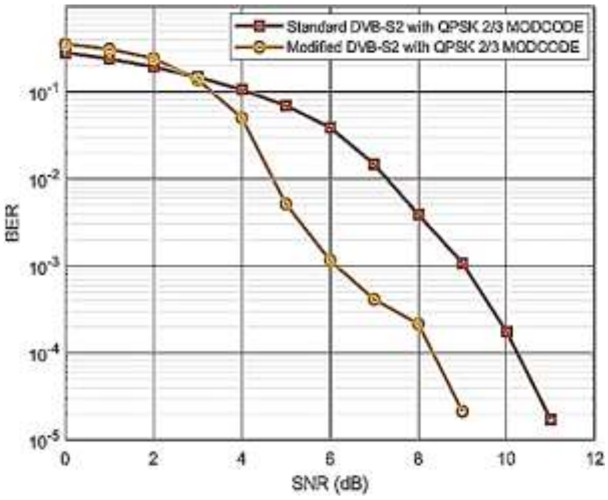

Figure 6. BER vs SNR comparison with QPSK 2/3 MODCODE

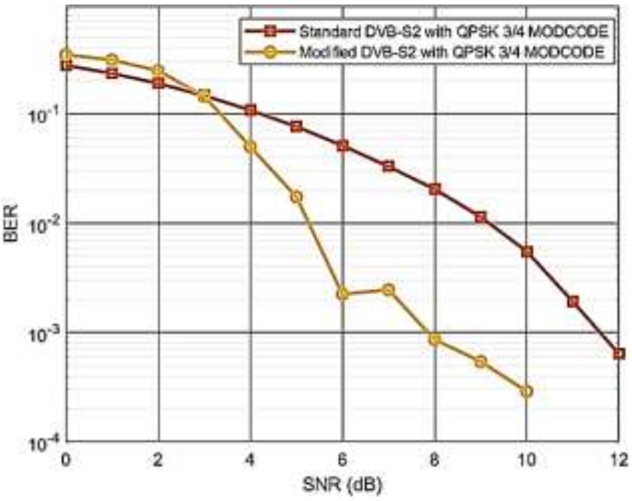

Figure 7. BER vs SNR comparison with QPSK 3/4 MODCODE

Fig. 6 shows that the BER performance of the standard model is equal to (1.715×10^{-5}) when the signal-to-noise ratio is equal to (11 dB). On the other hand, the BER performance of the modified model with PC Turbo codec (Outer Encoder) is equal to (2.116×10^{-5}) when the signal-to-noise ratio is equal to (11 dB) (9 dB). **Fig. 7** depicts the testing results with a 3/4 code rate conducted inside the same constellation order. The BER performance for the standard model is equal to (6.407×10^{-4}), whereas the BER performance for the modified model is equal to (2.9×10^{-4}) when the signal-to-noise ratio is equal to (12 dB) and (10 dB) respectively. For the first two situations described above, the BER performance of the improved system shifts in the direction of mitigating in the case where the SNR level is equivalent to (>3 dB).

An additional testing scenario for the two models was investigated under an 8PSK constellation order with 3/5 and 4/5 coding rates. **Figs. 8 and 9** present the testing results conducted in this scenario.

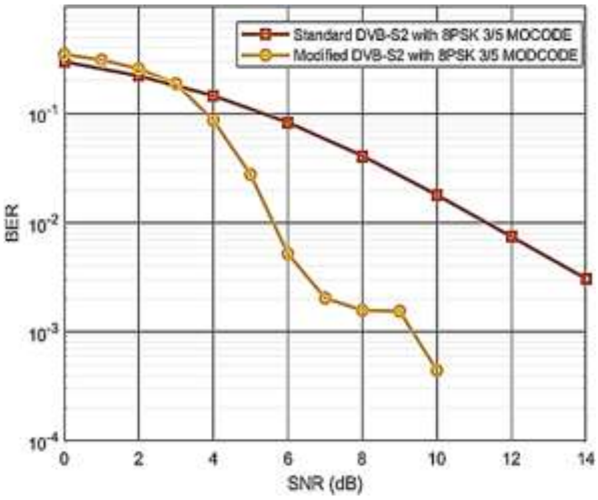

Figure 8. BER vs SNR comparison with 8PSK 3/5 MODCODE

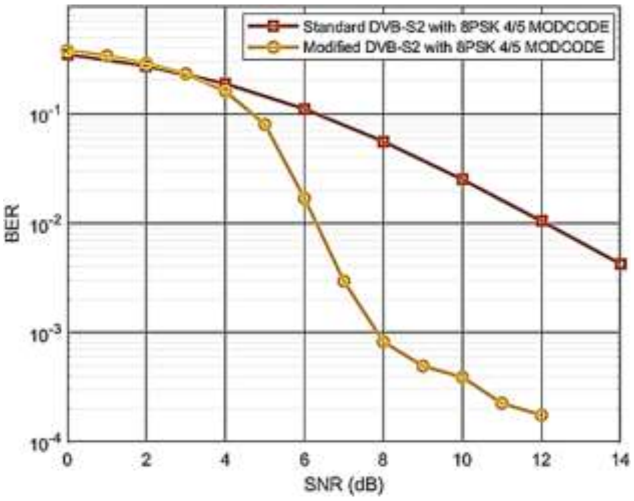

Figure 9. BER vs SNR comparison with 8PSK 4/5 MODCODE

Fig. 8 demonstrates that the performance of BER for the standard model is equivalent to (3.071×10^{-4}) at an SNR level of (14 dB), whereas the performance of BER for the modified system is equal to (4.438×10^{-4}) at an SNR level of (10 dB). **Fig. 9** depicts the same constellation order, but this time with a code rate of 4/5, indicating that 80% of the transmitted data is accurate. In the standard model, the BER value is equivalent (4.24×10^{-3}) at (14 dB), whereas in the modified model, it is (1.75×10^{-4}) at (12 dB) SNR. The BER behavior of the modified system begins to be mitigated in the case of 8PSK 3/5 MODCODE when it reaches (>3 dB), whereas, in the case of 8PSK 4/5 MODCODE, mitigation begins when it goes (> 4 dB).

The third testing scenario consisted of a 16APSK constellation type with two levels of code rates, 4/5 and 5/6, along with a range of SNR forms ranging from (0 dB) to (16 dB). Both **Figs. 10** and **11** compared the findings obtained by the two models.

According to **Fig. 10**, the BER performance for the standard model is equivalent to (5.07×10^{-6}) at (16 dB) SNR, while the BER value that the modified model attained was (1.996×10^{-7}) at (14 dB) SNR. **Fig. 11** also presents the test results for the two models under 16APSK 5/6 MODCODE. At (16 dB) SNR, the BER performance is equal to (2.92×10^{-5}) for the standard model, and for the modified model, the BER value is equivalent to (3.998×10^{-7}) at (14 dB) SNR. For the two cases above, the BER curve for the modified model performs more reliability than the conventional model when the SNR threshold is reached (6 dB).

Within the scope of the final test, **Figs. 12 and 13** illustrate the findings achieved for the two models with 32APSK constellation and code rate levels 4/5 and 5/6. The range investigated for the best outcomes was from (0 dB) to (16 dB).

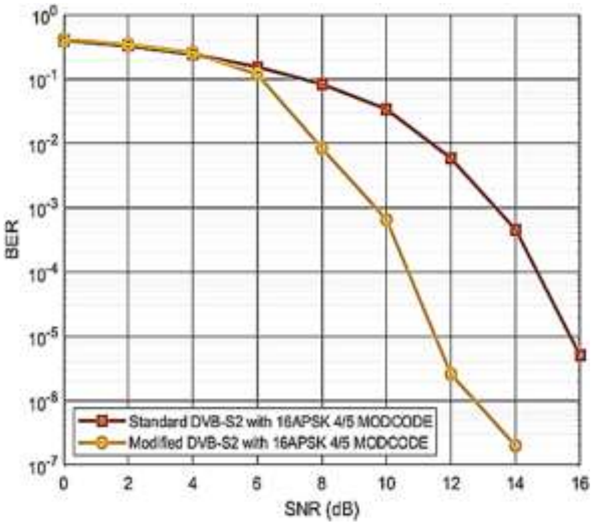

Figure 10. BER vs SNR comparison with 16APSK 4/5 MODCODE

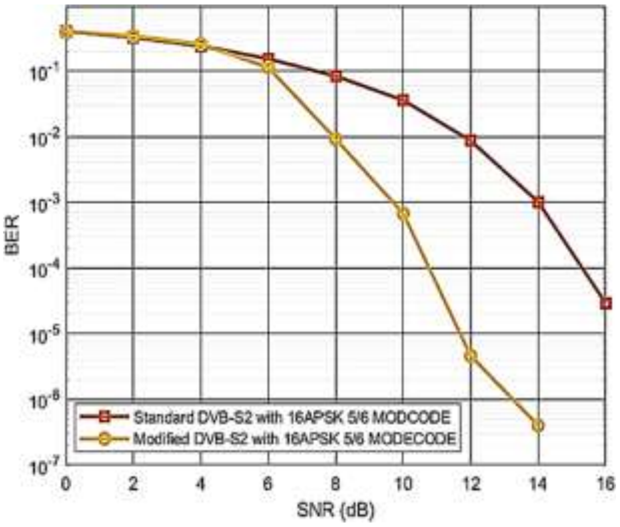

Figure 11. BER vs. SNR comparison with 16PSK 5/6 MODCODE

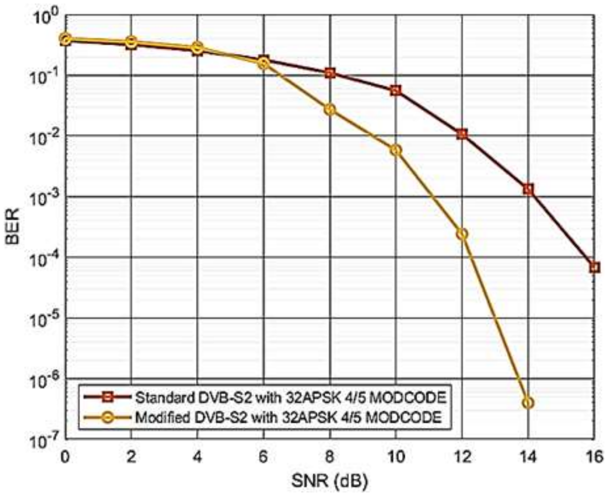

Figure 12. BER vs SNR comparison with 32APSK 4/5 MODCODE

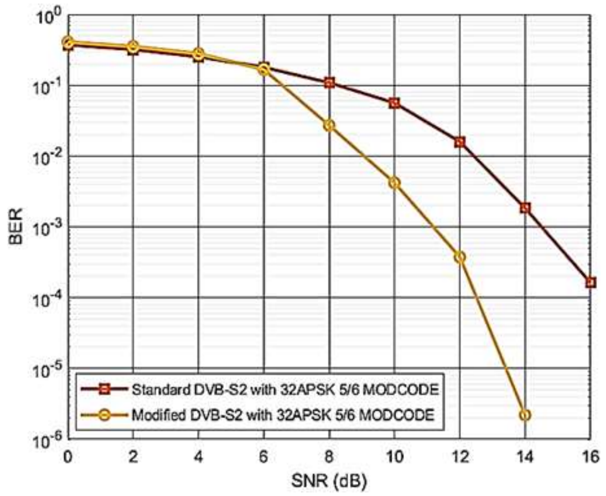

Figure 13. BER vs. SNR comparison with 32APSK 5/6 MODCODE

According to **Fig. 12,** the BER performance of a conventional system is equivalent to (6.844×10^{-5}) when the signal-to-noise ratio is equal to (16 dB). The modified system obtained (3.992×10^{-7}) when the SNR was similar to (14 dB). With an increase in the coding rate to 5/6, the standard system achieved (1.632×10^{-4}) BER value at (16 dB) SNR, whereas at (14 dB), the modified system achieved BER is equivalent to (2.199×10^{-6}).

The proposed concatenation of PCC Turbo coding (Outer Encoder) with Low-Density Parity check (LDPC) (Inner Encoder) in terms of Forwarding Error Correction (FEC) achieved a higher level of reliability for the (DVB-S2) Link system while maintaining the acceptable level of computational complexity (CC). The Bit Error Rate (BER) concerning the Signal Noise Ratio was the main factor to quantify this performance. **Table 3** displays the findings achieved for the power gain and the reduction in BER for both the conventional and modified system configurations.

Table 3. The achieved results of the modified system

Case No.	Constellation	Code rate	Power Gain in (dB)	BER Reduction
1	QPSK	2/3	2	-
2		3/4	2	3.507×10^{-4}
3	8PSK	3/5	4	2.6272×10^{-3}
4		4/5	2	4.0643×10^{-3}
5	16APSK	4/5	2	4.8704×10^{-6}
6		5/6	2	2.88002×10^{-5}
7	32APSK	4/5	2	6.80408×10^{-5}
8		5/6	2	1.61001×10^{-4}

7. CONCLUSIONS

This project has been completed and discusses the performance tuning results of the DVB-S2 BICM system. The impacts of several modulation schemes and encoding rates were examined on the Rayleigh fading channel. Utilizing the 8PSK 3/5 MODCODE, the combination of PCC turbo coding and LDPC produced better performance than the standard model regarding BER mitigation and SNR gain. The standard model's adaptability achieved the modification of the outer encoder.

Simulation work continues to produce higher gain values for a broader range of DVB modes and additional propagation situations at the time of authoring this paper by using more channel models and targeting the next-gen digital video transmission standard in particular. This structure allows for incorporating a wide variety of operations with the potential to boost the system's performance.

- Evaluation of the operation of the (DVB-S2) system within communication channels of the fifth generation, involving analysis and performance assessment.
- Employing Filter Bank Multi Carrier (FBMC) strategies to accelerate the transmission of data inside the system by omitting the (CP) to the greatest extent possible to minimize the transmitted error rate.
- (MIMO) methods can be employed by increasing the number of sending and receiving antennas to increase the amount of data carried by the (DVB-S2) system.
- Enhancement of FEC layer frame for the DVB-S2 system by coupling Tail Biting convolutional code (TBCC) with LDPC codec to reduce BER within a low SNR range.
- To evaluate the behavior of significant data transmission agents of the system, such as (MSE), it is possible to utilize (CE) approaches on the receiving side of the system, in addition to a small amount of communication channel effects intensity.
- To develop and improve the transmitting and receiving characteristics of the system, it is possible to activate the adaptive and variable coding modulation (ACM & VCM) capabilities of the system's (BICM) scheme and employ various modulation advanced types.

NOMENCLATURE

Symbol	Description	Symbol	Description
α	The amplitude of the channel fades	t	Number of error correcting for BCH Coder
C_w	LDPC decoder syndrome	$w(n)$	AWGN added
G	Matrix Linear Block code for LDPC Encoder	$x(n)$	Broadcast (transmission) signal
H	Matrix Linear Block code for LDPC Decoder	$y(n)$	Received signal
i^{th}	Number of paths	y_k^s	Estimate of the systematic series
K	The information length	y_{k1}^p	Estimate of the systematic parity1 vector
K_{bch}	Data word for BCH Coder	y_{k2}^p	Estimate of the systematic parity2 vector
N	The total number of Code Words	$\alpha_i(t)$	The factor of attenuation
N-K	number of redundancy bits added to the data block during the encoding process	$\Lambda(d_k)$	PCC-TC O/Code to BBframe Unbuffering
pdf	The Rayleigh probability density function	σ^2	The time-averaged power of the received signal.
P	Probability of error	$\tau_i(t)$	Represent the signal propagation delay.
R_c	Code Rate		
Abbreviations			
ACM	Adaptive Coding and Modulation	LDPC	Low-Density Parity Check
APSK	Amplitude Phase Shift Keying	LLR	Likelihood Ratio
ASK	Amplitude Shift Keying	LoS	Line of Sight
AWGN	Additive White Gaussian Noise	MIMO	Multiple Input Multiple Output
BBFrame	Base Band Frame	MSE	Mean Square Error
BICM	Bit-Interleaved Coded Modulation	N_BCH	Redundant bits for the BCH Code word
DVB	Digital Video Broadcasting	OLE	Outer Layer Encoding
DVB-S2	Digital Video Broadcasting – Satellite – 2nd Generation	PC	Polar Coding
ETSI	European Telecommunication Standards Institute	PCCC	Parallel Concatenated Convolutional Code
EXT1	The first data word from Turbo DEC1	PSK	Phase Shift Keying
EXT2	The Second data word from Turbo DEC2	QPSK	Quadrature Phase Shift Keying
FBMC	Filter Bank Multi Carrier	Rc	Coding Rates
FEC	Forward Error Correction	RSC	Recursive Systematic Convolutional encoders
FECFRAME	Forward Error Correction Frame	SNR	Signal to Noise Ratio
FPGA	Field Programmable Gate Array	TBCC	Tail Biting Convolutional Code
ISI	Inter Symbol Interference	VCM	Variable Coding and Modulation
JDDD	Joint Detection Demodulation, and Decoding		

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Credit Authorship Contribution Statement

Omar M. Salih: Writing – original draft. Ashwaq Q. Hameed: Writing – review & editing, Validation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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