Implementation and Performance Study of the LDPC Coding in the DVB-S2 Link system Using Matlab

Lamia Fathi Abusedra[1], Amer Mohamed Daeri[2] and Amer Ragab Zerek[3]

[1] Benghazi University. Faculty of Engineering , Electrical Eng. Department
Benghazi Libya
E-mail l_abusedra@yahoo.com
[2] Zawia University. Faculty of Engineering , Computer Eng. Department
Zawia Libya
E-mail amer.daeri@zu.edu.ly
[3] Zawia University. Faculty of Engineering , Electrical and Electronic Eng. Department
Zawia Libya
E-mail anas_az94@yahoo.co.uk

Abstract**:** Low Density Parity Check (LDPC) and Bose-Chaudhuri- Hochquenghem (BCH) are channel coding that have been recently developed associated with QPSK, 8PSK, 16APSK, and 32APSK modulations for the system to work properly on the nonlinear satellite channel. The likelihood of either system bit error or block error probability is one of the most commonly used features in modern communication systems. This paper initially introduces the main components used to build a video broadcast digital system model - satellite second generation (DVB-S2). The next part of this work implement's MATLAB Simulink model to use low-density parity check code *(LDPC)* since it is a key element in this system. Next this paper examines the extent of performance of this application at small set of ModCods with (QPSK) at different values of (E_S / N_o) of energy per symbol noise ratio PSD's. Finally the relationship between (BER) and (E_S / N_o) is presented as the output values obtained by this order.

Key Words **:** DVB-S2, ModCods , QPSK, BCH ,BER ,Matlab, LDPC

I. Introduction

The adaptation of Digital Video Broadcasting - Cable, (DVB-C) and Digital Video Broadcasting - Satellite, (DVB-S) started in 1994. The main modulation scheme implemented for these systems is QPSK where Reed-Solomon FEC and convolution coding are used as a concatenated error protection system . In 1997, the DVB for Digital Satellite News Gathering (DSNG) standard [ETS301210] was adopted for reporting purposes. Broadcast vans at big public events were used to transmit satellite live signals . from outside to the studios. DVB DSNG already uses 8PSK and 16QAM. In 2003 the Digital Video Broadcasting DVB Project had developed DVB-S2 the second-generation specification for satellite broad-band applications, which proved to be an improvement over the DVB-S in terms of increasing capacity by about 30% [1]. The system is designed to be a toolkit that allow the implementation of some satellite applications of which are TV and sound broadcasting, interactivity (i.e., Internet access) and professional services, such as digital satellite news gathering. Three concepts were specified for this system which included reasonable receiver complexity, the best transmission performance very near to the Shannon limit and total flexibility [3]

Low Density Parity Check codes (LDPC) as a channel coding technique as well as QPSK, 8PSK, 16APSK, and 32APSK modulation schemes are adopted based on more recent developments by the scientific community to enable the system to work properly on the nonlinear satellite channel. Maximum flexibility in a versatile system as well as synchronization in worst case configurations (low signal-to-noise ratios) are allowed by the framing structure . Achieving optimization of the transmission parameters for each individual user in one-to-one links is made possible by Adaptive coding and modulation (ACM), which is, dependent on path conditions. This allows the existing DVB-S integrated receivers–decoders to be used during the transitional period due to the availability of Backward-compatible modes. [2, 5].

in [6] the authors studied improvement of spectrum efficiency of the DVB-S2 by applying QPSK and 32APSK hierarchical modulation. Their findings indicate that QPSK modulation improved the spectrum efficiency by 12% for a poor channel condition i.e.≤ 2 dB SNR. For better channel conditions the improvement was 7% at 11 dB SNR for the 32APSK.

The performance of LDPC codes with AWGN and Rayleigh fading channels was investigated in [7] for the DVB-S2 system. The authors showed that for the AWGN channel the lower the code rate the better the performance and that the Rayleigh channel is worse than AWGN for both algorithms of LDPC that were implemented namely Log belief Propagation (Log-BP) and Minimum sum (MS).

The effect of selecting Adaptive coding and Modulation (ACM) schemes on the performance of DVB-S2 and DVB-RCS are considered in [7], where authors proved that even by using a subset of codes it is possible to get performance very near to the optimum. The authors showed that by using less than 5 ModCods, reaching the same overall system capacity is possible as with the full set, which in turn reduce system complexity.

In this paper a small subset of ModCods is used with the QPSK modulation to evaluate DVB-S2 performance in terms of BER and number of iteration which confirms a reasonable system performance even for poor channel conditions with reduced system complexity.

The paper is structured as follows: In II a comprehensive description is given to the DVB-S2 system. Section III provides details of the DVB-S2 frame and packet structure. Outline of the physical layer of the DVB-S2 system is dealt with in IV. simulation and results of the simulated DVB-S2 system are discussed in V. Final conclusions are provided in VI.

II. The DVB-S2 System

LDPC codes that have very limited algebraic structure which is basically a simple block codes are behind achieving the best performance for DVB-S2. In 1962 R. Gallager discovered these codes. One feature of LDPC codes is that they do decoding using an algorithm adopting parallelization scheme that uses simple operations such as table look-up, comparison and addition. More over due to the adjustable nature of the degree of parallelism which allows a trade-off between complexity and throughput. The most notable characteristics of these codes that allow operation with no quasi-error which is very close to the Shannon limit within a range of 0.6 to 1.2 dB and that is due to :

- LDPC has very large normal frame code block length of 64 800 bits, and a short frame of 16 200 bits ;
- Decoding iterations are around 50 SISO iterations,
- Bose-Chaudhuri-Hochquenghem (BCH) (without any interleaver) outer concatenated code which the designers define as a "cheap insurance against unwanted error floors at high C/N ratios".

The soft-decision Viterbi decoder used in DVB-S and DVB-DSNG use 100 symbols blocks without iterations as bases for their decisions in comparison to the RS code which uses 1600 bits blocks with an interleaving factor of 12. This results in an acceptable performance , close to 3 dB from the Shannon limit. Power and bandwidth limitations are the main two factors affecting digital transmissions via satellite .[3]

Figure.1 illustrates the DVB-S2 modulator block diagram where MPEG-2 data stream is the input to the interface.

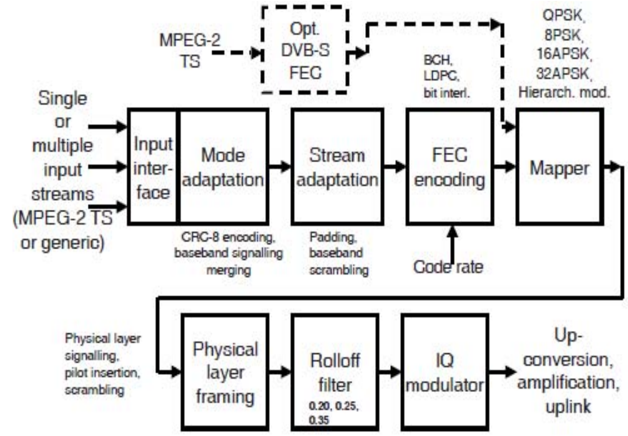

Figure. 1. DVB-S2 modulator block diagram

For many transmission modes DVB-S2 has provided the trade-offs between power and spectrum efficiency. System requirements and the selected modulation requires different code rates like 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9 and 9/10. When link conditions are exceptionally poor in that case the noise level is much higher the signal level QPSK modulation scheme is used with coding rates 1/4, 1/3 and 2/5. The four possible DVB-S2 constellations are shown in Figure 2.

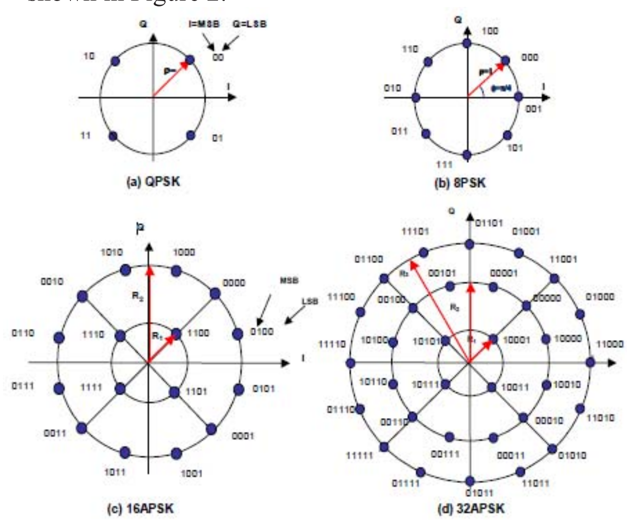

Figure 2: The four possible DVB-S2 constellations

Computer simulations with modulation scheme BPSK and 1/2, 2/3 and 4/5 code rates demonstrated the superiority of these modes . FEC code block lengths of 64 800 bits and 16 200 have been introduced to mitigate two opposite needs [2].

Long block lengths improves the C/N performance with the cost of increasing the modem end-to-end latency. Hence the long frames are the best solution for no delay sensitive applications (broadcasting), while for interactive applications a shorter frame could be more efficient when the transmitting station needs to forward a short information packet immediately. For the transmitted payload four modulation modes can be selected.

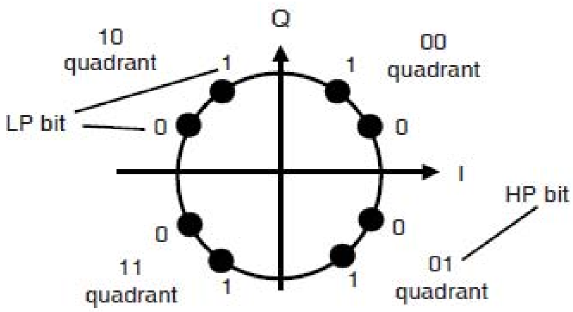

Figure . 3. Hierarchical QPSK modulation

Figure.3 shows the hierarchical modulation mode. Two different ways are used to interpret the constellation. Each constellation point in each quadrant for the high priority path can be 2 bits that are gained which conforms to DVB-S. Table.1 shows a comparisons quoted from the DVB-S2 draft standard [2].

Table .1. DVB-S and DVB-S2 minimum C/N ratio

N	Modulation Scheme	Min .required C/N [dB]
1	DVB-S2 QPSK	appr. -2.4…6.5
2	DVB-S2 8PSK	appr. 5.5…11
3	DVB-S2 16APSK	appr. 9…13.1
4	DVB-S2 32APSK	appr. 12.7…15.6

III. Frame and Packet Structures of DVB-S2

The DVB-S2 consists of two frames an FEC and a physical layer. The data to be transmitted is contained within the FEC frame which might take the structure form of transport stream such as MPEG-2 or other forms of data , so-called generic data. Following the data field is a baseband header of 80 bit long. [4]
The selected code rate of the error protection is padded to the data block with the baseband header and then the BCH code plus the LDPC code are added. The DVB-S" FEC frame is illustrated in Figure 4 with a frame length of 64800 or 16200 bits.

IV. DVB-S2 Physical Layer Frame

The framing structure has been designed so that the physical layer provides robust synchronization and signaling. Therefore detection of modulation and coding parameters can be achieved by a receiver through synchronization (carrier and phase recovery, frame

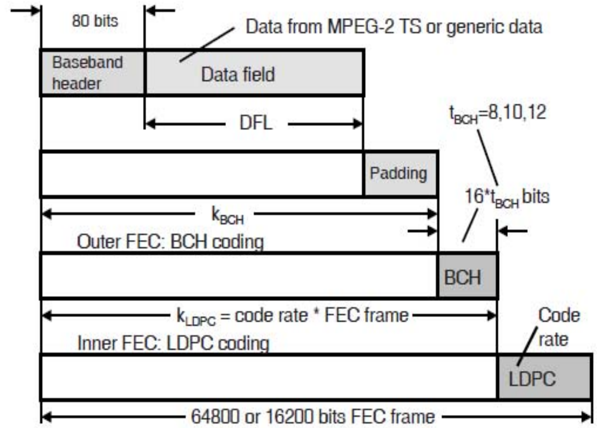

Figure. 4. DVB-S2FEC frame

synchronization) before demodulation and FEC decoding. The modulation and coding scheme are homogeneous due to periodic frames (physical layer frames, PL Frame) that are composing the physical layer of the DVB-S2 which are in regular sequence , but this may change in adjacent frames (Variable Coding and Modulation) [5]. Depending on the application either Variable Coding and Modulation or Constant Coding and Modulation could be contained in the PL framing structure . The PL Frame consists of:

- A payload of 64 800 bits long FEC frame or 16 200 bits short FEC frame that is generated through encoding of the user bits depending on FEC scheme that being selected and therefore the payload corresponds to the FEC code block concatenation of LDPC/BCH .
- Signaling information and Synchronization in the PL header such as modulation type and rate of FEC, length of frame, pilot symbols presence/absence in order to allow synchronization.

The PL-Header consist of 90 binary modulation symbols so that an integer multiple of the 90 symbols (excluding pilot symbols) are always composing the payload .Protecting the PL Header is not possible by the powerful LDPC/BCH FEC scheme due to the fact that the header is the first thing to be decoded by the receiver and hence under worst-case link conditions the header has to be perfectly decodable.
In order to reduce decoding complexity as well as global efficiency loss a suitable soft-decision correlation decoding with a block code with very low-rate of 7/64, was selected by designers to minimize the number of signaling bits. Taking a 64 800 bit frame as an example yields an efficiency of 99.3 % for the PL Frame as a worst case scenario (excluding pilot symbols). [3]

The modulated carrier of the starting one-slot-long physical layer header is π/2 shift BPSK in the physical layer frame . Followed by slot 1 ... slot 16. When pilots are transmitted (optional), Slot 17 may be a pilot block. This is can be clearly seen in Figure 6. [2]

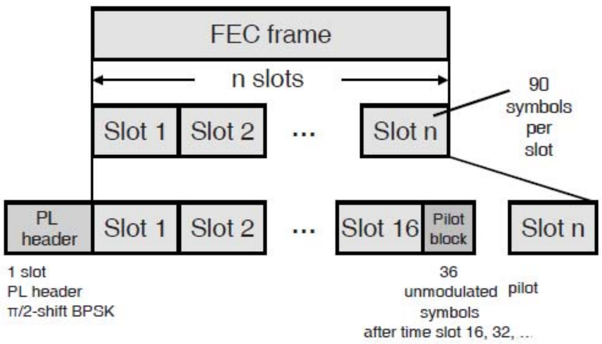

Fig. 6. DVB-S2 Physical layer frame

V. Simulation and Results

In this work a Matlab Simulink is used to design the transmitter circuit and the receiver system DVB-S2 and the review of the form of spectrum signal transmitter (TX) and compare the signal reception (RX). The model in Fig(7) (at the end of paper) shows channel coding scheme of the Digital Video Broadcasting standard (DVB-S.2) used in the second generation, which will be deployed by DIRECTV in the United States. The adopted coding scheme for this system is a concatenation of LDPC and BCH codes. LDPC codes, which can achieve extremely low error rates near channel capacity by using a low-complexity iterative decoding algorithm. The sporadic errors made by the LDPC decoder are corrected by the outer BCH codes.

The model is a collection of many components that are Generation of BBFRAME by a random source including BCH encoding, for all coding parameters and normal FEC FRAME , LDPC encoding, for all coding parameters and normal FEC FRAME, Interleaving ,Modulation (QPSK or 8PSK), AWGN channel modeling ,Soft-decision demodulation , Deinterleaving , LDPC decoding, by means of the message passing algorithm BCH decoding ,and BB FRAME un-buffering .

Table 2 shows some of the simulation parameters That are used to simulate the DVB-S.2 system at hand. It also creates the System objects making up the DVB-S.2 system. Figure 7 at the end of paper shows the block diagram for DVB-S2 and how the various system components are connected

The simulation studies the performance of the DVB-S2 system using the external symbols to correct errors made by different decoding LDPC code. The settings of sub-modulated system has been changed three times for three systems (QPSK 1/2, QPSK 2 / 3, QPSK 9/10). Also several of the values of signal power ratio of signal to noise from (0.1dB to (1dB) has been taken. The bit error rate of LDPC code has been calculated at different values, to rerun the system under test with a vector of E_b/N_o's and visualization turned off to generate an LDPC curve.

Table .2. Simulation Model Input Parameters

Parameter	Value
Modulation Type	'QPSK'
Num Bits Per Packet	1504
Es/No dB	1
BCH Codeword Length	32400
Num Packets Per BB Frame	21
Num Info Bits Per Codeword	31584
Bit Period	3.1662e-05
LDPC Codeword Length	64800
LDPC Num Iterations	50
Interleave Order	[64800x1 double]
Constellation	[4x1 double]
Symbol Mapping	[0 2 3 1]
Phase Offset	0.7854
Bits Per Symbol	2
Sequence Index	2
Num Symbols Per Codeword	32400
Noise Var.	0.7943
Noise VarEst.	0.5617

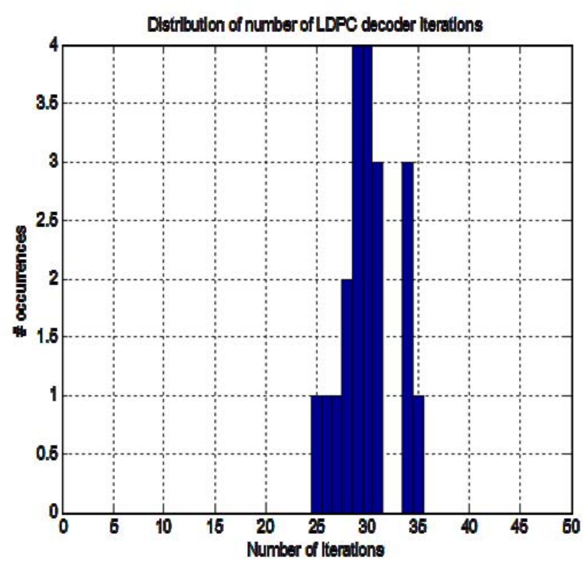

Figure 10 Distribution of the number of iterations performed by the LDPC decoder

Figures 8 and 9 show the relationship between the signal-to-noise ratio, were different QPSK code values were used, (The LDPC bit error rate).From the figures it can be clearly noted that 1/2 QPSK converges to very low BER values at very low SNR values and this is because of the great effect of the LDPC decoder. While figure 10 illustrates the distribution of the number of iterations performed by the LDPC decoder .

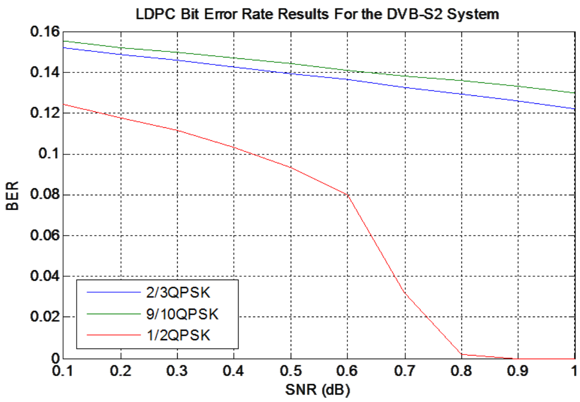

Figure.8 Bit Error Rate Results System for the DVB-S2 SNR (0.1-1.0 dB)

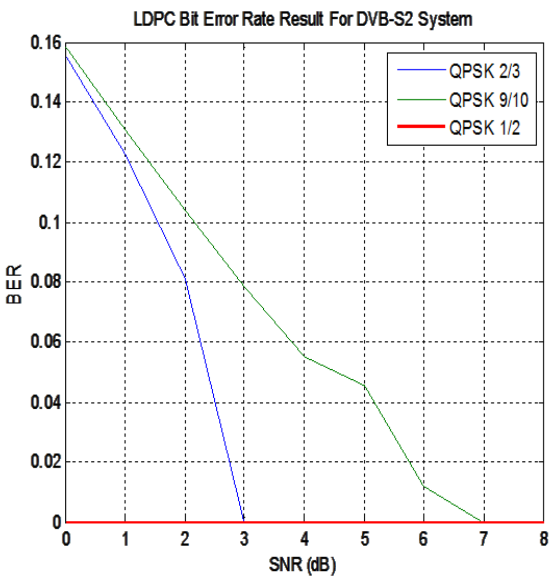

Figure.9 Bit Error Rate Results System for the DVB-S2 at SNR (1.0-8.0 dB)

VI. Conclusion

In this work a DVB-S2 system is successfully simulated using MATLAB with Simulink, where the BCH and LDPC coders/decoders were implemented. It is shown that the used model conforms to the ESTI standard in terms of BER performance. In this simulation determined the performance of (LDPC) at (QPSK 1 / 2, QPSK 2 / 3, QPSK 9 /10), and achieved result confirms to the ETSI standard and also it demonstrates that the lower the ModCod the better the BER. The system performs very well since it converges within the maximum limit of the number of iteration which is in this case is 50.

VII. References

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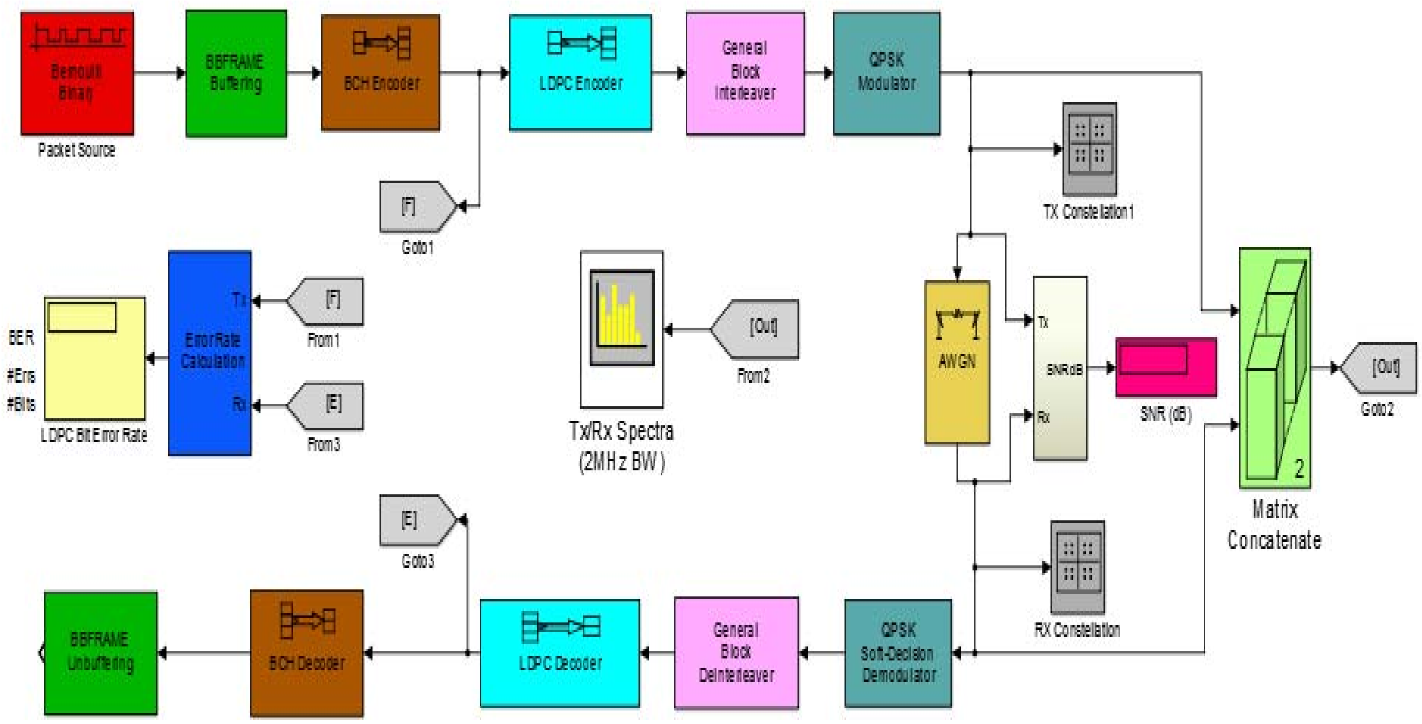

Fig.7. DVB-S2 Transmitter and Receiver system