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Modeling of a DVB-S2 Transmission Chain with Optimization of Adjustment Parameters for a Good Quality of the Reception Signal

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Abstract

Digital television is part of our daily lives. We took an interest in the DVB-S2 standard in particular, because it is the one that governs the transmission by satellite of multimedia content from television programs. With ever-changing user needs, there are new challenges that the DVB-S2 standard is no longer able to meet due to errors caused by weather and hardware limitations. The main purpose of a satellite TV transmission is to obtain a video signal in reception of the best possible quality and at a high bit rate. It is therefore important to determine all the factors which could intervene in the process of transmission and which have a negative impact on the yield at the reception of the signal. We therefore designed and simulated the DVB-S and DVB-S2 transmission chains with QPSK modulation (and an FEC coding rate of 1/2), on MATLAB software (Simulink), and with an AWGN channel for the sake of comparison performance between these two chains. Then we carried out the design of the DVB-S2 transmission chain with an RF (Radio Frequency) satellite channel, by materializing all the elements which intervene in the downlink to evaluate the performance of this chain according to the factors which influence and/or degrade the signal quality between transmission and reception at the receiving earth station. The main results obtained relate to the DVB-S2 transmission chain and were interpreted using the visualization of the error rate blocks: With an AWGN channel, increasing the signal-to-noise ratio decreases the rate of erroneous packets and therefore improves the quality of the received signal. With an RF satellite channel on the downlink: increasing the transmit power improves the receive performance, this is useful for correcting most RF imperfections; having larger parabolic antennas is an advantage because they have greater gains; this makes it possible to minimize the rate of erroneous packets. These simulations allowed us to determine the precise and numerical impact of RF degradations on the performance of the downlink DVB-S2 transmission chain.

Keywords

DVB-S2, Modulation, AWGN, RF Imperfection, TV Transmission

1. Introduction

Digital television plays an important role in most digital communication systems. By digital television, we mean the broadcasting of television programs in digital form, starting with the transformation of images into digital data streams. Compared to analogue mode, digital television offers significantly better picture and sound quality [1]. The broadcasting of television programs in most countries of the world goes through the DVB standard (Digital Video Broadcasting), which, in addition to radio programs, offers additional information and services [1]. There are several variants, namely DVB-S, DVB-H, DVB-C and DVB-T. DVB-S (Digital Video Broadcasting-Satellite) is the variant for broadcasting DVB via satellite. This variant is the most used. Thanks to its broadband, most radio and TV channels as well as additional services are broadcast here. The DVB-S2 (Digital Video Broadcasting-Satellite second generation) standard was ratified in March 2005 by the ETSI (European Telecommunications Standards Institute) to overcome the limitations of the DVB-S standard [2]. In recent years, there has been a growing shortage of frequencies, accentuated by the advent of new high-definition broadcasting services [3]. DVB-S2 is a standard system for transmitting the TV signal by satellite and it is currently used as the standard for the transmission of multimedia content by satellite in several local and international media. It allows the transmission of audio and video signals in MPEG format. It is an improvement of DVB-S, which increases the efficiency and the reliability of the channels and represents the solution to increase the transmission capacity, in particular that of digital high definition television by satellite [3]. The DVB-S2 standard also comes to overcome the limitations of DVB-S whose transmission performance is out-dated today. Since the aim of a TV transmission by satellite is to obtain a video signal of the best possible quality at a high bit rate, it is important to determine all the factors which could intervene in the transmission process and which have a harmful impact on the performance between transmission and reception of the signal.

2. DVB-S2 as a Solution for Increasing Transmission Capacity

DVB-S2 represents the solution to increase the transmission capacity, in particular that of digital high definition television by satellite. The error correction used in DVB-S2 uses BCH (Bose-Chaudhuri-Hocquenghem) with LDPC (low density parity check) internal coding, its coding rate being 1/4, 1/3, 2/5.1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9 or 9/10. Since the conditions are very unfavourable with a signal-to-noise ratio of less than 0 dB, the coding rates of 1/4, 1/3 or 2/5 with a QPSK modulation scheme are mainly used.

DVB-S2 uses an MPEG-4 compression algorithm which delivers HDTV (High Definition TV channels) and in the same bandwidth for SDTV (Standard Definition TV channels) [3].

We can cite, as characteristics of the DVB-S2 standard:

- More powerful LDPC (Low Density Parity Check) and BCH (Bose Chaudhuri Hocquenghem) channel coding.
- An adaptive mode where the transmission chain varies the useful bit rate according to the transmission conditions.
- A wide range of coding and modulations with a total of 28 "modulation coding" ranging from QPSK 1/4 to 32APSK 9/10, which cover a wide range of signal-to-noise values from approximately −2 dB to +17 dB.
- A more efficient framing format and encapsulation scheme that accommodates a variety of input sources (streams, MPEG-TS multiplexes, IP packets, etc.).
- The standard is no longer restricted to the MPEG-2 compression standard (audio and video). It adapts to a wide range of compression and coding schemes, in particular MPEG-4 and its AVC option [3].

3. Functional Diagram of the DVB-S2 Standard Transmission Chain

DVB-S2 represents the solution to increase the transmission capacity, in particular that of digital high definition television by satellite. The error correction used in DVB-S2 uses BCH (Bose-Chaudhuri-Hocquenghem) with LDPC (low density parity check) internal coding, its coding rate being 1/4, 1/3, 2/5.1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9 or 9/10. Since the conditions are very described with a signal-to-noise ratio of less than 0 dB, the coding rates of 1/4, 1/3 or 2/5 with a QPSK modulation scheme are mainly used. DVB-S2 uses an MPEG-4 compression algorithm which delivers HDTV (High Definition TV channels) and in the same bandwidth for SDTV (Standard Definition TV channels). The DVB-S2 transmission chain is presented in the ETSI standard in the form of a functional block diagram defined by **Figure 1** [3].

- **Fashion adaptation:**

The input interface is configurable according to the flows:

- Simple (SPTS) or multiple (MPTS) MPEG "Transport Stream", with TV services encoded in MPEG-2 or MPEG-4;
- Continuous binaries (unstructured streams, in the form of data);
- IP datagrams, ATM cells.

The first input block is therefore a very flexible input stream adapter, which can optionally be associated, depending on the application, with a synchronization that works in CBR (Constant Bit Rate). Indeed, the data processing in the DVB-S2 modulator can produce variable transmission delays. Thanks to this

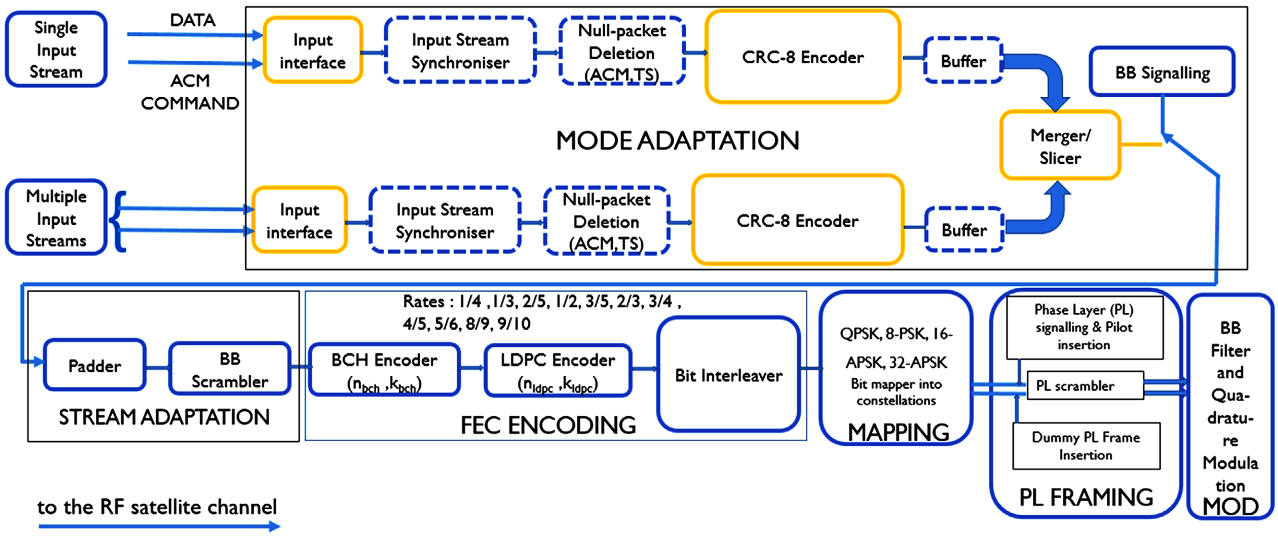

Figure 1. Functional block diagram of the DVS-S2 transmission chain [3].

synchronization, it is possible to guarantee a constant point-to-point transmission delay for packeted input streams.

In order to avoid saturating the transmitter, the null packets are then erased for the input formats of the TS type (Transport Stream—packets of 188 bytes) and for the ACM (Adaptive Coding Modulation) mode. These are the famous "stuffing packets" or stuffing packets.

Then, we perform a CRC-8 encoding (encodes the information on 1 byte of 8 bits) to allow the detection of errors at the level of the packets in the receiver, and again this is only valid for multiple input streams. For the record, this CRC coder is an error correcting code, but is not an error detecting code.

Depending on the manufacturer and the option chosen, you can also have a buffer to store the data to allow the mixing of input streams, obviously, if several streams are processed.

At the same time, baseband signalling (BB Signalling) is generated. A baseband header (BB Header) is applied before the Data Field (DFL). This information which is added makes it possible to indicate to the receiver (IRD) on which type of generic stream one is working (in plain text the format of the input stream): SPTS, MPTS, TS and according to which type of mode adaptation (CCM (Constant Coding Modulation), ACM, VCM (Variable Coding Modulation), etc.)

The flow frame is of the BB Header type followed by a Data Field (DFL) [4].

- **Flux adaptation:**

If the Data Field is not complete, padding characters are inserted.

The energy dispersion created by the "BB Scrambler" coder (Baseband scrambler) avoids having a strong energy line on the carrier frequency at the output of the modulator when at the input there is a signal modulated by a continuous component. The inter-modulation products are thus eliminated as much as possible.

The dispersion of energy, produced from a shift register of 15 cells, thus makes it possible to avoid disturbing interference from existing HF (High Frequency) networks in the same frequency bands. It also makes it possible to increase the number of signal transitions to facilitate clock recovery. The frame completed in baseband by the padding becomes an output stream in BBFrame (baseband frame) [4].

- **FEC coding:**

The channel coding system uses external BCH (Bose-Chaudhuri-Hocquenghem) and internal LDPC (Low Density Parity Check) codes.

The value of the FEC (forward error corrector) determines the efficiency of the LDPC encoder (for the record, remember that for DVB-S, the FEC (Forward Error Correction) is associated with the convolutional encoder).

For the DVB-S2 standard, the code rate can take the values: 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10. When VCM or ACM modes are used, the FEC and modulation may change in different frames, but remain, of course, constant within a frame.

At the output of the LDPC encoder, there can be blocks of 64,800 bits (in broadcast applications) or 16,200 bits (interactive applications).

Finally, the bit interleaver avoids having too large errors at the input of the LDPC decoder (obviously in reception), because we work at the "Bit" and not "Symbol" level. At the output, a stream is generated in FEC Frame (forward error corrector frame). Note that bit interleaving will only be applied for 8-PSK, 16-APSK and 32-APSK modulations.

For the record, whatever the broadcasting mode, digital television requires error-free transmission qualified as "Quasi Error Free" (QEF). In DVB-S2, we accept a rate of less than one uncorrected error per hour of transmission for a bit rate of 5 Mbit/s for a TV service.

In reception, before the demultiplexer, the TS-PER (Transport Stream Packet Error Rate) must be less than 10^{-7}. It is important to note that we no longer work in BER (Bit Error Rate), as in DVB-S, where we compared the rate of the number of false bits to the number of bits received, whereas in DVB-S2, we use a packet of 188 bytes [4].

- **Mapping:**

The mapping makes it possible to create the modulation constellations: QPSK, 8-PSK, 16-APSK, and 32-APSK. Note that the GRAY mapping (1 single bit changes between two successive states of the carrier) is only applied for the QPSK and 8-PSK constellations [4].

- **The physical layer:**

The structuring of the physical layer (PL: Physical Layer) is synchronized with the FEC frames. Physical layer signalling and optional pilot symbol insertion indicate the FEC value and modulation type.

The insertion of dummy frames of the physical layer ("Dummy PL FRAME") is used when there is no information ready to be transmitted on the satellite channel, therefore "unnecessary" information is transmitted.

Finally, the channel is scrambled, for energy dispersion, to obtain the physical layer frame ("PL Frame") [4].

- **Modulation:**

The filtering, the purpose of which is to limit the band occupied by the modulated signal, is carried out by a Nyquist filter with a rounding coefficient (commonly called "Roll-off") variable according to three values 0.20; 0.25; 0.35. It thus makes it possible to limit the useful throughput. This filter is distributed between the modulator and the demodulator.

Quadrature phase modulation can be carried on the satellite RF channel [4].

4. Implementation of the DVB-S2 Standard Transmission Chain with AWGN Channel with Simulink

We sent a binary signal as Bernoulli binary data which goes through Baseband frame buffering, and is then encoded by BCH as outer encoder and LDPC as inner encoder; the signal is interleaved by a general block interleaver, then is modulated by QPSK; finally the signal is transmitted by an AWGN (Additive White Gaussian Noise) channel. The output signal of AWGN is demodulated by QPSK demodulation (like soft-decision), which is deinterleaved by general block de-interleaver, then the signal is decoded by LDPC decoder as internal decoder and then decoded by BCH as internal decoder than external decoder. The signal goes through Baseband frame unbuffering and at the end we have received the data. The parameters of the different blocks of this transmission chain are:

1) Transmitter:

- Bernoulli binary generator with zero probability of 0.5 and bit sampling time is 2 ms.
- Frame buffering (32,208-bits).
- BCH encoder codeword length (Nbch = 32,400 bits) and message length (Kbch = 32,208 bits).
- LDPC encoder (64,800 bits).
- General block interleaver.
- QPSK modulator (32,400 bit).

2) Channel:

- In the AWGN block, we change the SNR from 1 to 15 dB to calculate the PER of the system.

3) Receiver:

- QPSK soft decision demodulator (64,800 bits).
- General block deinterlacer.
- LDPC decoder (32,400 bits).
- BCH decoder code word length (Nbch = 32,400 bits) & message length (Kbch = 32,208 bits).
- Bbframe debuffing (32,208 bit).

The block diagram designed on SIMULINK of the Matlab's software modelisation is illustrated in **Figure 2**.

- The "BB Frame buffering" subsystem in Figure 3 is composed of buffer and PAD blocks:

Their parameters are showing in Figure 4.

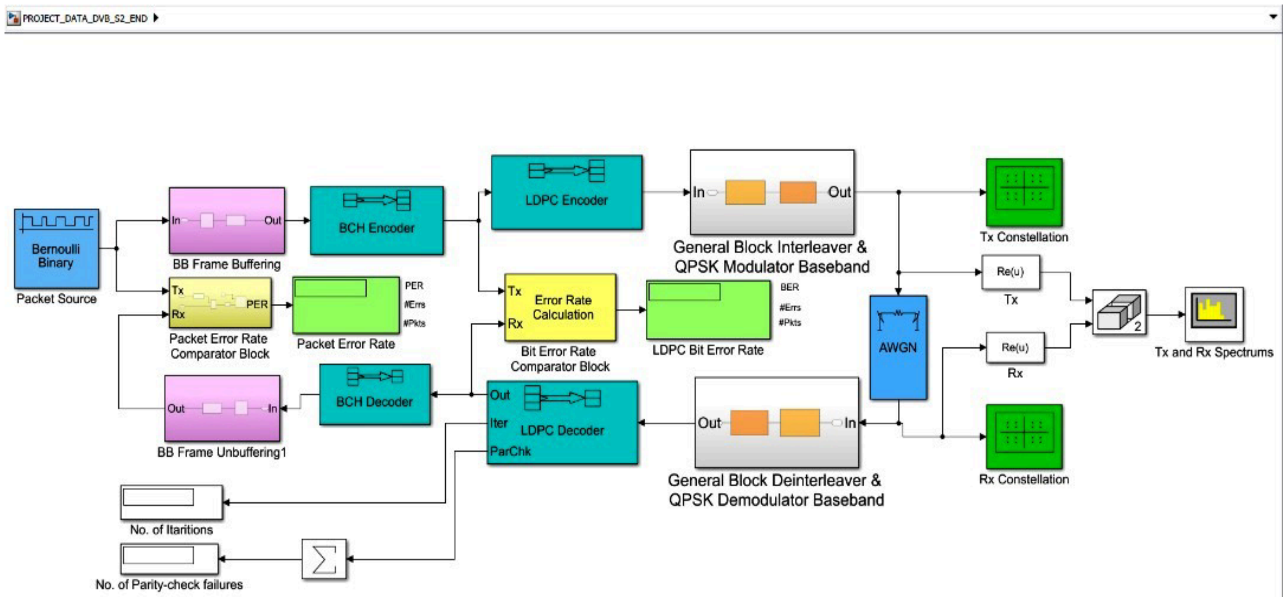

Figure 2. Block diagram of the transmission chain of the DVB-S2 standard with AWGN channel on SIMULINK.

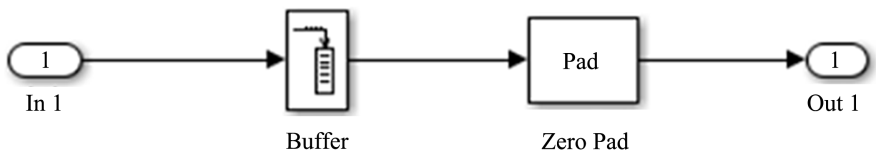

Figure 3. Structure of the "BB Frame buffering" block.

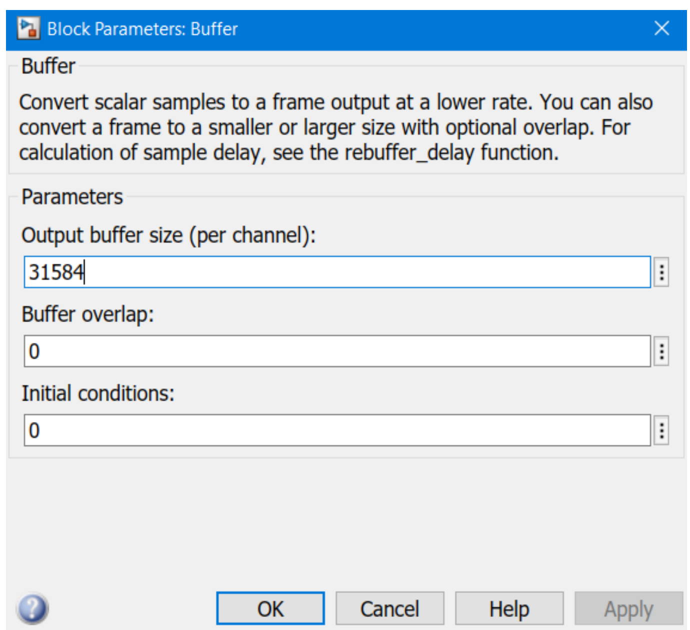

Figure 4. Parameters of the Buffer block (BB Frame buffering).

Output buffer size (per channel) is showing in Figure 5: [number of information bits per code word] = 31,584

Column size: BCH Message Length = 32,208

- The "BCH encoder" block has the following parameters in Figure 6.

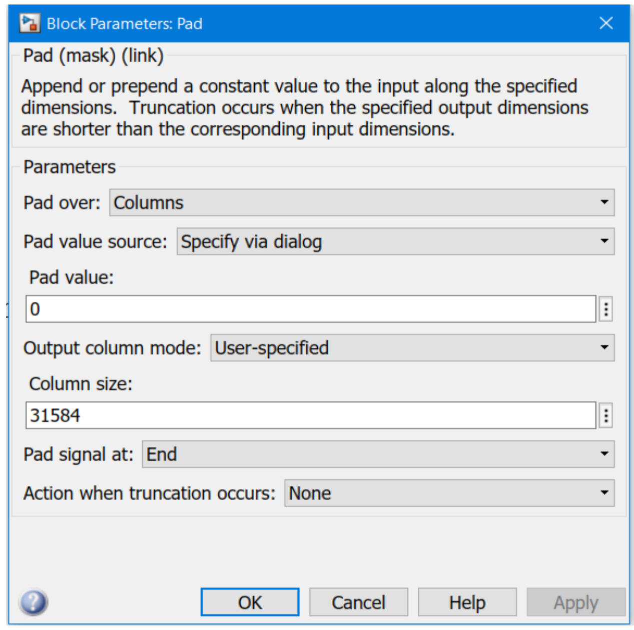

Figure 5. Parameters of the "PAD" block (BB Frame Buffering).

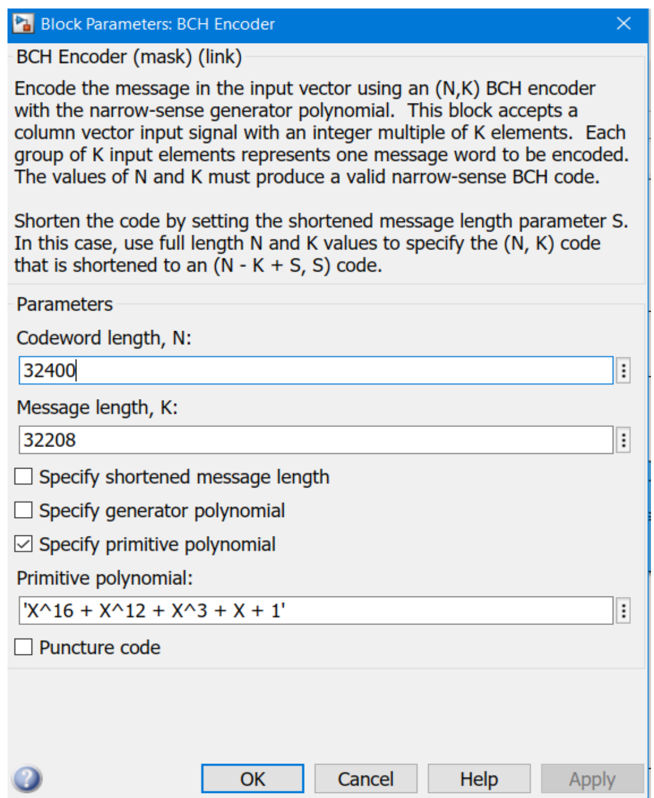

Figure 6. Parameters of the "BCH encoder" block.

Filling the primitive polynomial field is mandatory for this FEC encoding rate. It allows the pair (Nbch, Kbch) to have a narrow valid meaning.

- The "LDPC encoder" in Figure 7 block has the following parameters:

The relationship between BCH and LDPC encoders is as follows:

Normal FEC frame length: 64,800 bits

Desired FEC coding rate: 1/2 so according to the BCH code table

N_{bch} = 32,400 bits and K_{bch} = 32,208 bits

FEC coding rate = Code word length N_{bch}/FEC frame length

So 64,800/32,400 = 1/2 (desired FEC encoding rate)

- The "LDPC decoder" block in Figure 8 has the following parameters:
- The Packet Error Rate Comparator subsystem is showing in Figure 9.

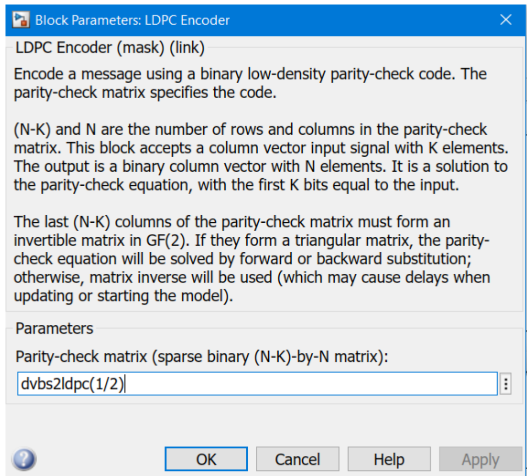

Figure 7. Parameters of the "LDPC encoder" block (LDPC encoder it takes as input the FEC coding rate (1/2 in our case).

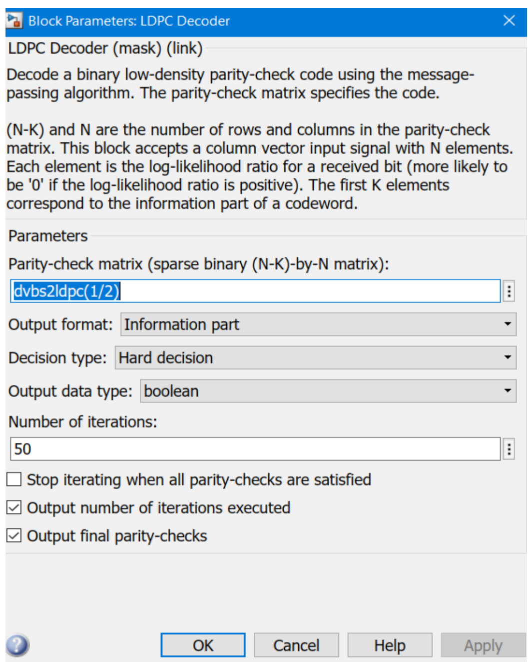

Figure 8. Parameters of the "LDPC decoder" block.

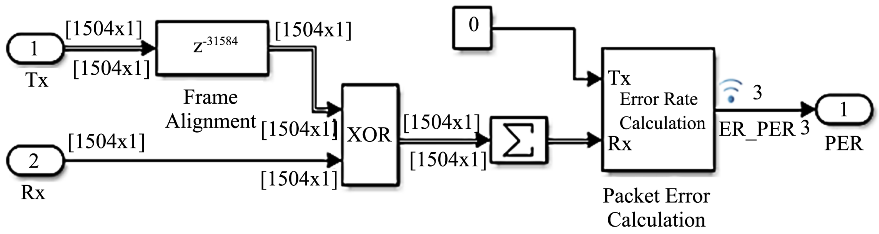

Figure 9. Packet error rate comparator subsystem.

5. Implementation of the DVB-S2 Transmission Chain of a Video Signal and of a Communication Signal with RF Satellite Channel (on a Downlink) with Simulink

We realized the DVB-S2 transmission chain of a video signal and a communication signal with RF satellite channel on a downlink. The block diagram designed on SIMULINK of the Matlab's software modelisation is illustrated in Figure 10.

1) RF degradations occurring on the satellite link

The RF degradations that occur on a satellite link can be represented by:

- **High Power Amplifier (HPA) memoryless non-linearity with optional digital predistortion (Saleh model):**

This block allows to model a travelling wave tube amplifier using the Saleh model option of non-linearity without memory and optionally corrects AM/AM and AM/PM distortions with a digital pre-distortion block [5]. It is also used to model memory-less non-linear impairments caused by signal amplification in the radio frequency (RF) transmitter or receiver [6]. AM/AM distortion is the difference between the supply voltage and the RF output voltage envelope. Such a difference is caused by a non-linear relationship between the supply voltage and the RF output signal envelope. AM/PM distortion occurs when the phase modulation of the output signal is amplitude dependent and has a more severe effect on system performance. This distortion is an unwanted phase modulation of the RF output carrier due to the modulation of the supply voltage However, the non-linearity of the high power amplifier and the AM/AM and AM/PM distortions cause an amplitude error and a phase error on the output signal, which seriously degrades the transmission performance of the system [7]. This high power amplifier has three (03) back-off levels. This parameter is used to determine how far the satellite's HPA is driven into saturation. The selected back-off is used to set the input and output gain of the memory-less non-linearity block. The possible choices are:

✓ 30 dB (negligible non-linearity): sets the average input power to 30 decibels below the input power that causes the amplifier to saturate. This results in negligible AM/AM and AM/PM conversion.

✓ 7 dB (moderate non-linearity): sets the average input power to 7 decibels below the input power that causes the amplifier to saturate. This results in moderate AM/AM and AM/PM conversion, which can be corrected by digital pre-distortion.

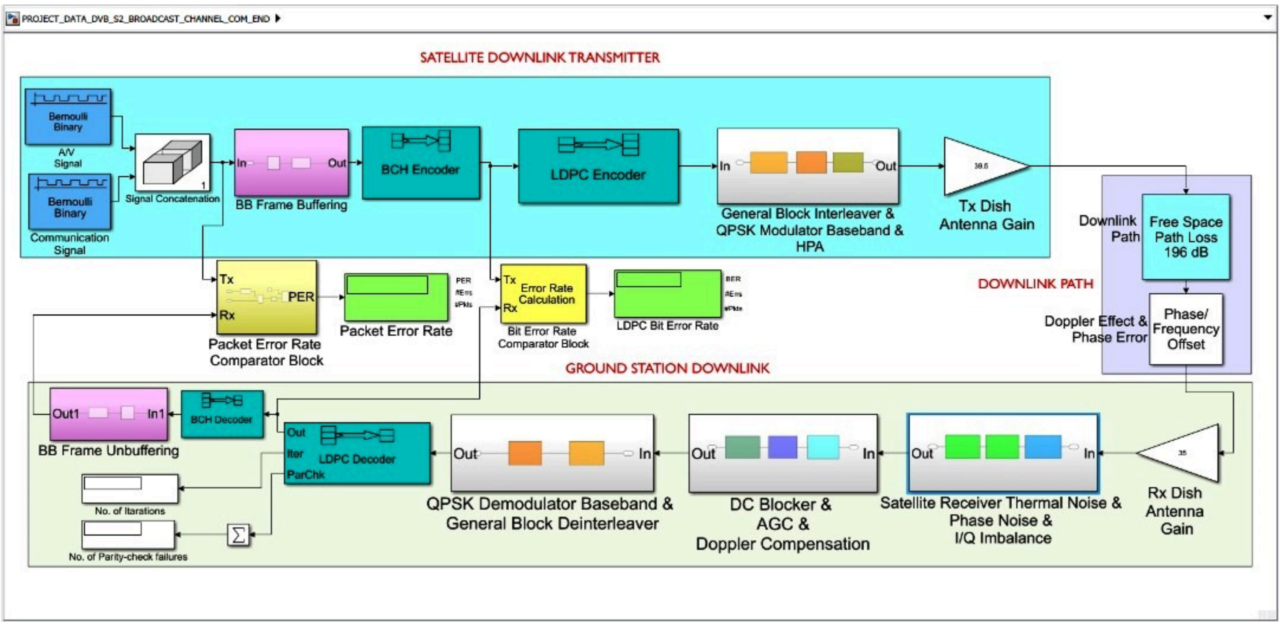

Figure 10. Block diagram of the DVB-S2 transmission chain of a video signal and a communication signal with RF satellite channel (on a downlink) on SIMULINK.

✓ 1 dB (moderate non-linearity): sets the average input power to 1 decibel below the input power that causes the amplifier to saturate. This results in severe AM/AM and AM/PM conversion, which cannot be corrected by digital pre-distortion [5].

We chose an arbitrary output power of 28 dB and an input power for negligible non-linearity.

- **Free space path loss:**

It is the ideal reduction by propagation of a signal inside a space where there would be only the two antennas of transmission and reception. This phenomenon depends only on the distance travelled in the vacuum of space and the frequency, but it is also affected by other factors in the atmosphere.

The formula for free space path loss is:

$$A_0 = 32.4 + 20\log_{10}(f) + 20\log_{10}(d)\ \text{dB} \quad [8] \tag{1}$$

where: *f*: frequency (MHz) *d*: distance (km)

Since we are in a tropical zone where there is a lot of bad weather (heavy rain, thunder, winds, high temperatures), we transmit signals in C band (in a frequency band between 4 and 8 GHz). We have therefore chosen a base frequency of 4 GHz and an average distance of 35,600 km between the receiving antenna of the earth station and the satellite.

- **Doppler error or Doppler-Fizeau effect:**

It is the frequency shift of a wave (mechanical, acoustic, electromagnetic or of another nature) observed between the measurements at transmission and at reception, when the distance between the transmitter and the receiver varies during time. If this physical phenomenon is generally referred to as the Doppler effect, the name "Doppler-Fizeau effect" is reserved for electromagnetic waves [9].

Thus, this block rotates the signal to model the Doppler error on the link.

This frequency offset is set by the Phase and Frequency Offset block. By default, this offset is zero if the Doppler effect is neglected.

- **The satellite reception thermal noise:**

It is materialized by the block "Receiver thermal noise" (thermal noise of the receiver) allows to add a Gaussian white noise which represents the effective temperature of the receiver system (in degrees Kelvin).

The default setting is 20 K. The choices are as follows [5]:

- 0 (no noise) to be used as a parameter to visualize other RF impairments without the disturbing effects of this noise.
- 20 (noise level very low). This parameter shows us how easy the low noise, combined with other RF impairments, can degrade link performance.
- 290 (typical noise level). This parameter visualizes the operation of a typical silent satellite receiver.
- 500 (high noise level). This parameter is used to visualize the behaviour of the receiver when the system noise figure is 2.4 dB and the antenna noise temperature is 290 K.

- **Receiver phase noise:**

Phase noise is the frequency domain representation of random fluctuations in the phase of a waveform. It corresponds to deviations in the time domain from perfect periodicity [8] [10] [11]. This RF degradation is materialized by the "Phase noise" block and its particular choices are [5]:

- Negligible (−100 dBc/Hz @ 100 Hz)—Almost no phase noise.
- Low (−55 dBc/Hz @ 100 Hz)—Sufficient phase noise to be visible in both the spectral and I/Q domains, and cause bit errors when combined with thermal noise or d other RF impairments.
- High (−48 dBc/Hz @ 100 Hz)—Sufficient phase noise to cause errors without the addition of thermal noise or other RF degradation.

In-phase and quadrature imbalance/dc offset:

It is materialized by the "I/Q Imbalance" block. This block applies amplitude imbalance, phase imbalance, and DC offset to the in-phase and quadrature signal components. It allows you to select from five types of phase and quadrature imbalances at the receiver.

The default setting is "None". For example according to the information in this reference [5]:

Some specific blocks will be used to correct RF imperfections in particular:

- The Doppler effect compensation block:

This is a Phase and Frequency Offset block used to compensate for the receive frequency offset due to the Doppler effect.

- The "DC blocker" block

This block compensates for the DC offset in the I/Q imbalance block.

2) Specific blocks for correcting certain RF degradations

Some specific blocks will be used to correct particular RF imperfections:

- **The Doppler Shift Compensation Block:**

This is a "Phase and Frequency Offset" block used to compensate for the receive frequency offset due to the Doppler effect.

- **The DC blocker**

This block compensates for the DC offset in the I/Q imbalance block.

3) Other blocks involved in the DVB-S2 transmission chain with RF satellite channel on a downlink

Other important blocks complete this transmission chain with RF satellite channel:

- **The gain of the transmitting satellite dish (transponder):**

We set this gain to Ge = 39.5 dB base.

- **The gain of the receiving satellite dish:**

We set this gain to Gr = 37.5 dB base.

- **The AGC block ("Automatic Gain Controller"):**

This block adjusts the receive signal strength to a desired level.

We set the output power value to 180 Watts. It will remain unchanged until the end of our simulations.

6. Results & Discussions

6.1. Results of the Transmission Chain DVB-S2 with Channel AWGN

1) Script 1: When the signal to noise ratio (SNR) = 1:

➢ The Tx transmit (left) and Rx receive (right) constellations are shown in Figure 11:

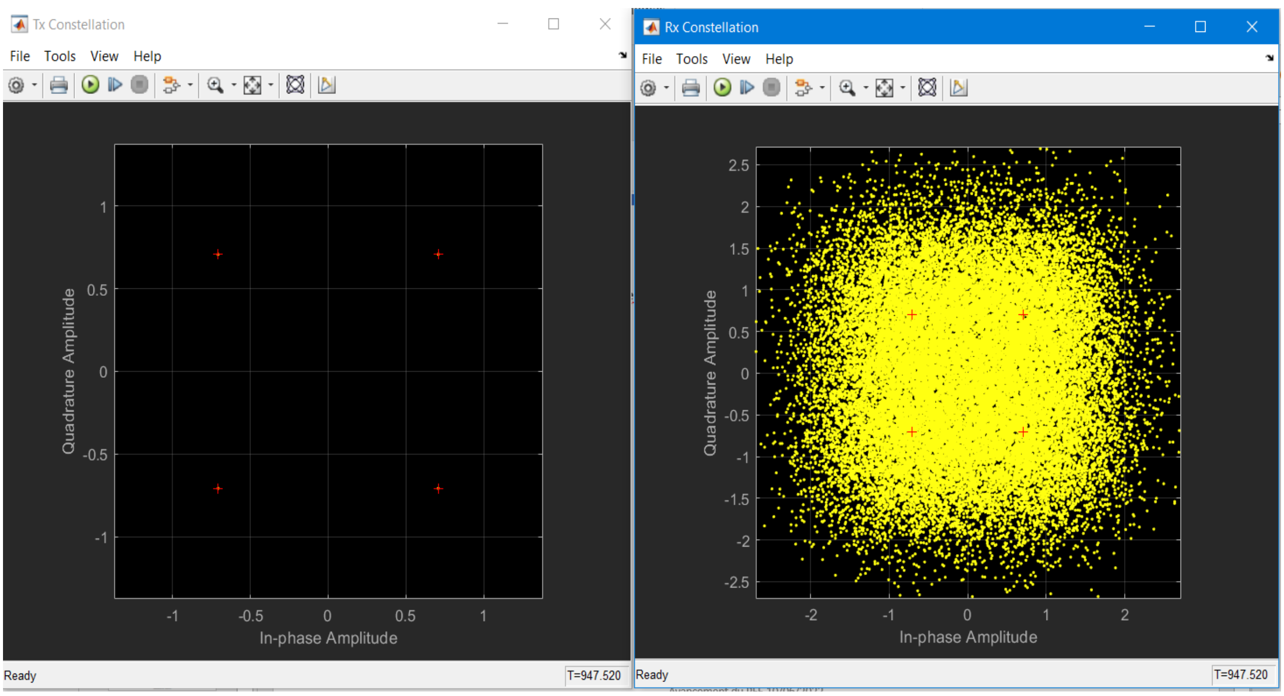

Figure 11. Tx et Rx constellations for SNR = 1 (DVB-S2).

- **The received signal is noisy because with the addition of white noise, we can no longer distinguish the 4 states of the QPSK constellation. The Rx constellation is noisy and it is difficult to extract the information.**
- **For this signal to be good, it is necessary that the 4 states of the QPSK constellation can approximately form as clearly as possible. The more distant the points are from each other by state, the easier the retrieval of information.**

➢ The Tx transmission (in yellow) and Rx reception (in blue) spectra are shown in Figure 12.

- It is difficult to retrieve the information because with the addition of white noise, we find that the two spectra are clearly shifted.
- For it to be easy to extract information from the spectral point of view, two spectra must be clearly merged.

➢ The "Packet error rate" block in Figure 13 gives us information about packets lost between transmission and reception of frames.

- We have a substantially zero erroneous packet rate with 312 packets as samples during our simulation between transmission and reception. There is no noticeable error in reception.
- The total number of packets (samples) transmitted varies with the sampling period and the simulation duration.

➢ The LDPC bit error rate block in Figure 14 gives us information about the bit error rate between LDPC encoding and decoding.

- We have a substantially zero error bit rate between encoding and LDPC decoding, which means that the 1/2 encoding rate we use for this signal-to-noise ratio is practically good. There is no LDPC coding error on reception.
- The total number of coding bits (samples) transmitted varies with the sampling period and the simulation duration.

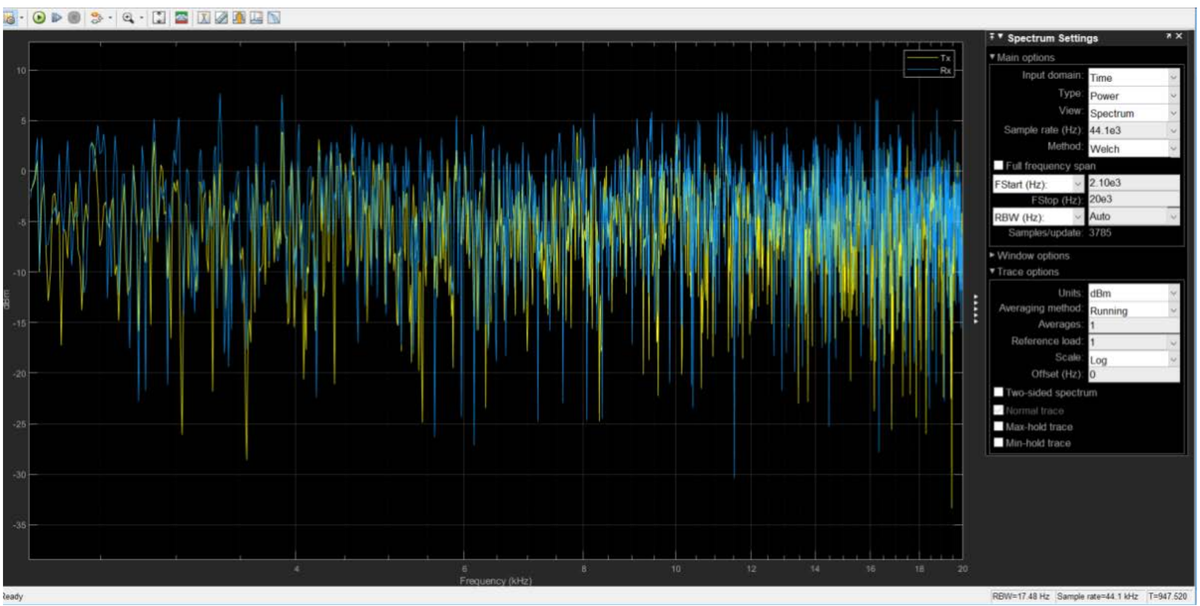

Figure 12. Spectra of Tx & Rx for SNR = 1 (DVB-S2).

2) Script 2: When the signal to noise ratio (SNR) = 15:

- The Tx transmit (left) and Rx receive (right) constellations are shown in Figure 15.
  - The reception signal is good because with the addition of white noise, we manage to distinguish the 4 states of the QPSK constellation. The points are quite distant by state of the QPSK constellation, which facilitates the retrieval of information.
- The Tx transmission (in yellow) and Rx reception (in blue) spectra are shown in Figure 16.
  - It is easy to retrieve the information because with the addition of white noise, we find that the two spectra are practically confused.
- The "Packet error rate" block in Figure 17.

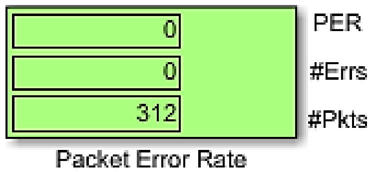

Figure 13. Error packet rate for SNR = 1 (DVB-S2).

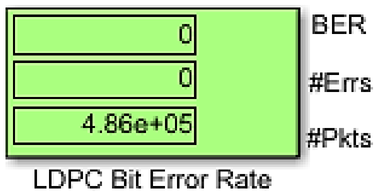

Figure 14. Error bit rate of LDPC decoding for SNR = 1 (DVB-S2).

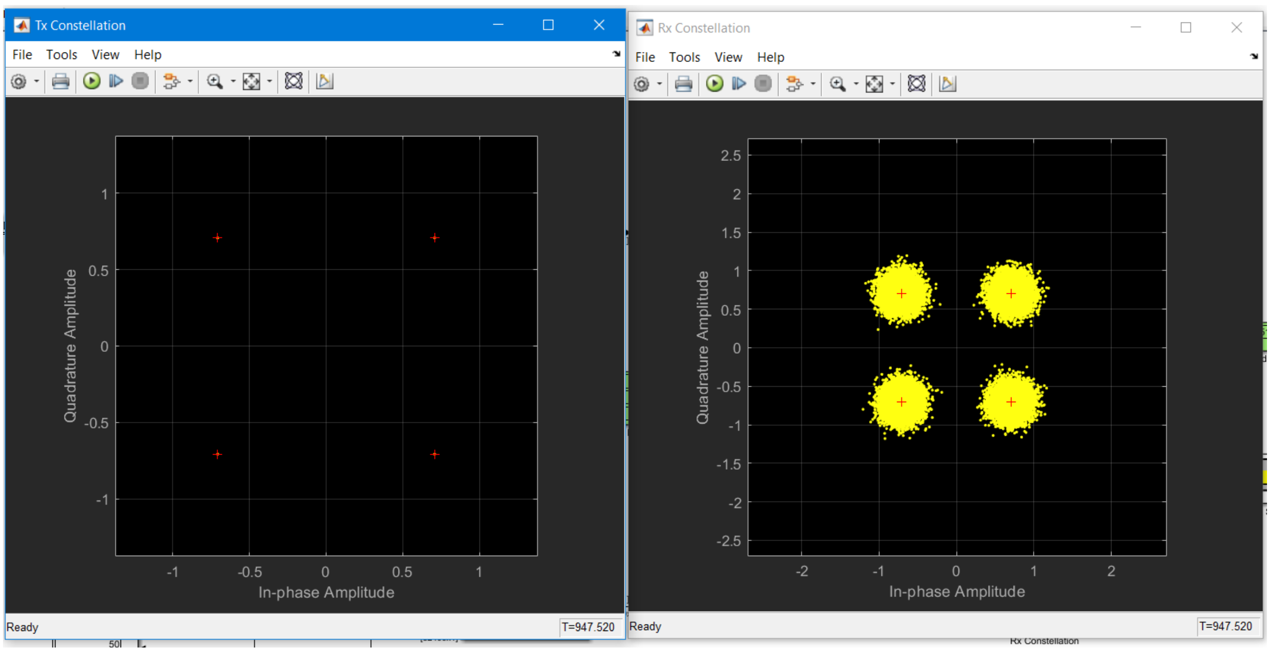

Figure 15. Tx & Rx constellations for SNR = 15 (DVB-S2).

- We have a substantially zero erroneous packet rate with 312 packets as samples during our simulation between transmission and reception. There is no noticeable error in reception.
- The total number of packets (samples) transmitted varies with the sampling period and the simulation duration.

➢ The LDPC bit error rate block in Figure 18.

- We have a substantially zero error bit rate between encoding and LDPC decoding, which means that the 1/2 encoding rate we use for this signal-to-noise ratio is practically good. There is no LDPC coding error on reception.
- The total number of coding bits (samples) transmitted varies with the sampling period and the simulation duration.

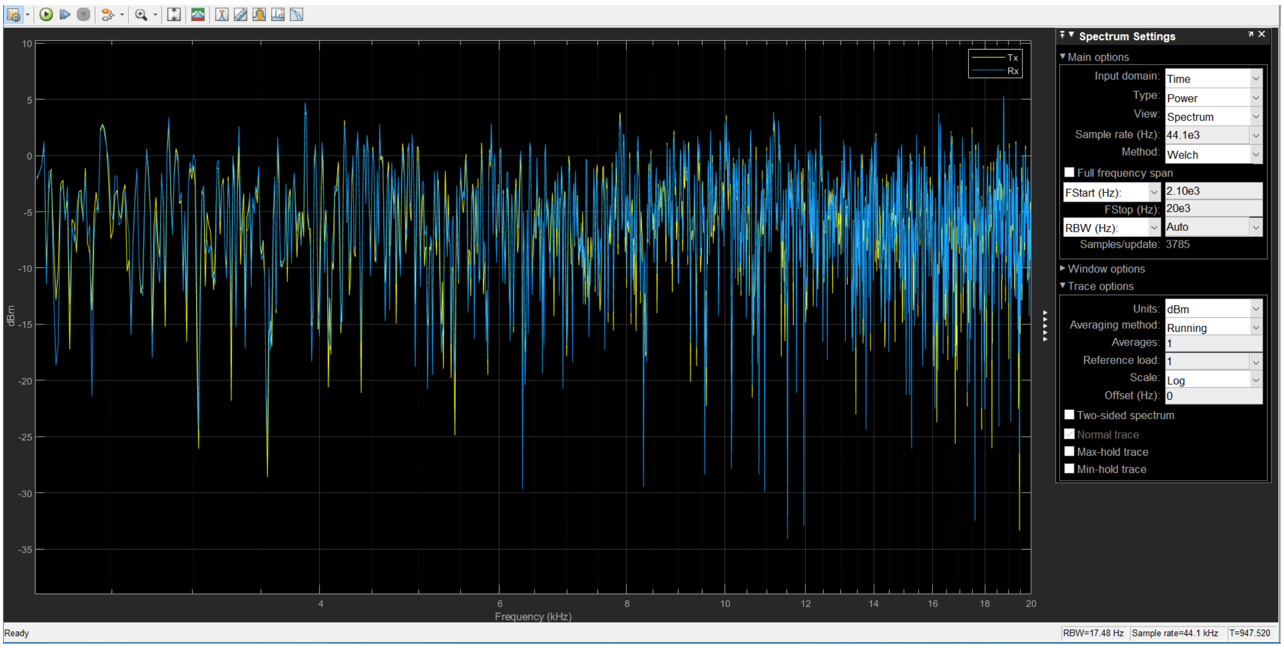

Figure 16. Spectra of Tx & Rx for SNR = 15 (DVB-S2).

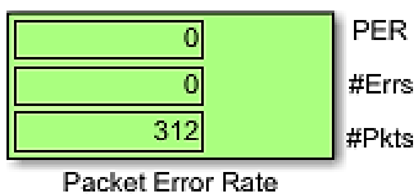

Figure 17. Packet error rate for SNR = 15 (DVB-S2).

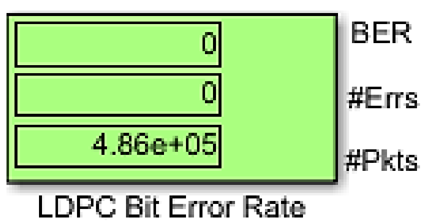

Figure 18. LDPC decoding error bit rate for SNR = 15 (DVB-S2).

6.2. Results of the Simulation of a Transmission Chain DVB-S2 with an RF Satellite Channel on a Downlink

We simulated the impact of most RF impairments to assess the performance of the DVB-S2 transmission chain on a satellite downlink. The aspect of non-linearity without memory of the high power amplifier (in Saleh model) is neglected throughout these simulations.

The free space loss (AEL) is calculated as a base with a frequency of 4 GHz and a distance of 35,600 km between the antenna of the receiving earth station and the satellite; therefore AEL = 196 dB.

1) Script 1

In script 1, we will vary several RF impairments and the gains of the transmitting and receiving antennas. The parameters for this scenario are given in Table 1.

By modifying the following parameters:

- We increase the AEL up to 202 dB.
- We increase the temperature noise of the receiver up to 290 K (typical level).
- We reduce the gain of the transmitting antenna up to Ge = 35 dB.
- We reduce the gain of the receiving antenna up to Gr = 28 dB.

We obtain the following results as shown in Figure 19.

We have an error packet rate of 100% meaning the received signal is totally compromised.

After having:

- **Increasing the gain of the transmitting antenna up to Ge = 37 dB;**
- **Increasing the gain of the receiving antenna up to Gr = 35 dB;**

We had the following results as shown in Figure 20.

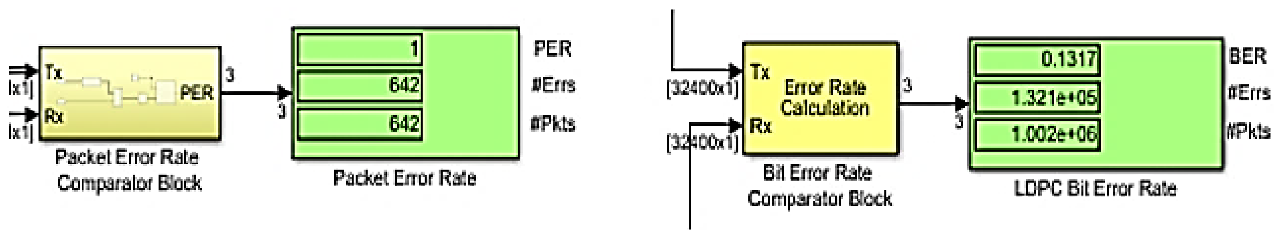

Figure 19. Error rate in the presence of RF damage of script 1.

Table 1. Parameters considered in the script 1.

Facteur de variation	Puissance de sortie du HPA	Gain de l'antenne émettrice (Ge)	Gain de l'antenne réceptrice (Gr)	AEL	Effet Doppler (Décalage de fréquence)	Bruit de température du récepteur	Bruit de phase du récepteur	Déséquilibre I/Q	Compensation de l'effet Doppler
Paramètres de base	28 dB	39.5 dB	37.5 dB	196 dB	/	0 Kelvin (négligeable)	−100 dBc/Hz (négligeable)	Aucun	/
Paramètres du scenario 1	28 dB	35 dB	28 dB	202 dB	/	290 Kelvins (typique)	−100 dBc/Hz (négligeable)	Aucun	/

2) Script 2

In Scenario 2, we will vary several RF impairments and the gains of the transmitting and receiving antennas. The parameters for this scenario are given in Table 2.

We had the following results as shown in Figure 21.

The packet loss rate is 100% so the received signal is totally compromised.

When we increase the power of the high power amplifier (HPA) up to 31 dB, we got the following results as shown in Figure 22.

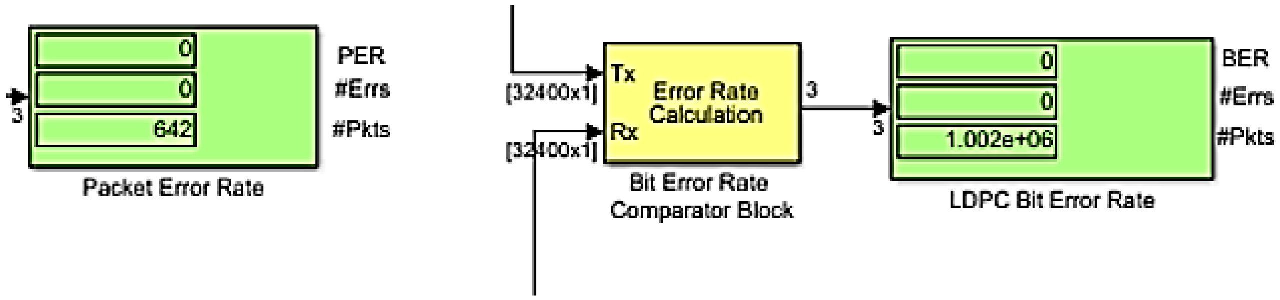

Figure 20. The error rate after correction of RF damage of script 1.

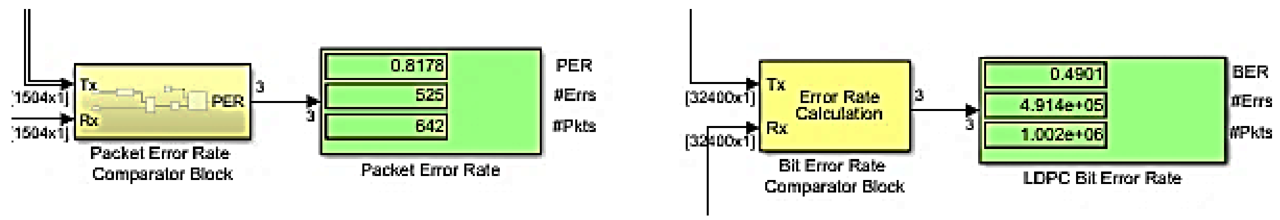

Figure 21. Error rate due to Doppler effect of script 2.

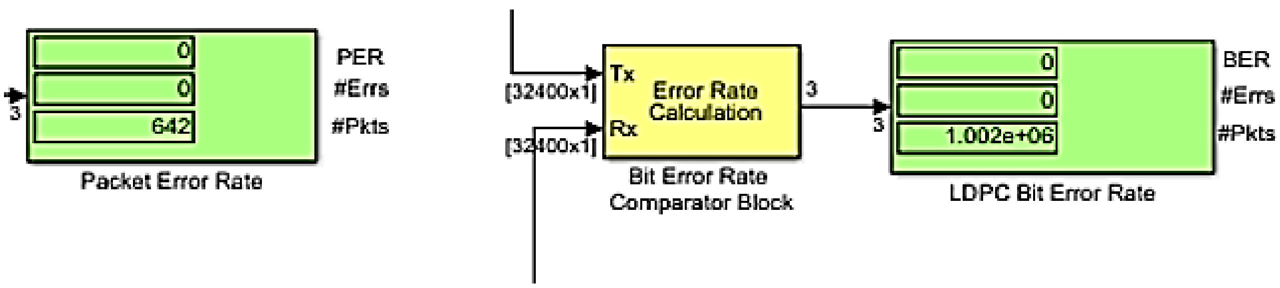

Figure 22. Error rate after correcting the Doppler effect of script 2.

Table 2. Parameters considered for script 2.

Facteur de variation	Puissance de sortie du HPA	Gain de l'antenne émettrice (Ce)	Cain de l'antenne réceptrice (Gr)	AEL	Effet Doppler (Décalage de fréquence)	Bruit de température du récepteur	Bruit de phase du récepteur	Déséquilibre I/Q	Compensation de l'ellet Doppler
Paramètres de base	28 dB	39.5 dB	37.5 dB	196 dB	/	0 Kelvin (négligeable)	−100 dBc/Hz (négligeable)	Aucun	/
Paramètres du scénario 2	28 dB	39.5 dB	37.5 dB	196 dB	1.9 Hz	0 Kelvin (négligeable)	−100 dBc/Hz (négligeable)	Aucun	/

The lost packet rate became zero so we were able to correct these RF imperfections by increasing the signal transmission power.

7. Conclusions

We carried out a study on the modelling of a DVB-S2 transmission chain with optimization of the adjustment parameters for a good quality of the reception signal. We have located the context which highlights all the equipment involved at the level of the transmitting station and we have noted any errors in the reception of the audio/video TV signal.

The main purpose of a satellite TV transmission being to obtain an audio/video signal of the best possible quality and at a high bit rate, we simulated the DVB-S2 standard and its transmission chain, particularly with a satellite channel. RF is to understand and assess any degradation that could affect the signal on a satellite link. In addition, we also carried out the simulations of the DVB-S2 transmission chains with an AWGN channel and with an RF satellite channel. At the end of this work, we can conclude that:

➢ **With a AWGN channel:**

- For the DVB-S2 standard, with QPSK modulation and an FEC coding rate of 1/2, we find that for a signal to noise ratio (SNR) greater than or equal to 1, the rate of erroneous packets is always zero so the received signal is always loss-free; which corresponds to the expected results.

➢ **With a satellite channel:**

- Having parabolic antennas with bigger gains is an advantage to have a better error rate; this means having wider antennas, and therefore larger diameters.
- Increasing the transmit power with the high power amplifier reduces the receive error rate. This is handy for correcting most RF imperfections.

As perspectives, we can:

- Improve these results with the addition of a raised cosine filter in the transmission chain on Simulink (MATLAB) to optimize the error rate and the signal to noise ratio. Simply use the "Raise Cosine Transmit Filter" block on the transmit chain and the "Raise Cosine Receive Filter" block on the receive chain with an adjustable Roll-off factor depending on the DVB-S variant or DVBS-2.
- Perform the simulation of the DVB-S2 transmission chain with other coding rates (greater than 1/2) for the same QPSK modulation. This will help to improve the reception error rate.
- Use other types of modulation (8-PSK, 16-APSK, 32-APSK). These other modulations offer coding rates strictly greater than 1/2, so the performance of the DVB-S2 chain will inevitably improve.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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