Research Article

Channel estimation based on the fixed DVB-S2 system to transfer images

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Abstract: The growth of modern wireless communications has increased the demand for high quality data services. This article presents an analysis of the performance of a DVB-S2 system with MIMO technology. A method for using a receiver-transmitter based on DVB-S2 with MIMO technology, provides a better quality of service for data transmission and discusses ways to improve the quality of data transmission using size and type converters of transmitting and receiving data, an amplifier and a normalizer Gain. The circuit was examined for bit error rate (*BER*) and peak signal-to-noise ratio *(PSNR*) between AWGN and multipath Rayleigh fading images operating under intersymbol interference *(ISI*). The analysis was carried out and a graph of the influence of ISI was obtained. The proposed system has the best quality of service for data transmission for fading channels. The transmission of images in the system includes a Rayleigh channel and AWGN with different values of the signal-to-noise ratio (SNR, dB) and different values of Gain. The Gain values change the BER and PSNR values (7.834 dB, 8.385 dB, and inf) at an SNR of -58 dB with respect to Gain values of 1, 32400 and 648000, respectively. Also obtained eye diagrams, where you can see a decrease in the negative impact of intersymbol interference with an increase in the value of Gain..This system can be used to wirelessly transmit higher quality, high-resolution radiological images (such as computed tomography or magnetic resonance imaging) over a wireless network to remote healthcare workers.

Keywords: intersymbol interference, MIMO, BER, PSNR, AWGN, SNR, Rayleigh channel, LDPC code, BCH code, amplifier, eye diagrams

1. Introduction

The increasing requirements for the efficiency and timeliness of data transmission in specialized computer systems and networks for various purposes (military, medical, etc.), combined with stringent requirements for the probabilistic and temporal characteristics of information delivery, require the improvement and development of hardware and software processing, protection and transmission of information [1].

As you know, for any communication channel, error correction is the key to achieving its best performance (especially when the channel is prone to random errors). For channels with random error patterns, only some of the dozens of known codes are of practical interest. Most often, developers use three types of codes: convolutional, Reed-Solomon and turbo codes, which include low-density parity check codes (LDPC).

At present, when choosing an error-correcting encoder, its parameters must be consistent with the source of the message, the communication channel, as well as the requirements for the reliability of communicating information to the recipient. However, it is difficult to pre-select the code parameters if the quality of the communication channel is unknown, and sometimes it can change altogether during the operation of the system. Thus, the parameters of the error-correcting code are selected based on a certain "average" state of the communication channel, which leads to a decrease in the information transmission rate due to the greater redundancy of the code. This can lead to a loss of communication when using codes whose parameters remain constant and are not designed to significantly degrade the channel quality. One of the ways to eliminate this drawback is the use of adaptive coding systems with automatic and targeted correction of the code parameters as the channel quality changes while ensuring a given message delivery probability with minimal redundancy of the error-correcting code.

One of the known methods of adaptive transmission is adaptive modulation, which consists in maintaining a constant signal-to-noise ratio by adjusting the transmitter power, transmission rate, modulation and coding techniques. This allows a given error rate to be achieved by transmitting data at a higher rate when the channel is in good condition and decreasing the rate when it is degraded. Currently, forms of adaptive modulation are implemented in some radio applications such as the HSDPA subsystem of the W-CDMA standard (up to 16-QAM); IEEE 802.11, IEEE 802.16 (up to 64-KAM), DVB-S2.

DVB-S2 is the second generation of the satellite broadcasting standard. This standard uses the latest developments in the field of channel coding in combination with various types of modulation and special options, which significantly increase the capacity of the satellite channel and ensure the performance of services in adverse weather conditions. The DVS-S2 standard uses adaptive modulation and coding (ACM), which optimizes transmission parameters for each user, depending on the transmission conditions [2]. The DVS-S2 standard uses concatenated coding: the inner code is LDPC and the outer code is Bose-Chaudhuri-Hocquenghem (BCH). This scheme provides an extended number of coding coefficients (FEC 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9 / 10) with different types of modulation (QPSK, 8PSK, 16APSK, 32APSK).

With adaptive coding and modulation technology, you can dynamically change the modulation type and coding rate for each individual forward channel frame depending on the signal propagation conditions while maintaining a constant symbol rate. In order to apply an LDPC code to an actual communication system, the LDPC code must be designed to match the required data rate in the communication system. In particular, according to the system requirements in adaptive communication systems, LDPC codes with different codeword lengths are required to support different data rates. However, the LDPC code used in the DVS-S2 system has only two types of codeword lengths - 16200 and 64800, which limits its use, and each type of LDPC code uses an independent parity check matrix.

In information transmission systems where maximum transmission rate with limited bandwidth is required, it is efficient to use LDPC codes. BCH and LDPC codes are more efficient than cascades of Reed-Solomon codes and convolutional codes, their use allows you to reduce the signal-to-noise ratio for reliable system operation. With LDPC and BCH, gains of several decibels can be achieved in relation to the achieved signal / noise. But on the other hand, the LDPC and BCH coding method requires more performance and primarily the receiving equipment, which will lead to a higher cost of receivers and decoders [3].

The following advantages of LDPC codes in the DVB-S2 standard can be noted:

- lag of 0.6-0.8 dB from the Shannon border in total;
- 0.3 dB advantage over turbo code;
- in comparison with the DVB-S standard, the advantage is 2.5 - 3.0 dB, i.e. increase in power by 30% [4].

In digital communication, the normalized version of *SNR* (Signal Noise Ratio, defined as the ratio of the average signal power *S* to the average noise power *N*), denoted by E_b/N_0, is often used as a quality criterion, where E_b is the bit energy and can be described as the signal power *S*, multiplied by the transmission time of the T_b bit. N_0 is the noise power spectral density, and it can be expressed as the noise power *N* divided by the bandwidth *W*. Since the bit time and bit rate R_b are reciprocal, T_b can be replaced by $1/R_b$:

$$\frac{E_b}{N_0} = \frac{ST_b}{N/W} = \frac{S/R_b}{N/W} = \frac{S}{N}\left(\frac{W}{R}\right) \quad (1)$$

$$SNR = \frac{P_{signal}}{P_{noise}} \quad (2)$$

SNR in logarithmic units using decibels:

$$SNR = 10log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) \quad (3)$$

– If $P_{signal} = P_{noise}$, then $SNR = 0$.
– If $P_{signal} > P_{noise}$, then the number of decibels is positive.
– If $P_{signal} < P_{noise}$, then decibels are expressed in negative numbers.

An important performance measure used to compare digital modulation schemes is the bit error probability, P_b from E_b/N_0 [5].

In order to investigate the improveme nt of ways to provide better quality of service for data transmission, the bit error rate metrics from *SNR*, from *PSNR* (Peak Signal to Noise Ratio between images) were considered and analyzed, and intersymbol interference at the receiver side was also considered by analyzing eye diagrams.

2. Formulation of the problem

Here, using Simulink, the physical layer of the DVB-S2 standard is developed, and its performance is evaluated under the conditions of Rayleigh attenuation and *AWGN* noise effects. This system includes *MIMO* technologies and considers ways to improve the quality of data transmission using a converter of size and type of transmitting and receiving data, an amplifier and a normalizer Gain. Models are modeled by transmitting and receiving data/images through the developed system. The system performance is then measured in relation to *BER* and peak signal-to-noise ratio (*PSNR*).

BER measures the physical layer performance of a simulated system and is measured by transmitting and receiving uint8 (8-bit unsigned integer arrays) data / images from the proposed wireless transceiver system. *PSNR* determines the transmission quality of a transmitted image and is measured by transmitting and receiving an image.

The channel encoder takes the picture and generates a codeword using LDPC/BCH codes, with which error correction can be achieved. An interleaver helps reduce errors for burst error cases by performing an interleaving operation on the generated codeword. QPSK modulation is performed including the constellation mapping process.

Linear amplifier Gain boosts or attenuates the signal according to the specified *K*-factor*:*

$$S_{out}(t) = K * S_{in}(t) \tag{4}$$

Consider a transmitter. Transmitter input is digital data / image to be supplied in uint8 form. The developed system uses the Image From File block, which transfers the image, also the Image Pad block, which resizes the image, and the Reshape block is also used. The Reshape block changes the dimension of the signal, converts the received multidimensional input signal into a matrix-column. The transformed matrix is passed to the encoder in the form of a vector.

The channel coding unit receives input data / picture and generates a codeword based on the channel coding scheme. The LDPC / BCH coding scheme is used here to generate the codewords. The interleaver permutes the coded symbols without skipping or repeating a single symbol to avoid the effect of burst errors in the received signal. The design uses a random interleaver that takes an input vector and permutes them in a random permutation. The phase modulation block converts the input bitstream into a complex signal. This complex signal represents one of the constellation points in the IQ plane. Here a QPSK block has been developed that takes an alternating sequence and maps them to one of 4 constellation points. We also used the Gain amplifier and space-time block codes (OSTBC encoder), where Alamouti coding is used. This block code, named after the author, is for MIMO systems with two or more transmit antennas. More detailed information on the use of MIMO technologies can be found in [6], [7], [8]. The Alamouti scheme provides significant signal diversity and increases the transmission rate or reduces the likelihood of erroneous transmission by introducing phase orthogonality between simultaneously transmitted signals and pairs of signals successively emitted by each antenna. More details are written in [8], [9], [10], [11] and [12] about the algorithm and the code matrix of the Alamouti scheme.

Now let's look at the receiver. The receiver block starts with the OSTBC Combiner block. This block combines the received signal and channel estimation inputs according to an Orthogonal Space Time Block Code (OSTBC) structure. OSTBC can be rate 1 for 2 transmit antennas, rate 1/2 or 3/4 for 3 and 4 transmit antennas.

A Gain block is introduced into the receiver for signal normalization, where the K coefficient is 1, 1/32400, 1/648000, respectively. The modulated symbols are converted to bits using a QPSK demodulator. The constellation evaluation points act as input to the block to be mapped to the corresponding binary bits. The de-interleaver performs an inverse interleaving operation. The arrangement of the coded bits in the de-interleaver will be reversed as in the interleaver block. The de-interleaved coded sequence is transmitted through a channel decoder (LDPC / BCH decoder) to decode the data.

Also in the circuit was used the block Eye Diagram Scope, this block displays multiple traces of the modulated signal to obtain an eye diagram. For a qualitative assessment of the degree of ISI, an eye diagram is most often used. As the eye opens, the ISI decreases, and as the eye is closed, it increases (Figures 6, 7 and 8).

The image is transmitted over the additive white Gaussian noise (AWGN) channel and the Rayleigh fading multipath channel. In order to increase the throughput and quality of information transmission, the channel uses several transmit and receive antennas.

Tables 1 and 2 below show the design specification for the fixed DVB-S2 standard.

Table 1: Multipath channel parameters

Fading distrubution	Rayleigh
Max Doppler shift (f)	0.001
Doppler spectrum type	Jakes
Number of transmit antennas	4
Number of receive antennas	4

Table 2: Noise characteristics of the AWGN channel

Initial sead	25

Mode	Signal to Noise rate (Eb/No)
Eb/No(dB)	-60
No. of bits/symbol	1
Input signal power	1/32400
Symbol Period	1

3. Experiment Analysis

The performance of the developed model is estimated under the condition of a fading channel and the *BER* and *PSNR* values are analyzed at low *SNR* values, eye diagrams are also analyzed at various Gain values to effectively reduce the negative impact of intersymbol interference.

The theoretical values are obtained using the *BER* calculation module present in the MATLAB software. Figure 1 shows a screenshot of a MATLAB-generated project for an image transmission system.

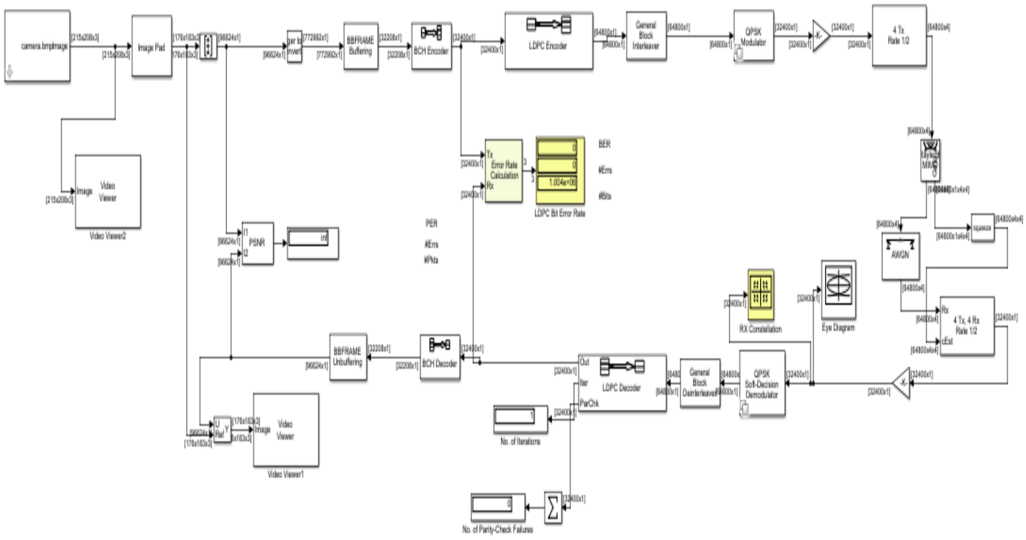

Figure 1 Block Diagram of Simulink Transmitter / Transmitter of DVB-S2 System Using MIMO

Fixed data transmission with fading with different values of the gain of 1, 32400 and 648000 is shown in Table 3 and Figure 2.

Table 3. Probability of an erroneous bit at low SNR

SNR (dB)	BER	PSNR
K = 648000		
-80	0.4625	8.137
-78	0.4522	8.2
-76	0.4403	8.3
-74	0.4241	8.45
-72	0.4043	8.90
-70	0.3795	8.977
-68	0.3477	9.92
-66	0.3091	10.05
-64	0.2586	10.17
-62	0.1916	11.91
-60	5e-06	inf
-58	0	inf
K = 32400		
-50	0.4405	8.35
-48	0.4254	8.501
-46	0.4037	8.702
-44	0.3792	8.795

-42	0.3485	8.801
-40	0.3102	8.826
-38	0.2618	12.45
-36	0.1934	13.05
-34	7.71E	40.44
-32	0.0`	inf
K = 1		
20	0.4931	7.857
22	0.4919	7.867
24	0.4901	7.875
26	0.4875	7.905
28	0.4851	7.915
30	0.4817	7.957
32	0.4762	8.005
34	0.4712	8.065
36	0.4631	8.101
38	0.4535	8.209
40	0.4417	8.329
42	0.4260	8.445
44	0.4071	8.701
46	0.3821	8.805
48	0.3514	9.015
50	0.3136	9.779
52	0.2653	10.5
54	0.2010	11.7
56	0.0823	15.57
58	0.0	inf

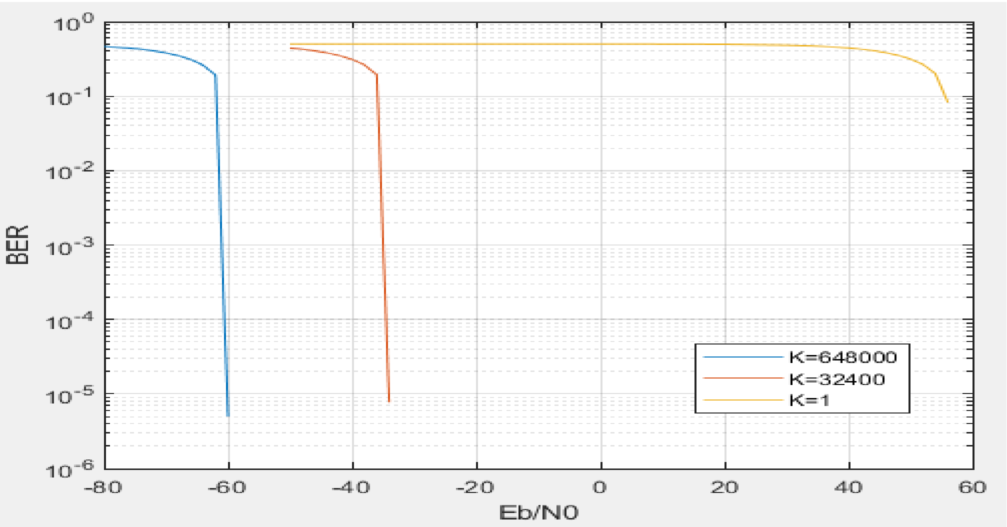

Figure 2. Probabilities of errors in the Rayleigh and Gaussian channels for different values of the amplifier coefficient K

Image transmission in the DVB-S2 system is performed at different SNR values, which is shown in Figure 3. You can see (see Figure 3) that the clarity of the received image improves with increasing SNR and the identity of the received and transmitted image is achieved at SNR = -60dB.

Transferred image

The resulting image when *SNR*= -70

The resulting image when SNR= -65

The resulting image when SNR= -62

The resulting image when SNR= -61

The resulting image when SNR= -60

Figure 3 Image transmission at different values *SNR*

The graph of SNR and PSNR ratios at K = 648000 is shown in Figure 4.

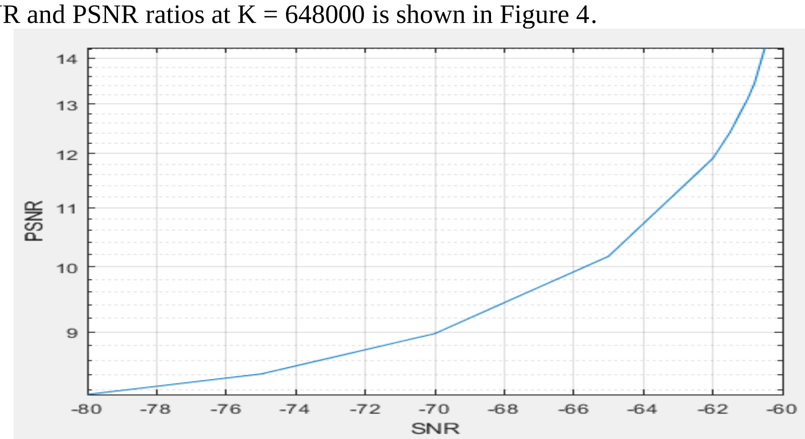

Figure 4 Graph of *SNR* and *PSNR* ratios at K = 648000

Comparison of the *PSNR* value at *SNR* = -34 dB with an amplifier (K = 32400) and without an amplifier (K = 1) is shown in Table 4, an improvement of 80% was found.

Table 4 Comparison of *PSNR* value at *SNR* = -34 dB

	SNR, dB	*PSNR*, dB
K=1	-34	7.793
K=32400	-34	40.44

Figure 5 shows the constellation diagram for this model at K = 648,000 and SNR = -50 dB. You can see the effect of distortion on the constellation, resulting in reduced receiver noise immunity

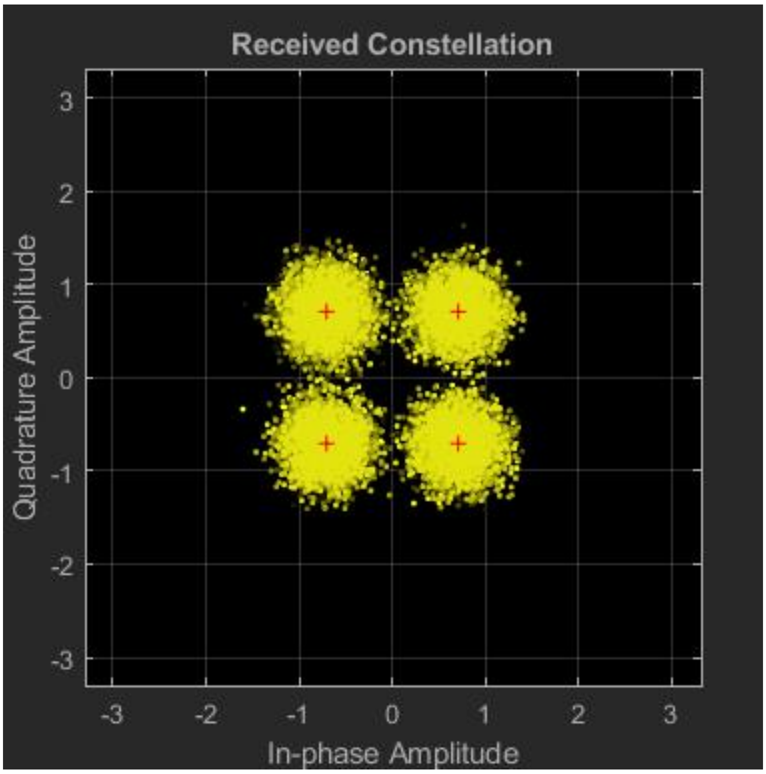

Figure 5 signal constellation

When designing radio devices for transmitting and receiving information, the goal is to minimize the effect of intersymbol interference and thus deliver digital data to its destination with the lowest possible error rate. The effect of receiving delayed and distorted versions of a signal can be seen in the loss of clarity in signal transitions. The presence of intersymbol interferences in the system introduces errors into the decision making device at the output of the receiver. Therefore, the Eye Diagram Scope block was used to determine the ISI in the system. Block shows an eye diagram.

Ideally, the eye diagram, as the name suggests, is an "open eye", in Figure 6 with an amplifier K = 648000 at *SNR* = -50dB one can see "open eyes". The eye signal-to-noise ratio (eye *SNR*) is defined as the ratio of the amplitude of the eye to the sum of the standard deviations of the two eye levels, which is 3.66.

Figure 7 shows an eye diagram for a circuit with a K = 32400 amplifier. The eye signal-to-noise ratio (eye *SNR*) is 1.67.

In Figure 8, without an amplifier, we see an obvious superposition of waves on each other - the phenomenon of interference.

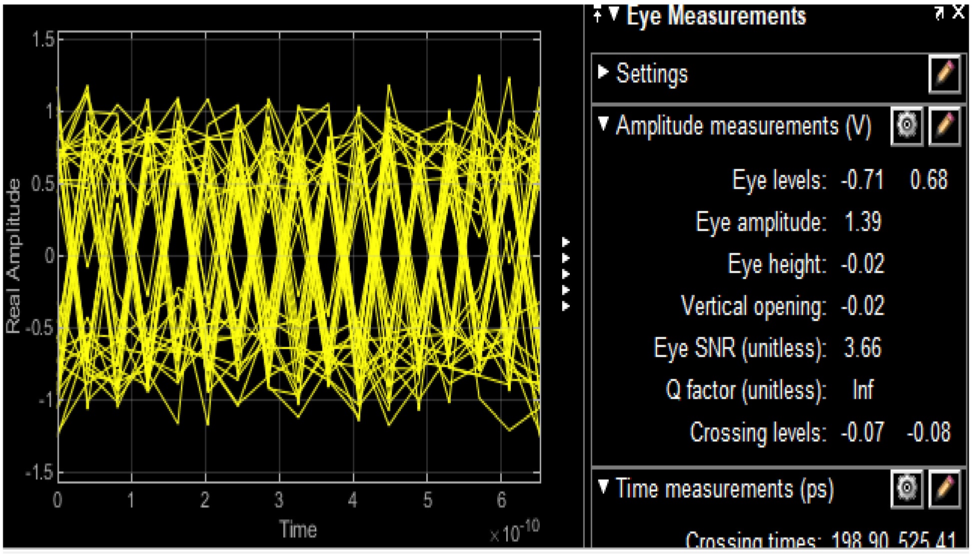

Figure 6. Eye diagram at SNR = -50 for a circuit with an amplifier K = 648000

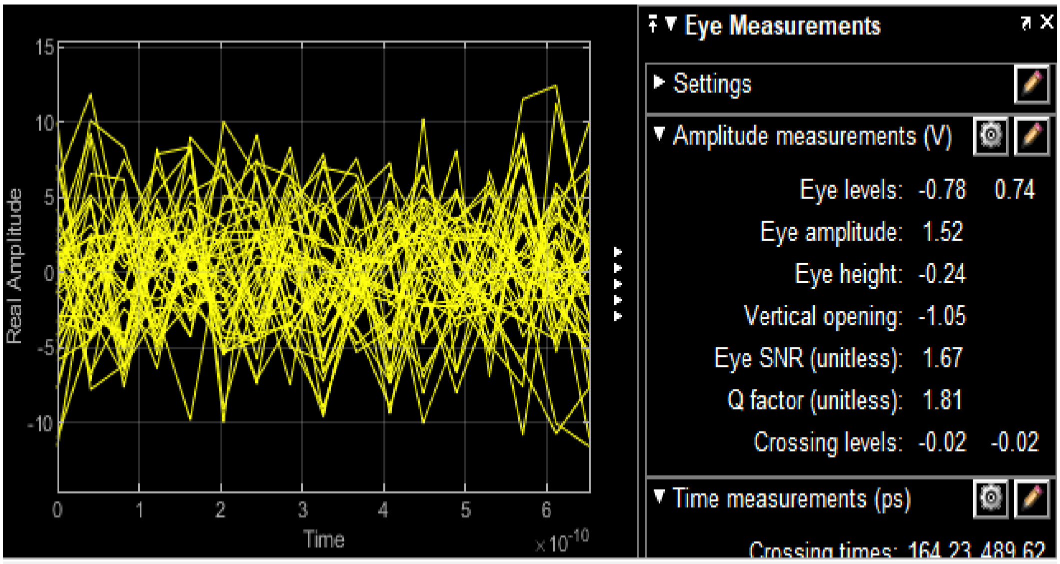

Figure 7. Eye diagram at SNR = -50 for a circuit with an amplifier K = 32400

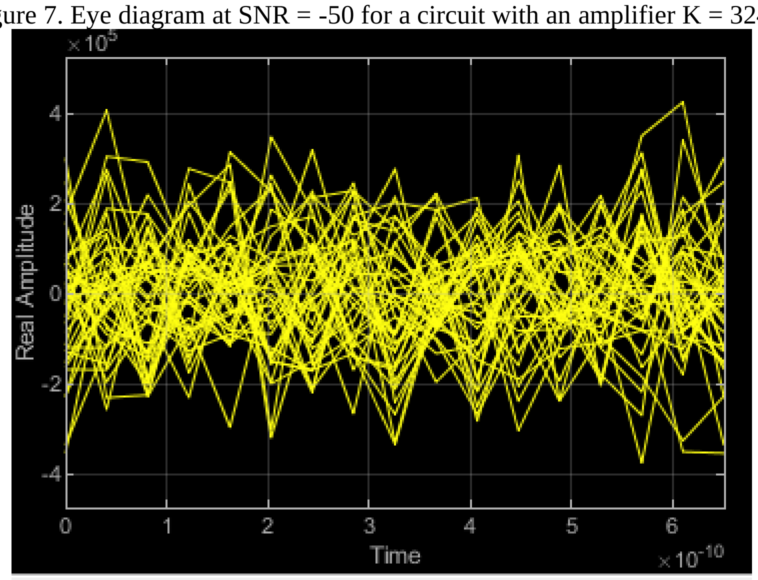

Figure 8. Eye diagram at SNR = -50 for a circuit without an amplifier

The paper [13] presents an assessment of the performance of an OFDM system using a cyclic prefix implemented in the 16QAM modulation scheme. In this paper, an OFDM system was evaluated for data / image transmission in the WIMAX system. OFDM is simulated with MATLAB-based Simulink. An analysis of the transmission performance of an OFDM image with different values of the cyclic prefix with and without fading in relation to *SNR* and *PSNR* is constructed. The proposed design provides 19.94 dB *PSNR* for an *SNR* of 7 dB. A comparison of the *PSNR* value at *SNR* = 7dB was carried out and an improvement in the image of about 42% was found. In our DVB-S2 system, the gain is 80%.

In this work [14] modeling of the transmission of ECG signals through a communication system using digital video broadcasting technology - terrestrial (DVB-T) or digital video broadcasting - satellite version 2 (DVB-S2) was done and the BER was assessed relative to the SNR value. The study shows that DVB-S2 technology provides improved performance on an *AWGN* channel. It is also shown that the use of *MIMO* along with DVB-S2 mitigates the effects of multipath and improves performance. The value of BER≈0 was obtained in this work at *SNR* = 1 dB. In our system, by improving the DVB-S2 system (we used converters of the size and type of transmitting and receiving data, an amplifier and a Gain normalizer), we obtained a BER≈0 value at *SNR* = -58dB.

4. Conclusion

This paper presents an assessment of the performance of a wireless system based on the DVB-S2 standard with MIMO technology using amplifiers and converters. An assessment of the proposed system for image transmission in a wireless network is carried out. The proposed model is simulated using Simulink based on MATLAB. Obtained a graph of data transmission performance with different Gain values (Gain values change respectively for transmitter and receiver) in a multipath channel with fading in relation to *BER* and *SNR* (see Fig. 2). When SNR is -60dB, *BER* values of 0.6, 0.4805 and $5.8*10^{-6}$ are generated for 1, 32400 and 648000 different Gain values respectively.

An analysis of the performance of image transmission with the value of the amplifier coefficient at K = 648000 in a multipath channel with fading in relation to *SNR* and *PSNR* is constructed (see Fig. 4). The *PSNR* value was compared at low *SNR* values with the model without an amplifier and an 80% improvement was found at K = 32400, which improves the performance of the wireless system based on the variable value of the amplifier and converter.

The improvement when using the Gain amplifier is about 116dB at BER≈0. The reasons for this are most likely due to the best error coding and modulation techniques used in DVB-S2.

The survey data can be used in the design of radio devices to transmit better, high-resolution radiological images (such as computed tomography or magnetic resonance imaging) over a wireless network to remote healthcare workers. Telecardiology uses telecommunication and information technology and provides clinical care to people at a distance.

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