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AN EXPERIMENTAL STUDY OF QUALITY ANALYSIS METHODS IN DVB-S/S2 SYSTEMS

Alexandru-Florin ANTONE, Radu ARSINTE
Technical University of Cluj Napoca, Faculty of Electronics, Telecommunications and Information Technology, Communications Department
26-28 G. Bariţiu Street, 400027 Cluj-Napoca, Romania, Phone +40-264-595699,
Email:AntoneAlexandru@student.utcluj.ro; Radu.Arsinte@com.utcluj.ro

Abstract: The paper is proposing a study and practical experiments of testing methods in digital television, transmitted in Digital Video Broadcasting standard. The main objective of the research presented in this paper was to establish if the testing tools designed and validated for DVB-S, are useable to evaluate DVB-S2. This is important in educational environments and small enterprises, to find new applications for the existing equipment. Testing methods follows three directions: transmitted services (data link layer), RF (Radio Frequency) interface and reception (physical layer). We pursued the following objectives: DVB-S2 model study (from Simulink Matlab), to establish the key measurement points in this evaluation, analysis of DVB-S/S2 streams, RF parameters measurements in terms of C/N (Carrier to Noise Ratio) and spectrum.

Keywords: *Digital Video Broadcasting Satellite, RF Test Bed, Multiplex stream.*

I. INTRODUCTION

Quality assurance in DVB systems is very important for installation, setup, and verification of hardware equipment. Furthermore simulation models are almost vital for designing, operating and forecasting DVB systems.

The suite of DVB standards specifies basic systems for broadcasting digital TV (first and second generation) according to transmission environment: satellite (DVB-S/S2), cable (DVB-C/C2), terrestrial (DVB-T/T2), and an extension of terrestrial standard for handheld devices (DVB-H/H2).

Each standard, defines physical link pre-processing: Transport Stream (TS) or Generic Stream (GS) adaption for channel coding: adaptation (modulation and coding scheme according to communication environment and standard generation). Source coding of digital TV broadcasting systems is not actually a part of DVB standards, but it's specified according to multimedia compression standards as follows:

- MPEG-2 for video coding and MPEG Level 2 – Digital Audio Broadcasting (DAB) for audio coding in first generation systems
- MPEG-2, MPEG-4, H.264/H.265 Advanced Video Coding (AVC) and Advanced Audio Coding (AAC) in second generation systems.

Designing those systems has created a need for understanding measurement techniques and result evaluation. In this field of testing, there are general recommendations by means of defining a number of measurement techniques, for compatibility of the testing results between different systems that uses those standards, as long as those testing techniques are according to the standards. Although the majority of specified parameters specified in this article are well known, they have to be rendered according to communication environment, TV digital signals, or other services. Inclusion of this parameters in this paper, are accordance to the requirements of those who envision to work with current existing procedures on today's market (network operators, equipment providers for network startup, Integrated Receiver/Test Decoders providers) [1].

There are several general testing steps recommendations as follows: set up test beds or laboratory equipment, for hardware testing of digital TV services/other services; set up parameters of adequate instruments; obtain coherent results, which can be directly compared with results from other tests; set up an efficient way of communicating the tests results [1].

The execution of a unitary professionally analysis of all DVB systems is made by specialized companies, with high tech equipment unavailable to large public due to very high costs of such equipment. Other providers or companies choose to analyze each system in particular, for equipment costs reasons.

For quality testing of these systems there are several recommendations grouped in a few categories. One category is intended for verification procedures description of parameters, accessible in TS packet header. The scope of tests is to provide of an accurate and simple verification, according to DVB standards. A different test aspect is intended for description of distinctive media transmission parameters. For example: measurements of transmission or link availability. Other category turn to specific parameters of cable and satellite links, applicable to Satellite Master Antenna Television (SMATV) or Multichannel Multipoint Distribution Services (MMDS) systems and different aspects are addressed to specific parameters of terrestrial links. Another aspect is intended to describe the scope (objective) of recommended measurements procedures, and level of interface whereat measurement instrument has to be applied. Moreover, there are general recommendations for testing

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different aspects of a DVB system, test examples, and certain requirements for tests and measurement equipment [1, chapter 5].

This paper will focus on testing DVB-S/S2 systems. It will present the measurements and techniques for this system. A quick overview and evaluation about coding scheme model available in the simulation environment Simulink, from the Matlab package, was found necessary prior to the real measurement procedure.

II. TESTING METHODS IN DVB-S/S2 SYSTEMS

DVB-S standard covers, basically, the following main aspects [2]:

- TS scramble and adaption,
- FEC encoding scheme (an convolution inner encoder and an Reed Solomon outer encoder (RS(204,188)),
- QPSK modulation scheme

In practice the studies showed that a minimum SNR threshold of 4 dB, is enough for a reliable reception.

Satellite transmissions are relatively robust, the noise is mainly determined by free space attenuation and microwaves link interference. Therefore, the key parameters in evaluating DVB-S signals are: C/N, signal level, BER, signal attenuation.

For a professional testing it is necessary, at least, a DVB-S spectrum analyzer and a receiver with BER measurement capabilities.

The key improvements in DVB-S2 systems are the implementation of adaptive code and modulation (ACM), and the use of more efficient FEC schemes close to Shannon limit in theory (down to SNR of 1 dB) [3]. In practice, the studies showed that for acceptable reception, the minimum SNR threshold is about 1.6 dB, and increases overall system performance by 30%.

Figure 1 is presenting the block diagram of DVB-S2 transmitter processing. This paper is focused on testing FEC encoding, Mapping, and Modulation blocks.

For testing those systems it is necessary to have DVB-S2 capable equipment to support Forward Encoding Correction (FEC) and modulation scheme in conformance to the second generation standards. Usually this equipment is downwards compatible with DVB-S.

It can be distinguished two major testing directions: testing TV digital signals and other services (ex. Internet distribution via satellite).

There are three main directions in this test procedure:

- Testing the functionality of different configurations and applications included in the standard;
- Testing the RF aspects;
- Testing the reception equipment performances for SD/HDTV programs, MPEG-2/MPEG-4 video compression/decompression parameters measurements ([5][6]).

A test scenario for testing DVB-S2 related to C/N and subjective evaluation is exemplified in figure 2.

It starts from the idea of comparing a real environment system with a simulation one, and analyses the simulation model performances in regard to the real one. According as above figure there is a test signal generator that includes an adjustable noise source. The receiver module is the tested equipment; and the test equipment are: Digital Video Quality Analyzer (DVQ) for decoding the signal, detection of static image; the TV monitor is for subjective evaluation (visualization); and the PC is the controlling equipment.

It verifies the empirically limit of C/N whereat the TV

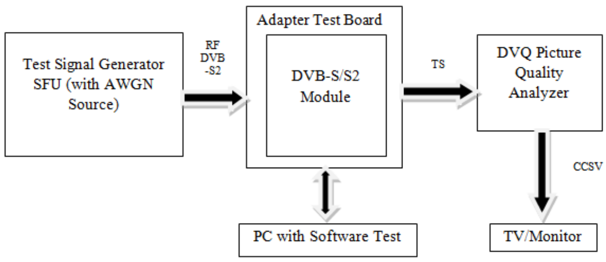

Figure 2. DVB-S2 test scenario (RF and subjective evaluation) [6].

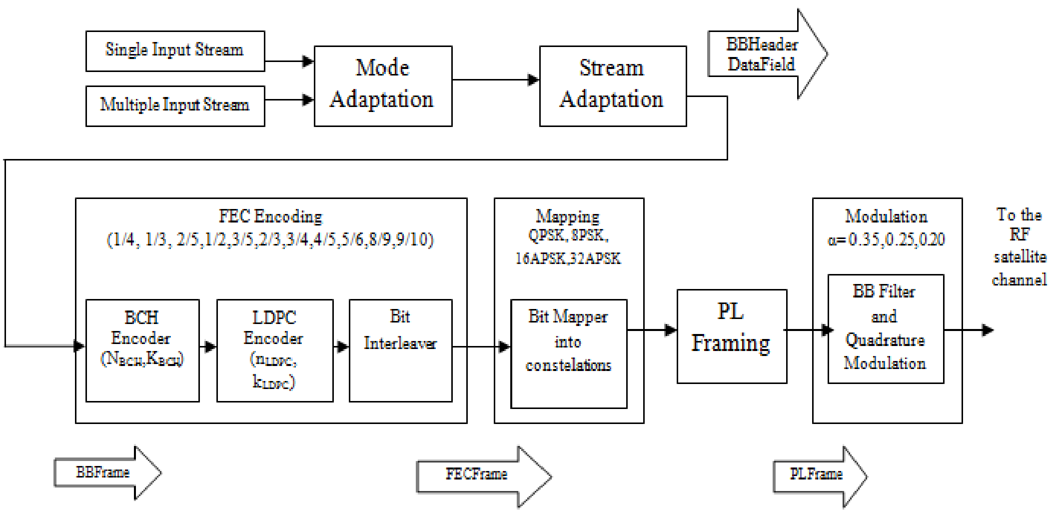

Figure 1. DVB-S2 transmission system. [3]

digital signal is acceptable from subjective point of view [6].

III. DVB-S/S2 STREAM ANALYSIS METHODS

The objective of this approach is to analyze DVB-S/S2 streams through using a real reception environment and to process and interpret the results. The main objective of the research presented in this paper, as mentioned in the abstract, was to establish if the testing tools designed and validated for DVB-S, are useable to evaluate DVB-S2.

To validate the described methods, we have analyzed DVB-S2 streams received via satellite from Astra 19.2° E group of four coordinated satellites (generic named Astra satellite): Astra 1H, Astra 1KR, Astra 1L, Astra 1M; working in (10.7 – 12.75) GHz frequency band. This satellite has a transponder bandwidth of 27.5 MHz [9].

To analyze the RF quality and the received streams we used as hardware equipment two different PC receiver cards (Skystar 2 for DVB-S and Skystar HD for DVB-S2), installed

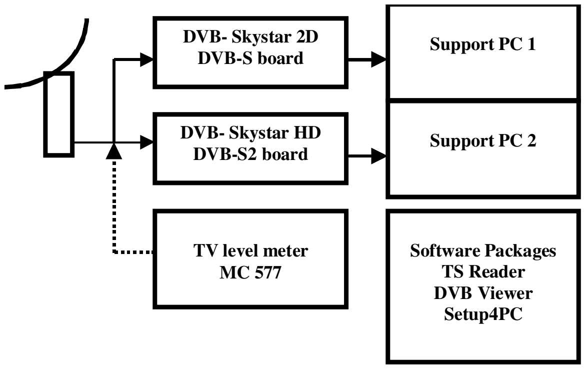

Figure 3. Configuration of the test system

in two different PCs; and a spectral analyzer for TV and satellite signals "*TV Signal Level Meter MC-577*". Additionally, we used a set of software packages and applications:

- *DVB Viewer* – necessary for DVB board support (tuning and viewing capabilities);
- *TSReader Lite* - for Transport Stream (TS) analysis;
- *Setup4PC* – used to analyze internal RF parameters delivered from the satellite tuner.

The configuration of the test system is suggested in figure 3.

Test scenario:

We have evaluated DVB-S/S2 TV broadcast signals. The DVB-S signals use only QPSK modulation and the DVB-S2 signals uses both QPSK and 8PSK modulation. Those streams are received from Astra satellite, as mentioned before.

The RF measurements are carried out in Intermediate Frequency (IF) bandwidth of 950 to 2150 (MHz). This method is introducing a degree of errors, since the transfer global characteristic of the LNB usually remains unknown. To determine the central frequency of the transponders we used the following equation:

$$f_i = f_s - f_{LO}, \tag{1}$$

where f_i is the intermediate frequency, f_s is the satellite frequency, and f_{LO} is the local oscillator (translation) frequency. In case $f_s \leq 11.6$ GHz then f_{LO}=9.75 GHz, while if $f_s \geq 11.6$ GHz then f_{LO}=10.6 GHz. Those calculation are useful for identifying multiplexes in IF bandwidth using the MC-577 Analyzer.

We selected four DVB-S transponders and four DVB-S2 transponders. Each DVB-S transponder is carrying one multiplex stream including seven to eight Standard Definition (SDTV) programs and each DVB-S2 transponder is carrying one multiplex stream including four or five High Definition Television (HDTV) audio/video programs. [8].

Evaluation of DVB-S transmission

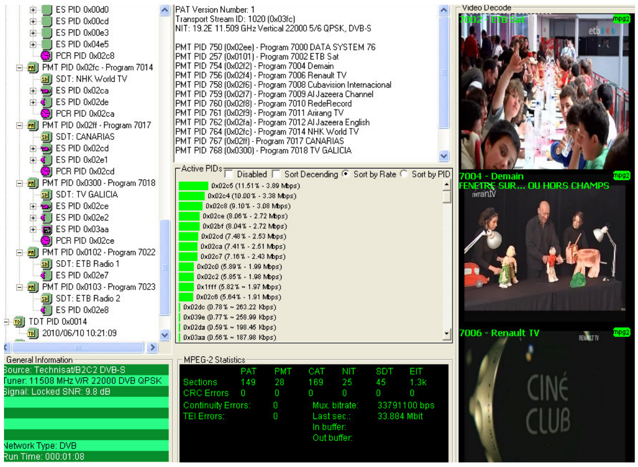

Figure 4. Multiplex analysis relative to transponder 20

First aspect in evaluating those streams is to analyze the RF spectrum through RF shape and measurement of C/N ratio. We connect the output cable to "TV Satellite Digital and Analogue Signal Level Meter MC-577". We identify the multiplex in IF bandwidth according to IF calculation and type of polarization. The RF spectrum of the signal is displayed on the equipment screen. From the RF spectrum it is possible to calculate C/N ratio. The obtained values (Table 1) are approximated as an average of dynamic values that vary with satellite environment attenuations or interferences.

In the case of the second aspect of evaluation we are using TSReader Lite (see figure 4). This software furnishes general information about multiplex at RF level such as IF, polarization, Signal to Noise Ratio (SNR a.k.a. C/N), transponder symbol rate, multiplex useful bit rate, type of

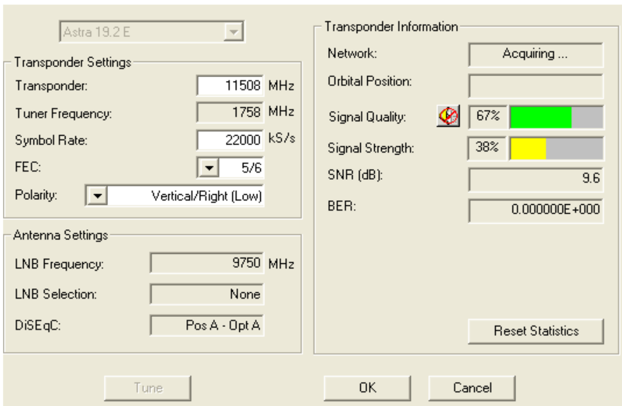

Figure 5. Information on transponder 20 (Setup4PC)

receiver card, and modulation type. It also provides TS information and program visualization by identifying and decoding MPEG-2 audio/video, table specific information packets. The application displays the programs from the multiplex (Video Decode section).

It also shows data about elementary streams from the TS such as Program Allocation Table (PAT), Program Map Table (PMT), Conditional Access Table (CAT), Network Information Table (NIT), Service Description Table (SDT), Event Information Table (EIT), programs bit rate, and multiplex received time period.

The third aspect of testing is evaluating the streams with Setup4PC application. This one is a TS Reader module, which allows transponder scanning and provides following

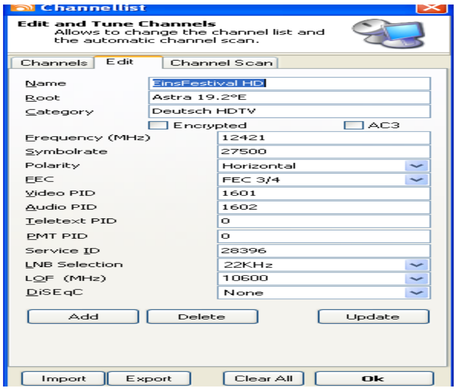

Figure 6. Information on the received program (DVB Viewer and Skystar HD2).

information: transponder settings such as multiplex frequency, IF, symbol rate, FEC rate and polarity; antenna settings: local oscillator frequency, Low Noise Block (LNB) selection, and DISEqC protocol if supported by the receiving system; and transponder information: signal quality, signal strength, SNR, BER (before source decoding, after channel decoding).

The fourth aspect is primary intended to evaluate subjectively the program received, by visualizing it. It also provides information like transponder frequency, Multiplex Symbol Rate, Signal polarity, FEC rate, video/audio PID,

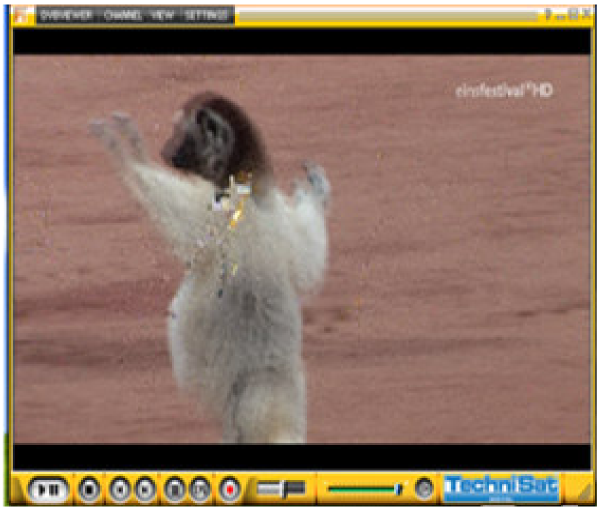

Figure 7. Playing of DVB-S2 received channel (DVB Viewer)

service ID etc., about the multiplex in which carries the program (see figure 5).

Evaluation of DVB-S2 transmission

First procedure used to evaluate the RF transmission is in analogue domain as mentioned already in DVB-S analysis. The only difference is that the input signal is using the DVB-S2 processing scheme.

The second evaluation procedure is primary intended to evaluate subjectively the program received, by visualizing it with DVB Viewer. It also shows some information (like transponder frequency, Multiplex Symbol Rate, Signal polarity, FEC rate, video/audio PID, service ID etc.) of the multiplex carrying the program (see figure 5). This DVB player also provides channel scan for the selected satellite.
As seen in figure 7, decoding DVB-S2 channel (MPEG-4 packets) introduces few macro blocks errors. We determined that in the case of this study, this is not caused by a poor reception (low quality signal), neither of improper receiving equipment, but as a result of limited hardware resources of the

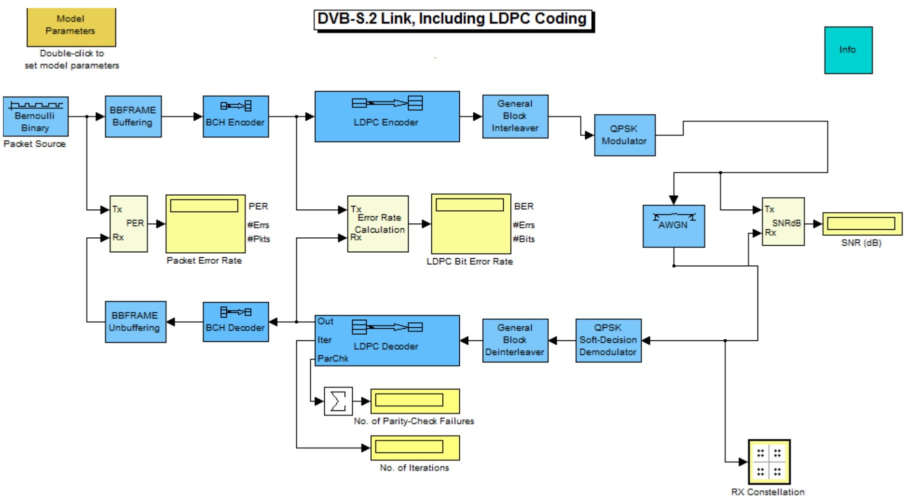

Figure 8. DVB-S2 model highlighting coding scheme [8]

PC.

Analysis of DVB-S2 simulation model

The brief study from this paragraph was necessary to establish the characteristics of DVB-S2 compared with DVB-S, to apply eventually corrections to the described procedure. This simulation, based on the specific module of Matlab, reveals the channel coding scheme. It is is based on concatenation of Low-Density Parity-Check (LDPC) and Bose and Ray-Chaudhuri (BCH) codes. LDPC codes, can achieve extremely low error rates near channel capacity by using a low-complexity iterative decoding algorithm. The outer BCH codes are used to correct sporadic errors made by the LDPC decoder.

The channel codes for DVB-S2 provide a significant capacity gain over DVB-S under the same transmission conditions and allow Quasi-Error-Free operation (QEF), a packet error rate ($PER \leq 10^{-7}$) at about 0.7 dB to 1 dB from the Shannon limit, depending on the transmission mode.

The reference model from Matlab is modeling the BCH encoder, LDPC encoder, interleaver, modulator, as well their counterparts in the receiver, according to the DVB-S2 standard (as seen in figure 8) [8]. Since the RF measurements are performed before the complex coding scheme of DVB-S2, in our opinion the results should be comparable with SVB-S.

IV. EXPERIMENTAL RESULTS

To evaluate the transmission we chose four DVB-S multiplexes and four DVB-S2 multiplexes as described previously in the testing scenario.

Although the RF quality testing method using "Signal Level Meter MC-577" is slightly invasive, introducing minor reading errors, compared with results from other methods of testing, but it is very useful for antenna positioning to the desired satellite (in the case when the antenna doesn't have an automatic targeting system).

Table 1 shows the C/N calculated from the RF spectrum adequate to selected DVB-S transponders according to [8]

Table 1

Satellite/ Transponder Number Frequency/ Intermediate Frequency [MHz] 1	Polari sation 2	Multiplex information (Modulation/FEC rate /$D_{net\ binary}$) [Mbps] 3	C/N [dB] 4
Astra 1M 20 11.5085 1758,5	V	QPSK 5/6 34,4	5 (65-60)
Astra 1L 26 11.5970 1847	V	QPSK 5/6 35,2	5 (66-61)
Astra 1H 71 11.8365 1236,5	H	QPSK 3/4 39,1	7 (67-60)
Astra 1H 87 12.1485 1548,5	H	QPSK 3/4 39,0	7 (63-56)

As observed, in the first column of Table 1is containing the satellite name, followed by transponder number and frequency, and also the intermediate frequency (for decoding) corresponding to satellite transponder frequency (specified above). The second column is containing the polarization of the signal; the third column shows the modulation type along with the data rate for the chosen multiplex. The last column specifies the C/N ratio obtained from the spectrum shape.

Table 2 the shows the C/N domain variation of the same DVB-S multiplexes, determined with Setup4PC application (the third testing method of DVB-S streams in previous paragraph). As we can see, this reading of C/N is more accurate than the previous one.

Table 2

Transponder Number	C/N Range [dB]
20	6.4 – 9.6
26	5.9 – 9.4
71	5 – 7
87	5 – 7.2

Table 3 shows the C/N calculated from the spectrum shape adequate to selected DVB-S2 transponders in conformance to [8].

Table 3

Satellite/ Transponder Frequency/ Intermediate Frequency [MHz]	Polari zation	Multiplex information (Modulation/ FEC rate /$D_{net\ binary}$) [Mbps]	C/N [dB]
Astra 1H 12.5220 1922	V	8PSK 2/3 46,3	5,5 (62-56,5)
Astra 1M 11.9140 1314	H	QPSK 9/10 50,0	8,5 (67,5-59)
Astra 1M 10.8320 1082	H	8PSK 2/3 43,7	10 (75-65)
Astra 1KR 10.8175 1067,5	V	8PSK 2/3 43,4	5 (70-65)

It can be seen that Table 3, illustrates measurement on the same parameters as Table 1, but DVB-S2 multiplexes on different transponders.

V. CONCLUSIONS

In case of DVB-S signal and stream analysis we have experimented and reviewed four basic testing steps:

- RF stream evaluation (spectrum shape, signal level, C/N) with Signal Level Meter MC-577, general information about multiplex at RF level;
- TS information, MPEG-2 tables, subjective evaluation

using TSReader Lite software;

- Signal quality antenna and transponder settings with Setup4PC application;
- Subjective evaluation and channel information with DVB Viewer.

In case of DVB-S2 stream analysis we have reviewed two testing directions:

- RF signal evaluation using the same analyzer specified previously;
- Subjective evaluation and channel information using DVB Viewer program.

The method of C/N evaluation using Level Meter MC-577 from spectrum shape introduces an acceptable degree of errors.

DVB-S2 simulation model faces serious limitations, due to the ambition to raise significantly the data rate. It highlights coding scheme aspects, close to Shannon limit. The simulation developed in Matlab [8], during the development of the standard, is rather simplified, assuming the following: perfect emission/reception synchronization, no baseband scrambling, only normal FEC frames are taken into account, only one LDPC code word is processed, no physical layer framing, no baseband filter, an AWGN channel model rather than a satellite channel. For ACM implementation the users sets the E_s/N_0 (symbol energy related to noise spectral density) rather than satellite C/N estimation, as in real environments systems.

The results of the measurement process are in some degree limited by the hardware resources and equipment, but this research proved that the basic aspects of service evaluation are covered with enough precision and reliability. In most practical applications (antenna setting, adjustment and programming of headend and basic TV distribution service) the precision and the number of evaluated parameters are satisfactory. The extended version of the measurement report is contained in reference [10].

Future work can be achieved by TS or GS (MPEG-4 tables) analyses of DVB-S2 multiplexes, with adequate software.

Possibly, processing the primary results of the measurements, in a manner similar with reference [11], the study could be extended to obtain additional results.

For future development we are considering testing of Video and audio quality metrics, important in applications like Video on Demand (VoD)/Pay TV, Conditional Access (CA) and Digital Video Recording (DVR) functions.

This paper is focused on DVB-S/S2 standards, but usually in central distribution systems (Headends) DVB-S is followed by a DVB-C conversion. The future work will try to explore this direction.

A promising future direction will be to test a two-way communication (data communication between multiple satellite users) according to DVB-S2 or DVB-RCS (Return Channel Satellite), using a DVB-RCS equipment, but this will require sensitive satellite equipment and subscriptions for two-way services.

ACKNOWLEDGMENT

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