EFFECTIVE METHODS TO ANALYZE SATELLITE LINK QUALITY USING THE BUILT-IN FEATURES OF THE DVB-S CARD

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Abstract: This paper presents aspects of a simple methodology to evaluate satellite link quality (especially for downlink segment) using accessible technologies and Satellite PC boards (DVB-S). Traditional methods are based on high end testing communication equipment, allowing better results in precision, but with significantly higher costs, not entirely justified in small communications companies or educational environment. The described methodology uses the BER delivered by the source decoder (a standard component in DVB-S receivers), allowing to estimate the C/N (carrier to noise) ratio, and by consequence, of all the main parameters of the satellite link. A limitation is the fact that only the downlink segment could be accurately evaluated, this comparative estimation in most application is more than needed (ex. Satellite TV reception).

Key words: Satellite Communication, Satellite Link, DVB-S, PC-Card.

I. SATELLITE BASIC CONCEPTS

A "passive" satellite transponder is a broadband RF channel used to amplify one or more carriers on the downlink side of a geostationary communications satellite. It is part of the microwave repeater and antenna system that is housed onboard. Examples of these satellites, for Europe, include ASTRA fleet and Hotbird fleet, located at 19.2 and 13 degrees east longitude, respectively. These satellites and most of their companions have geostationary orbit and repeaters using Ku bands; a repeater is simply a block that receives all signals in the uplink beam, translates them to the downlink band, and separates them into individual transponders of a fixed bandwidth. Figure 1 shows the basic concept. Each transponder is amplified by either a traveling wave tube amplifier (TWTA) or a solid-state power amplifier (SSPA). Satellites of this type are used for transmitting TV channels to broadcast stations, cable TV systems, or directly to the home (DTH). Other applications include very small aperture terminal (VSAT) data communications networks, international high bit rate pipes, and rural telephony. Integration of these information types is becoming popular as satellite transponders can deliver data rates in the range of 50 to 150 Mbps. Achieving these high data rates requires careful consideration of the design and performance of the repeater.

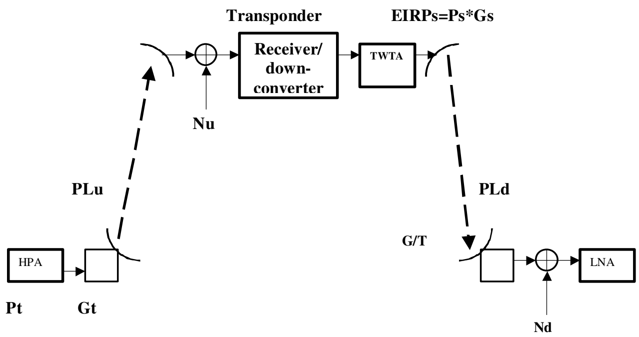

Figure 1. Satellite link model

The most significant impairments to digital transmission come about in the filtering, which constrains bandwidth and introduces delay distortion, and the power amplification, which produces AM/AM and AM/PM conversion. These effects will be discussed in detail later in this article. For maximum power output with the highest efficiency (e.g., to minimize solar panel DC supply), this amplifier should be operated at its saturation point. However, many services are sensitive and susceptible to AM/AM and AM/PM conversion,

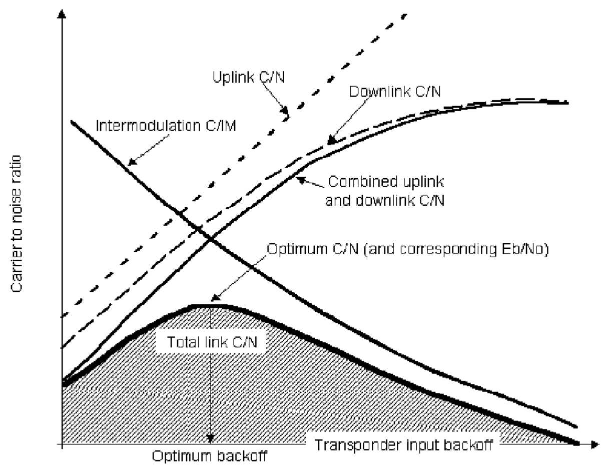

Figure 2. C/N calculation in satellite communications [1]

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for which backoff is necessary. With such an operating point, intermodulation distortion can be held to an acceptable level, however, back-off also reduces downlink power.

The transponder itself is simply a repeater. It takes in the signal from the uplink at a frequency f1, amplifies it and sends it back on a second frequency f2.

The basic system figure of merit is the carrier to noise ratio C/N. If we accurately calculate the C/N for each of the individual impairments, then the overall C/N of the system is given by the following formula:

$$C/N = \left\{ \sum_{k=1}^{n} \left\lfloor C/N_k \right\rfloor^{-1} \right\}^{-1} \quad (1)$$

Figure 2 (reproduced from [1]) shows the results of combining the above equation with individual simulations used to compute the individual terms. The independent parameter in this case is the TWTA BO previously described. Note that these components have competing effects. As the BO decreases there is more output power. Since the thermal noise floor is fixed, the C/N component increases as the BO decreases. On the other hand, at the BO decreases the signal is driven further into the nonlinear region of the TWT curve. This, of course, increases the power of the IM components. The net result is an optimum operating point that is determined via the simulation.

Another system measure is the bit error rate (BER)[2], or sometimes the message or packet error rate. Some user applications require the BER to be in the 10e-6 to 10e-9 range. To achieve such low rates the information data is usually protected by a variety of forward error correcting codes (FEC). The DVB-S system uses a concatenated code, or code within a code structure. The outer code is a [204,188, 8] shortened Reed Solomon (RS) code. This code is used because it is effective against burst errors. The inner code is a rate ½ punctured to 2/3, constraint length 7 convolutional code. The Viterbi algorithm is used as the decoder. The nature of the convolutional code and this decoder gives rise to errors occurring in bursts that are then ‘cleaned up’ by the RS code. Simulations employing Monte Carlo techniques can combine all of the impairments described here to determine the BER. Also, trade off studies can determine which impairments are the most damaging and which are not. This information leads to tolerance requirements for the various components. Thus component costs are controlled with time, energy, and money being devoted only to the extent that is required for performance.

II. DVB-S CARD ARCHITECTURE

Hardware Architecture

The DVB card consists of several components, both on the hardware and software aspects. The basic building block as shown in Figure 3 serves as a platform for standard-definition (SDTV, resolution of 720*576, which is defined as MP@ML (Main Profile at Mail Level)) television program decoding. The main schematic is close to the stand-alone version presented in [4].

A DVB PC card is composed form a channel-decoding module and a source-decoding module. The channel-decoding module deals with the transmission over the physical media and its main task is to deliver an error free signal to the source-decoding module. It is usually grouped under the term “forward error correction” (FEC) as it provides error detection and correction to the received signal.

On the other hand, the source decoding module descramble, demultiplex and decode the audio and video signal for reproduction. The main task of each functional module is presented in figure 3. The main tasks of source decoding, in a DVB PC-Card, are performed by the host processor (usually at least from Pentium III class).

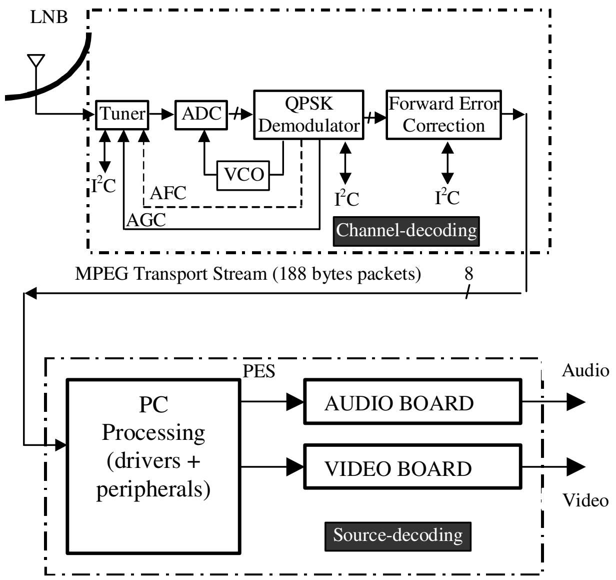

Figure 3. The Hardware Architecture of the DVB Card

We are briefly describing the functions of each module:

1. Tuner

The tuner (sometimes known as the ‘front-end’), generally select one of the RF (Radio Frequency) channel and converts it into IF (Intermediate Frequency).

2. ADC (Analogue to Digital Converter)

The ADC receives the analogue signals and converts it into a digital signal for QPSK processing.

3. QPSK Demodulation

This is the key element in the channel decoding process: It performs digital demodulation and half-Nyquist filtering, and reformatting/demapping into an appropriate form for the FEC circuit. It also plays a part in the clock and carrier recovery loops, as well as generating the AGC (automatic gain control) for control of the IF and RF amplifiers at the front end.

4. FFT (Fast Fourier Transform) processor

The FFT processor provides timing and frequency synchronization, channel estimation and equalization, generation of optimal soft decisions using the channel state information, symbol and bit de-interleaving.

5. Forward Error Correction (FEC)

The FEC block performs de-interleaving, Reed-Solomon decoding and energy dispersal de-randomizing. The output data are the 188 bytes transport packets in parallel form (8 bit data, clock and control signals). The channel-decoding module is highly integrated and it is usually offered as a single chip solution (module 2 to 5).

Software Architecture

The software required to power the DVB set-top boxes or PC cards is apparently more complex than the hardware requirement since most of the hardware are already highly integrated. An example of the software model used for the development is presented in figure 4.

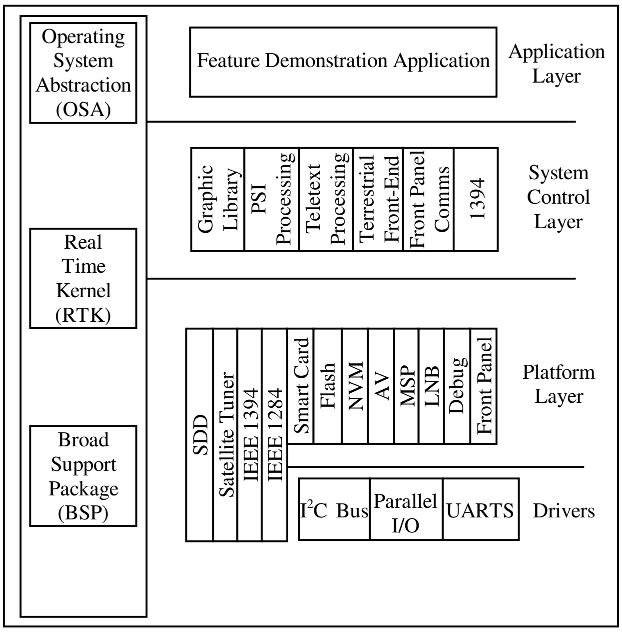

Figure 4: Software Architecture for the DVB-S Card

The task of decoding is mainly done in hardware, the software deals with configuring these devices upon power up and to handle user requests. Most of the software modules are required to program the EPG (Electronic Program Guide) and Interactive TV (if included). Not all the components are required for a specific function (TV reception, for example), but the software driver could be updated permanently to match new requirements in functionality.

III. SATELLITE LINK EVALUATION PROCEDURE

Downstream link analysis

Downstream link analysis is useful in many applications involving RO (receive only) systems. The most common example is the DTH (Direct to Home) television. The main ideas of the downstream link analysis are given in the following steps of calculation (similar with the procedure described in [3]). The procedure, followed by many other works, is based on the satellite link model described in paragraph I.

a). Pass Loss (Free Space Attenuation)

$$PL = 20\log\left(\frac{4\pi d}{\lambda}\right) \qquad (2)$$

If f = 12GHz, PL = 206dB. If f = 4GHz, PL = 196dB.

This value is an approximation. To fully evaluate the real losses it is necessary to consider also:

- coupling losses (wave guide, filter, coupler)
- alignment losses (alignment of antenna to satellite, alignment to direction of polarized wave)
- rain attenuation depends on the used frequency

b). Gain(G) of Satellite Dish Antenna

$$\mathbf{G = 10\log\left(\eta(\pi D\, f / c)^2\right)} \qquad (3)$$

η= antenna efficiency (55% - 70%)

c). Input Power at Earth Station

The Input Power (P_{in}) for the LNA/LNB positioned at the focal point of the receiving antenna depends on the EIRP, the Gain (G) of the satellite receiving antenna, and the Pass Loss (PL).

$$\mathbf{P_{in} = EIRP + G - PL} \qquad (4)$$

e). Noise N at input of the system

$$\mathbf{N = K + T_{sys} + B_n\ [dBW]} \qquad (5)$$

K = -228dBWs/K (Boltzmann Constant)
T = Temperature of antenna system
B_n = noise bandwidth of receiver

T_{sys} expressed in K contains all system noise sources as there are:

- T_a , noise temperature of the antenna which depends on elevation, frequency, and efficiency
- T_{LNB} , noise temperature of the LNA/LNB, see data sheet
- T_{amb} , ambient temperature
- T_{feed} , attenuation losses of the feed system

f). Figure of Merit (G/T)

G/T describes the system quality of antenna and LNB

$$\mathbf{G/T = G\text{-}T\ [dB]} \qquad (6)$$

Instead of giving the necessary antenna diameter for satellite reception it is more precisely to use the G/T figure as it contains the system noise T_{sys}.

g). Power Ratio of RF-carrier and noise (C/N)

$$\mathbf{C/N = EIRP + G/T - PL + 228dBWs/K - B_n\ [dB]} \qquad (7)$$

The $\mathbf{B_n}$ (noise bandwidth) is different in each satellite network. For example SES Astra uses 27MHz transponders, while Eutelsat 's transponder bandwidth is 36MHz.

The C/N value can be calculated as well measured by means of a spectrum analyzer. A receiving system requires a minimal C/N (threshold value) for an error free signal. This last formula is the main issue, and the starting point, in the procedure described.

Test procedure described in this paper is based on the evaluation of C/N realized and delivered in the front-end part of the DVB board. As already described in paragraph II the channel decoder has a built-in capability to deliver the C/N and BER of the received signal. The BER is the base of a so call "Quality" evaluation, but none of the producers (DVB cards or STB) is giving detailed information regarding exact "Quality" definition or evaluation. In fact, different brands of receivers shows different values for this parameter, for the same channel. Fortunately, the C/N ratio is a clearly defined value, and is delivered "as is" in the channel decoder's driver.

The “Transponder status” module of the setup4PC ([5]) software utility, presents in detail the described parameters. The main screen is presented in figure 5.

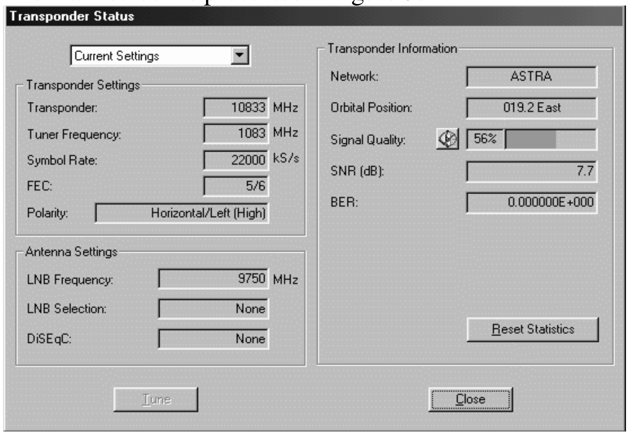

Figure 5. Transponder status module

IV. RESULTS

The described procedure was tested in a normal, DVB-S (TV) satellite reception system. This system consists from following components:

- Satellite dish 0.9m
- LNB 0.3 dB
- DVB-S board – SkyStar 2D
- Host PC – Pentium II – 400MHz

The results are included in Table 1.Last column contains the computed value for transponder EIRP, using the link model described. The columns have the following significance: Sat.-satellite, Pol.- polarity, SR-Symbol rate, C/N –carrier to noise, Q- quality (a measure of the error rate BER delivered in the demodulator part - not entirely explained in board’s documentation), EIRP -Effective Isotropic Radiated Power.

Table 1

Sat.	Program	Transp	Pol	SR	FEC	C/N	Q	EIRP (est)
Astra2C	Taquilla	10788	V	22000	5/6	11.5	80%	46.6
	TVVint	10818	V	22000	5/6	9.6	66%	44.7
	BibelTV	10832	H	22000	5/6	7.3	54%	42.4
	TVPolonia	10862	H	22000	5/6	6.5	49%	41.6
Astra1G	CNN	11778	V	27500	3/4	8.9	67%	44
	Canal+	11856	V	27500	3/4	6.1	50%	41.2
	Bloomberg	12552	V	22000	5/6	2.6	28%	37.7
	BVN	12574	H	22000	5/6	8.2	60%	43.3
	France4	12581	V	22000	5/6	6.9	53%	42
	STB	12604	H	22000	5/6	2.5	26%	37.6
	Disney FR.	12640	V	22000	5/6	7.3	54%	42.4
	MTV Germ.	11739	V	27500	3/4	9.4	70%	44.5
Astra1F	Premiere	11720	V	27500	3/4	7.3	57%	42.4
	Premiere1	11798	H	27500	3/4	6.1	50%	41.2
	13street	12032	H	27500	3/4	7	56%	42.1
Astra1H	COD	12699	V	22000	5/6	5.8	45%	40.9
	Arte	11837	H	27500	3/4	7.8	60%	42.9
	ZDF	11915	H	27500	3/4	6.5	53%	41.6
	3SAT	11954	H	27500	3/4	6.5	53%	41.6
	Pro7Aut	12051	V	27500	3/4	8	62%	43.1
	Kioskque	12129	V	27500	3/4	7.4	58%	42.5

V. CONCLUSIONS

This simple procedure makes possible a step forward in satellite link analysis compared with a classical (off line - model based) analysis described in paragraph III. It is possible to have real values, in every moment, regarding quality of signal, and estimations of the losses in downlink process. The values obtained in our measurements are different (with 2-3 dB) from values presented in the Coverage Map of Astra satellites ([6]), but this could be explained by the variations of the satellite footprint.

A second advantage is the fact that the actual quality of the receiving system is less important in this evaluation; multiple measurements could be used to eliminate errors (cable length, LNB noise, antenna efficiency), simply correlating two evaluations for equation (7), eliminating the G/T (common for the two measurements).

The described method allows obtaining the C/N ratio for a desired transponder, and consequently the EIRP, using either the link model (and a simple measurement) or multiple measurements to eliminate the G/T influence.

An important issue of these experiments is the fact that propagation losses are changing rapidly, in intervals of hours or even minutes. This makes imperative to perform all the measurements from the same set in the shortest time possible, to avoid this type of error. For the procedure described, done manually, and data processed in Excel, was extremely difficult to fulfill such requirements. Table 2 illustrates the fact that, after ½ hour, measured values (for few channels) are changed.

Table 2

Sat.	Program	Transp	Pol	SR	FEC	C/N	Q	EIRP (est)
Astra1F	Premiere	11720	V	27500	3/4	6.5	53%	41.6
Astra1G	CNN	11778	V	27500	3/4	8.5	64%	43.6
Astra2C	BibelTV	10832	H	22000	5/6	7.5	55%	42.6

Consequently, a recommendation for the future improvements will be to develop an integrated program (utility), capable to realize automatically, within few minutes, all the channel scanning and acquisition process. In this case the evaluation error will be minimal, opening the possibility to correlate more accurately the measurements and eliminating the fixed parameters (cable length, LNB noise- shortly G/T) influence. Using the SDK delivered by the board’s manufacturer could be a solution for this development.

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