Measurement of DVB-S and DVB-S2 parameters

Krešimir Malarić, Ivan Suć
Faculty of Electrical Engineering and Computing
University of Zagreb
Zagreb, Croatia

Iva Bačić
Rochester Institute of Technology Croatia
RIT Croatia
Zagreb, Croatia

***Abstract*— Satellite television is probably most used satellite technology today. One of the biggest providers is the ASTRA system of geostationary satellites. Television satellite standard widely used is the DVB-S which established a unified standard for a satellite transmission accepted both by customers as well as the industry. Standard DVB-S2 has improvements in efficiency (bits/Hz) and adaptive as well as variable coding and modulation. While DVB-S digital satellite standard has constant modulation and coding, standard DVB-S2 can adopt both modulation and coding depending on the weather conditions, channel interference, etc. Both technologies still co-exist today. This paper analyses the parameters of both DVB-S and DVB-S2 standards such as bit error rate, modulation error rate, signal to noise ratio and signal level in different weather conditions. The measurements were performed in clear sky, clouds and rain conditions. They included extensive coverage of digital video signal in thirty different weather conditions. The results showed that DVB-S2 standard performs similar to DVB-S standard in clear sky conditions as well as cloudy weather, while for rain DVB-S2 excels. Bit error rate for DVB-S2 standard stayed the same regardless of weather conditions and about four orders of magnitude compared to DVB-S standard.**

Keywords*— DVB-S;DVB-S2;adaptive coding and modulation; parameter measurement

I. INTRODUCTION

ASTRA [1] is a name for geostationary communication satellites, owned by SES (*fr. Societe Europeenne des Satellites Societe Anonyme*). ASTRA Satellites have more than two thousand digital television and radio channels across Europe and North Africa and reach more than 100 million homes.

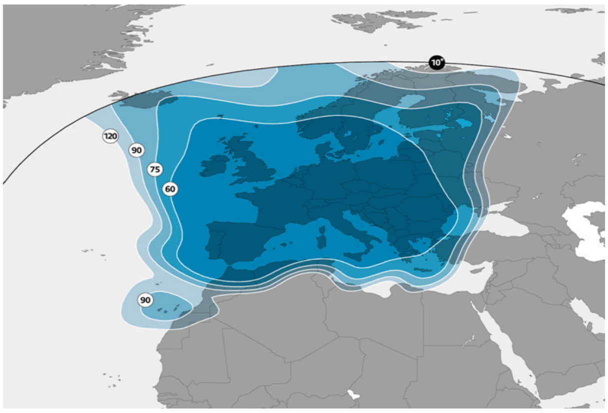

Fig. 1. ASTRA 1KR Ku band beam

Fig. 1 shows ASTRA 1KR satellite coverage (http://www.ses.com/4628698/astra-1kr, 19th March, 2015).

Apart from radio and TV, ASTRA provides multimedia, internet and telecommunication services as well. There are five sets of satellite positions: 19.2°E (1H, 1KR, 1L, 1M, 1N, 2C), 28.2°E (2A, 2D, 2E, 2F), 23.5°E (3B), 5°E (4A) and 31.5°E (1G, 5B). Europe is covered mainly with ASTRA 19.2°E.

Satellite signal is normally transmitted only if there is a line of sight (LOS). For satellite television reception or Direct to home (DTH) service a satellite antenna, TV receiver and a digital satellite receiver are necessary.

DVB-S or Digital Video Broadcasting – Satellite was the first standard for satellite television [2] introduced almost two decades ago. The standard defined the modulation procedures as well as coding for satellite multichannel TV/HDTV services such as Fixed Satellite Service (FSS) and Broadcast Satellite Service (BSS). DVB-S is actually a part of a wider DVB (Digital video broadcasting) which specifies distribution of digital services via cable network, satellites, terrestrial transmitters and internet as well as mobile communication systems and is compatible with MPEG-2 coded TV services.

The characteristics of DVB-S are: one transmission per carrier, modulation (QPSK, 8PSK, 16QAM), roll-off factor: 0.35, fixed modulation (QPSK), and coding (Convolution and Reed Solomon) with code rates: 1/2, 2/3, 3/4, 5/6 and 7/8 as well as transport packet of 188 bytes. Demodulator characteristics are expressed with E_b/N_0 (energy per bit to noise density spectral density ratio).

DVB-S2 standard was introduced in 2005 [3]. It is based on DVB-S and has two main improvements: variable coding and modulation which optimizes the transmission parameters for various users in the real time. TV channels can be coded either in SDTV or HDTV technique. While with constant coding and modulation (CCM) all frames use same parameters, with adaptive coding and modulation (ACM), each frame in transmission is coded according to the reception condition of the receiver. The characteristic of variable coding and modulation (VCM) is that different transmissions or services are coded according to different parameters [4, 5]. Furthermore, different modulation formats (QPSK, 8PSK, 16APSK and 32APSK) can be utilized. DVB-S2 is also compatible with MPEG-2 and MPEG-4 standards.

In theory, DVB-S2 has better spectral density compared to DVB-S, a 40% saving in the transmission bandwidth (30%

due to better coding and 10% due to the smaller roll-off factor). Margin error is 1.5 dB and Shannon limitation is only a 1 dB away.

The characteristics of DVB-S2 standard are [6]: use of adaptive coding and modulation, roll-off factor can be 0.25 or 0.2 for further limitation of bandwidth, more code rates (1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9 and 9/10) and more modulation choices (QPSK, 8PSK, 16APSK and 32APSK). Instead of inner convolution coding a LDPC is used [7]. All of the improvements mentioned have a result that DVB-S2 has 30% higher capacity compared to DVB-S standard with the same transmission conditions.

The paper is organized as follows: First, theory of coding and modulation techniques is given, namely constant, adaptive and variable coding and modulation. Furthermore, modulation schemes, satellite link, system parameters as well as measuring device are presented. Section III gives results and discussion for both DVB-S and DVB-S2 standards regarding the signal level signal to noise ratio, bit error rate as well as modulation error rate depending on the different weather conditions. The measurements were performed in thirty different weather situations during winter and spring including clear sky, clouds and rain. At the end, some concluding remarks are given.

II. THEORY

A. Constant Coding and Modulation (CCM)

DVB-S systems use constant coding and modulation. The frequency range of use is Ku (12 GHz - 18 GHz). All of the terminals use same constellation all the time and the system works in favor of the weakest terminal. This means that the system uses lower bit error rate in order to satisfy the worse transmission and reception conditions. CCM is used in systems where weather conditions do not influence the signal propagation.

B. Adaptive Coding and Modulation (ACM)

Adaptive Coding and Modulation (ACM) enables fast change of modulation, i.e. from QPSK to 8PSK as well as change of FEC (forward error correction) code rate. The possibility of such a fast change is enabled by feedback channel in the uplink. This means that receiver follows the quality of received signal parameters and sends the information on transmitting condition back to the transmitter. Feedback channel is not strictly defined and can be DVB-RCS (Return Channel via Satellite) or simple ADSL transmission over a telephone line.

DVB-S2 system of ACM effectively achieves maximum efficiency of signal transmission. ACM thus enables optimum downlink link with a minimum link budget margin still maintaining the maximum signal rate.

C. Variable Coding and Modulation (VCM)

Variable Coding and Modulation (VCM) is variation of Adaptive Coding and Modulation (ACM) mode of signal transmission. VCM does not require feedback and does not enable fast changes of modulation and FEC as ACM. VCM is mostly used for application transmission rather than for TV transmission [8]. Since some information can be send on different constellations, this enables reaching the users on edges of satellite signal reception in order for them to have equal conditions as other users. In general, VCM does not effectively utilize resources since the users with a good signal reception do not have the need for better coding and modulation.

D. Modulation Schemes

Primary mission of DVB-S2 system was to introduce higher modulation schemes than QPSK (Quadrature Phase Shift Keying) in order to increase the throughput of data [9]. Fig. 2 shows modulation schemes used in DVB-S2 ((a) - QPSK, (b) - 8PSK, (c) - 16APSK and (d) - 32APSK). Letter “A” means that aside from phase, modulation includes the amplitude as well.

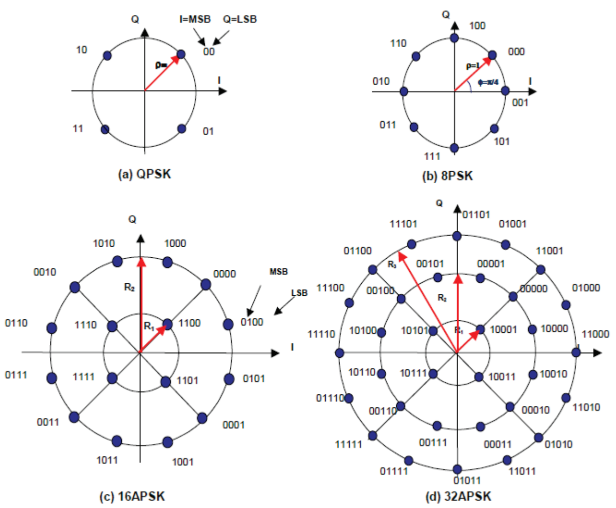

Fig. 2. DVB-S2 modulation types

Modulation scheme 16APSK and 32 APSK are similar to QAM (Quadrature Amplitude Modulation) since their circular shape better utilizes power in a limited channel which is a case with saturated transmitter.

E. Satellite link

Satellite link is shown on Fig. 3. On uplink there is a satellite and transmitting antenna(s), while downlink includes satellite, receiving antenna, satellite receiver and a TV. For measuring purposes, satellite receiver and TV were replaced with a measuring device. In this paper only downlink is tested.

The receiving antenna is a parabolic dish with a LNB converter. Low noise block down converter (or LNB converter) is placed in a focus of the antenna and down converts the received frequency band amplifying the signal at the same time. The received signal is in Ku band (11.7 to 12.2 GHz downlink), while the converted frequency band is from

950 MHz to 2150 MHz. The signal travels from LNB converter to the satellite receiver via 75 Ohm coaxial cable.

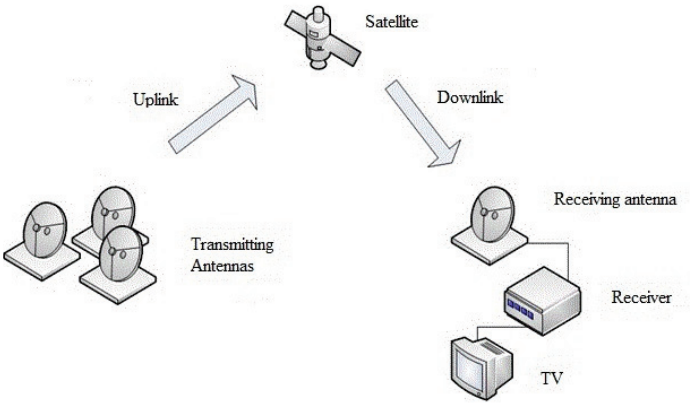

Fig. 3. Satellite link

F. System parameters

As mentioned above, digital mode of operation shows four thermometer levels: SIG, SNR, BER and MER. Higher level means better quality.

SIG or signal shows the signal level on current transponder frequency.

SNR or signal to noise ratio shows the level of useful signal compared to background noise. The ratio (in dB) can be expressed as

$$SNR = 10\log\left(\frac{P_{\text{signal}}}{P_{\text{noise}}}\right). \qquad (1)$$

BER or bit error rate is next parameter [11]. The smaller it is the better. On scale it is shown in reverse direction.

MER or modulation error ratio is a percentage of modulation errors in dB. MER is calculated from constellation errors and represents the distance between points of decision compared to ideal position on I-Q diagram [12]. Typical value is app. 16 dB. The higher value is better. Modulation error can be calculated from

$$\text{MER} = 10\log_{10}\left(\frac{\sum\left(I_{\text{ideal}}^2 + Q_{\text{ideal}}^2\right)}{\sum\left(I_{\text{error}}^2 + Q_{\text{error}}^2\right)}\right). \qquad (2)$$

G. Measuring device

The device used for measuring parameters of DVB-S and DVB-S2, a Satlook micro HD [10] was used. The instrument can receive DVB-S and DVB-S2 satellite signals. Signal levels are displayed with thermometer bars. In digital mode of operation, the instrument shows SIG (signal) level, SNR (signal to noise ratio), BER (bit error rate) and MER (modulation error ratio) as well as constellation diagram (Fig. 4). Display also shows the information of satellite (name and position), modulation type and FEC ratio.

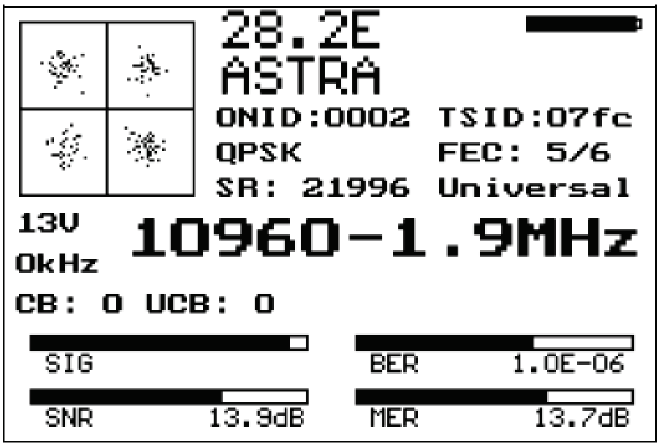

Fig. 4. Satellite link

III. Results And Discussion

The propagation is affected mostly by weather, that is, by fog, rain, low clouds, etc. The humidity and the size of raindrops influence both the depolarization as well as attenuation of a propagating signal. The measurements were performed for DVB-S and for DVB-S2 standard in various weather conditions, namely clear sky, clouds and rain. The measurements were repeated thirty times for each of the weather conditions at the same position in the city of Zagreb, Croatia. The following results show levels of SIG, SNR, BER and MER for DVB-S and DVB-S2.

A. DVB-S standard

Fig. 5 shows SIG level for DVB-S in different weather conditions. It can be seen that rain and clouds influence the reception by app. 4% and 2% compared to the clear sky conditions. Fig. 6 shows SNR level for DVB-S in different weather conditions. It can be seen that rain and clouds lower the SNR ratio by app. 0.4 dB and 0.7 dB respectively compared to clear sky conditions. Fig. 7 shows BER level for DVB-S in different weather conditions. It can be seen that both rain and clouds raises the BER ratio app. two times compared to the clear sky conditions.

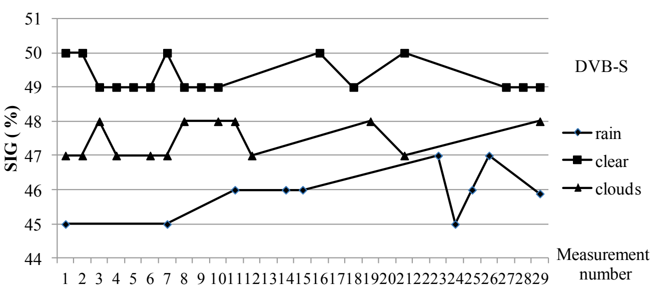

Fig. 5. DVB-S SIG level depending on weather conditions

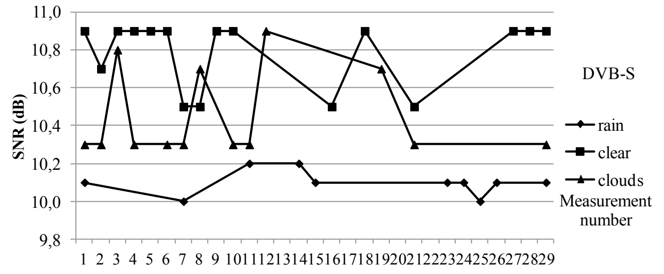

Fig. 6. DVB-S SNR level depending on weather conditions

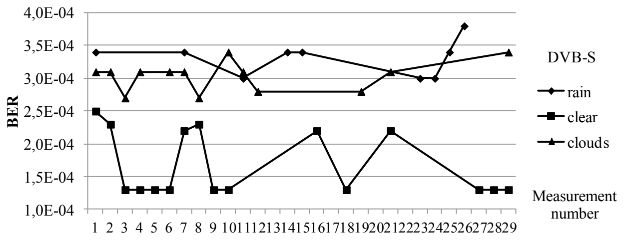

Fig. 7. DVB-S BER level depending on weather conditions

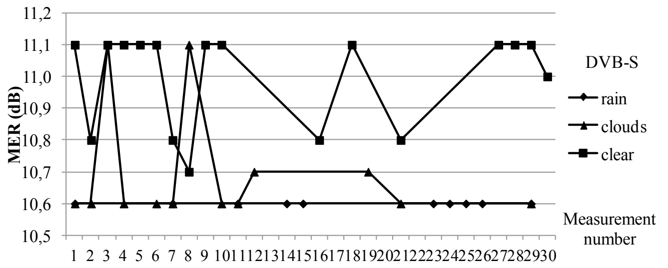

Fig. 8. DVB-S MER level depending on weather conditions

Fig. 8 shows MER level for DVB-S in different weather conditions. It can be seen that both rain and clouds lower the MER ratio by app. 0.5 dB compared to the clear sky conditions.

During the measurements FEC ratio did not changed and stayed constantly at 5/6. Throughput of data varied from 3.5E07 bit/s for clear sky to 1.4E07 bit/s for rain. Modulation stayed QPSK for all weather conditions.

B. DVB-S2 standard

Fig. 9 shows SIG level for DVB-S2 in different weather conditions. It can be seen that rain and clouds influence the reception by app. 11% and 8% compared to the clear sky conditions. All SIG values are higher compared to DVB-S. The influence (signal level drop) of rain and clouds are somewhat larger compared to DVB-S. Fig. 10 shows SNR level for DVB-S2 in different weather conditions. It can be seen that rain and clouds lower the SNR ratio app. 1 dB and 3 dB respectively compared to clear sky conditions. All levels are similar compared to DVB-S except for rain conditions which is app. 1.5 dB lower compared to DVB-S. Rain and cloud conditions influence DVB-S2 (drop in SNR) more than compared to DVB-S. Fig. 11 shows BER level for DVB-S2 in different weather conditions. It can be seen that BER stays at 1E-08 whole time regardless of weather conditions. BER value is also much better compared to DVB-S. Throughput stayed 6.4E07 bit/s all the time. FEC was changed only once from 5/6 to 3/4 during heavy rain [13]. Cyclones can cause satellite signal outage [14].

Cyclone (Fig. 12) present over a large part of Europe on 4th May of 2014 caused significant signal attenuation. During Cyclone, modulation was 8PSK and it did not change. However, FEC ratio after the storm changed back from 3/4 to 5/6.

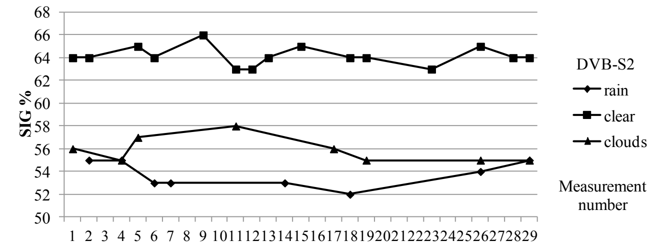

Fig. 9. DVB-S2 SIG level depending on weather conditions

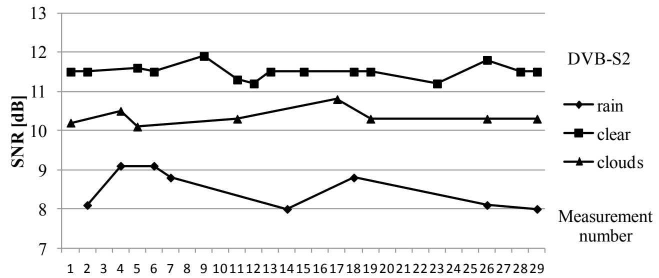

Fig. 10. DVB-S2 SNR level depending on weather conditions

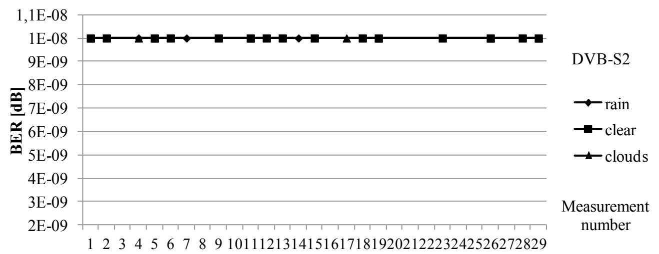

Fig. 11. DVB-S2 BER level depending on weather conditions

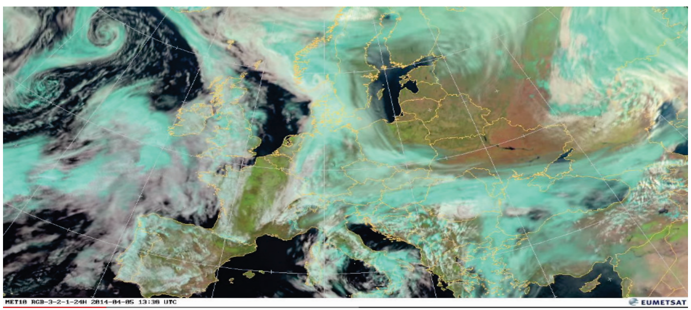

Fig. 12. Cyclone over Europe on 4th May 2014

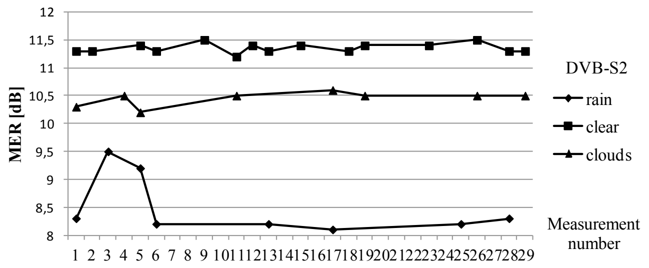

Fig. 13. DVB-S2 MER level depending on weather conditions

Fig. 13 shows MER level for DVB-S in different weather conditions. It can be seen that both rain and clouds lowered the MER ratio by app. 1 dB and 3 dB compared to the clear sky conditions. The values for clear weather and clouds are similar to DVB-S, but for rain the value of MER is lower compared to DVB-S. Fig. 14 shows all the comparison of DVB-S and DVB-S2 regarding SIG, SNR, MER and BER. Table I. gives numerical values of measured parameters.

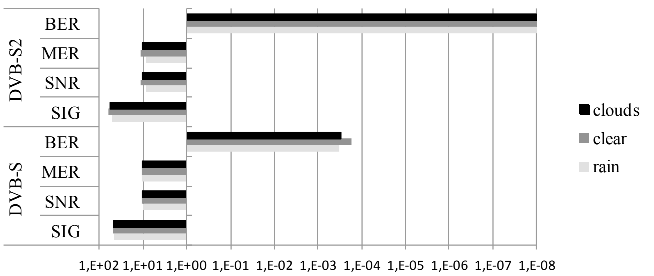

Fig. 14. DVB-S2 MER level depending on weather conditions

TABLE I. MEASURED SYSTEM PARAMETER VALUES

Weather	**DVB-S**				**DVB-S2**			
	SIG	*SNR*	*MER*	*BER*	*SIG*	*SNR*	*MER*	*BER*
Rain	45.89	10.1	10.6	3.31E-04	53.75	8.5	8.5	1.00E-08
Clear	49.31	10.79	11	1.67E-04	64.13	11.5	11.35	1.00E-08
Clouds	47.46	10.45	10.69	3.04E-04	55.88	10.35	10.45	1.00E-08

IV. CONCLUSIONS

As it can be seen from the results, rain most strongly influenced the parameters of satellite signal as it was expected. Clouds also had impact on the quality of signal but to a lesser extent. DVB-S2 showed more resiliant to weather conditions than DVB-S, which is most clear from the results regarding BER, where for DVB-S2 the value stayed constant regardless of weather conditions at value of 1E-08, while for DVB-S the values of BER changed, more with rain than with clouds, but stayed arround 3E-04. Signal level was higher for DVB-S2 than for DVB-S, while levels of SNR and MER are similar for both DVB-S and DVB-S2.

The standard DVB-S2 should therefore provide better quality and throughput thanks to its adaptive coding and modulation capabilities. New sattelites placed in orbit with DVB-S2 standard have the possibility of backward compatibility to DVB-S standard. New improvements and the need of a higher throughput resulted in proposal of a still newer DVB-S2X standard [15].

References

[1] SES – Your Satellite Company, http://www.ses.com/4232583/en, 17th March, 2015.

[2] EN 300 421 V1.1.2. Digital Video Broadcasting (DVB): Framing Structure, Channel Coding and Modulation for 11/12 GHz Satellite Services (1997/08). European Broadcasting Union 1997 and European Telecommunications Standards Institute 1997.

[3] ETSI TR 102 376 V1.1.1. Digital Video Broadcasting (DVB); User guidelines for the second generation system for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2) (2005-02). European Broadcasting Union 2005 and European Telecommunications Standards Institute 2005.

[4] A. Morello, V. Mignone, DVB-S2: The Second Generation Standard for Satellite Broad-band Services, Proceedings of the IEEE, Vol. 94, Issue 1, January 2006, pp. 210-227. DOI: 10.1109/JPROC.2005.861013.

[5] G. Albertazzi, S. Cioni, G.E. Corazza, M. Neri, R. Pedone, P. Salmi, A. Vanelli-Coralli, M. Villanti, "On the adaptive DVB-S2 Physical layer: design and performance", IEEE Wireless Communications, Vol. 12, Issue: 6, 2005, pp. 62-68, DOI: 10.1109/MWC.2005.1561946.

[6] B. Labsky and T. Kratochvil, "DVB-S/S2 satellite television broadcasting measurement and comparison", 20th International Conference Radioelektronika, 19-21 April 2010, pp. 1-4. DOI: 10.1109/RADIOELEK.2010.5478588.

[7] G. Masera, F. Quaglio, F. Vacca, "Implementation of a Flexible LDPC Decoder", IEEE Transactions on Circuits and Systems II: Express Briefs, Vol. 54, Issue: 6., 2007, pp. 542-546, DOI: 10.1109/TCSII.2007.894409

[8] B. Bennet, D. Hannan, J. Marshall, R. Gibbons, "Link Analysis of Commercial and Wideband Gapfiller Satellite (WGS) Satellites Using DVB-S2 with Variable Coding and Modulation (VCM)", IEEE MILCOM 2006, pp. 1-7, DOI: 10.1109/MILCOM.2006.302474

[9] R. De Gaudenzi, A.G. i Fabregas, A. Martinez, "Performance analysis of turbo-coded APSK modulations over nonlinear satellite channels", IEEE Transactions on Wireless Communication, Vol. 5, Issue: 9, 2006, pp. 2396-2407, DOI: 10.1109/TWC.2006.1687763

[10] Satlook Micro HD user Manual, http://wifimag.ro/pdf/SatlookMicroHDUserManual.pdf, 24th March 2015.

[11] M.T. Core, R. Campbell, P. Quan, J. Wada, "Semianalytic BER for PSK", IEEE Transactions on Wireless Communications, Vol. 8, Issue: 4, 2009, pp. 1644-1648, DOI: 10.1109/TWC.2009.071412

[12] M. Bertocco, M. Farias, D. Fortin, A. Sona, Cross-Layer Measurement for the analysis of DVB-T System Performance, IEEE Transactions on Instrumentation and Measurements, Vol. 57, Issue: 7, 2008, pp. 1304-1312, DOI: 10.1109/TIM.2008.917678

[13] EUMETSAT, "European weather April 2014", https://www.youtube.com/watch?v=Vjb3MHtWgJo, 15th March 2014.

[14] J. Petranovich, "Mitigating the Effect of Weather on Ka-band High-Capacity Satellites", March, 2012, http://www.viasat.com, 27th March, 2015.

[15] ETSI EN 302 307-2 v1.1.1. (2014-10) Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcating, Interactive Services, News Gathering and other broadband satellite applications; Part 2: DVB-S2 Extensions (DVB-S2X). European Broadcasting Union 2014 and European Telecommunications Standards Institute 2014, http://www.etsi.org/deliver/etsi_en/302300_302399/30230702/01.01.01_20/en_30230702v010101a.pdf, 24.07.2015.