REPORT ITU-R BO.2101*

Digital satellite broadcasting system (television, sound and data) with flexible configuration**

(2007)

1 Introduction

This Report describes studies undertaken by administrations on DVB-S2, the second-generation specification for satellite broadband applications, developed by the DVB (Digital Video Broadcasting) Project in 2003, targeting the following satellite applications: TV and sound broadcasting, interactivity (i.e. Internet Access) and contribution services, such as TV contribution links and DSNG (digital satellite news gathering).

DVB-S2 [1], [2], [3] is the second-generation system for satellite broadband services, defined by DVB in 2003, in the tenth anniversary of the birth of DVB-S [4], the first DVB system for satellite broadcasting.

The system has been designed for different types of applications:

– Broadcasting of standard definition and high-definition television (SDTV and HDTV);
– Interactive Services, including Internet Access, for satellite broadcasting applications (for IRDs – Integrated receivers decoders – and PC – personal computers);
– Contribution applications, such as digital TV contribution and news gathering;
– Data content distribution and Internet trunking.

The DVB-S2 standard has been specified around three key concepts: best transmission performance, total flexibility and reasonable receiver complexity. To achieve the best performance-complexity trade-off with an appreciable capacity gain over DVB-S, DVB-S2 benefits from more recent developments in channel coding and modulation.

LDPC, low density parity check codes, combined with QPSK (quadrature phase shift keying), 8-PSK(phase shift keying), 16 amplitude phase shift keying (APSK) and 32-APSK modulations allow the system to work properly on the non-linear satellite channel with a performance approaching the Shannon limit, whilst maintaining a reasonable receiver complexity. The framing structure allows for maximum flexibility in a versatile system and also synchronization in worst case configurations (low signal-to-noise ratio, SNR).

For interactive point-to-point applications such as Intenet Protocol (IP) unicasting, the adoption of the adaptive coding and modulation (ACM) functionality allows optimization of the transmission parameters for each individual user on a frame-by-frame basis, dependent on path conditions, under closed-loop control via a return channel (connecting the IRD/PC to the DVB-S2 up-link station via terrestrial or satellite links, signaling the IRD/PC reception condition). This results in a further increase in the spectrum utilization efficiency of DVB-S2 over DVB-S, allowing the optimization

* This Report is intended as a supporting information for the use of Recommendation ITU-R BO.1784 – Digital satellite broadcasting system with flexible configuration (television, sound and data). Eventually this Report may become a nucleus for a new handbook on satellite digital broadcasting in the BSS bands above 11.7 GHz.

** DVB-S2 is characterized by a multitude of configuration parameters (modulation and coding, framing structure, pilots signals) allowing the system to be flexibly used in different operating conditions.

of the space segment design, thus making possible a drastic reduction in the cost of satellite-based IP services.

DVB-S2 flexibility allows the system to cope with any existing satellite transponder characteristics, with a large variety of spectrum efficiencies and associated SNR requirements. Furthermore it is designed to handle the variety of advanced audio-video formats defined in DVB. DVB-S2 accommodates any input stream format, including single or multiple Moving Picture Expert Group – Transport Streams (MPEG-TS) (characterized by 188-byte packets), IP as well as asynchronous transfer mode (ATM) packets, continuous bit-streams.

Two years since the system publication as a European Telecommunication Standards Institute (ETSI) standard, a variety of DVB-S2 products is offered by the industry, and services are being launched by several broadcasters around the world. To verify the status of the DVB-S2 technology, the DVB-S2 ad-hoc group has launched a laboratory test campaign, with the task to verify the compliancy of available equipment to the standard, and the effective gain in performance with respect to the first generation system DVB-S.

The Annexes in this Report describe:

a) the results of the Laboratory tests carried out by Rai-CRIT[1] on equipment provided by seven different equipment manufacturers in June 2006. Furthermore, the first operational contribution network adopting DVB-S2 is described, as set up by EBU (European Broadcasting Union) in the Eurovision contribution network for HDTV transmissions during the 2006 FIFA World Cup. Finally, some references are provided for further documents giving useful guidelines for the use of the DVB-S2 system;

b) the results of studies carried out by Network Ten Australia, Nine Network Australia and Singtel Optus along with Australian agents for equipment suppliers, who loaned modulators and demodulators, and manufacturers of DVB-S2 equipment to assess the system performance for broadcast contribution with respect to DVB-SNG modem implementation margin and margin to threshold for each modulation mode.

References

[1] ETSI. EN 302 307 (V1.1.2) – Digital Video Broadcasting (DVB). Second generation framing structure, channel coding and modulation systems for Broadcasting. Interactive Services, News Gathering and other broadband satellite applications.

[2] ETSI. TR 102 376 – Digital Video Broadcasting (DVB). User guidelines for the second generation system for Broadcasting. Interactive Services. News Gathering and other broadband satellite applications (DVB-S2).

[3] *Internat. J. on Sat. Com. Networks* [May-June 2004]. Vol. 22, **3**, Special issue on The DVB-S2 standard for Broadband Satellite Systems.

[4] ETSI. EN 300 421 (V1.1.2) – Digital Video Broadcasting (DVB). Framing structure, channel coding and modulation for 11/12 GHz satellite services.

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Annex 1

Rai-CRIT laboratory tests

1 Introduction

The DVB ad hoc group responsible for the standardisation of DVB-S2 has launched a laboratory test campaign to evaluate the performance of the DVB-S2 equipment. Following this request, the European tests had been carried out by Rai in their CRIT laboratories in the second half of June 2006, with DVB-S2 equipment made available by manufacturers, either in the form of off-the-shelf products or of laboratory prototypes.

The tests carried out at Rai-CRIT laboratories include additive white gaussian noise (AWGN) performance, non-linear channel and phase noise degradation. The results clearly indicate that the equipment performance is in line with the simulation results presented in the DVB-S2 standard. Implementation loss is in the order of 0.2 dB for QPSK, 0.5 dB for 8-PSK, 0.8 dB for 16-APSK and 1.2 dB for 32-APSK.

Single carrier and multicarrier configuration have been implemented and compared to DVB-S equivalent configurations, showing that DVB-S2 can offer excellent gains both in terms of capacity or performance and in terms of flexibility. Furthermore variable coding and modulation (VCM) and ACM configurations have been implemented, and the equipment capability verified.

Finally, it is to be noted that the equipment under test showed optimum interoperability.

The Eurovision contribution network for HDTV transmissions during the 2006 FIFA World Cup shows the benefits of the use of DVB-S2 to increase the available system capacity. Thanks to DVB-S2, the EBU reports that it has been able to increase the available bit-rate by about 40%, compared to the usual DVB-S transmission parameters. This allowed transmitting HDTV contribution quality signals in a 36 MHz transponder, which would not otherwise have been possible.

2 Objectives of the Rai-CRIT DVB-S2 test campaign

The work has the important twofold objective to verify the status of DVB-S2 equipment, thus demonstrating the excellence of the standard in operation, and to help in the equipment development.

The tests that have been performed on the different modems are as follows:

a) *Constant coding and modulation (CCM) configuration*

Scope of the analysis of this configuration is the assessment of the equipment performance in the various modulation and coding rates offered by the standard, independently from the application. The tests include the following measures:

- Bit error rate (BER) and MPEG-TS packet error rate (PER) performance in the presence of additive white gaussian noise (AWGN), both at intermediate frequency (IF) main measures, and at radio frequency (RF). This allows the comparison of the theoretical performance indicated in the DVB-S2 standard [1], Table 13 with that of the real equipment.

– Bit error rate (BER) and MPEG-TS packet error rate (PER) performance in the presence of AWGN and satellite channel non-linearity. The scope of this test is the system performance verification on the nonlinear satellite channel, and the estimation of the optimum satellite operating point for each tested configuration.
– Performance in the presence of phase noise: typical and critical cases of low noise block (LNB) phase noise mask will be considered, representing contribution equipment as well as domestic ones, currently installed in the outdoor unit for DVB-S QPSK reception, which could result critical for higher order modulations. In fact, it is likely that the domestic users will probably not change their outdoor unit, when moving from DVB-S to DVB-S2.

b) *Variable coding and modulation (VCM) configuration*

Scope of the analysis of this configuration is to verify the receiver capability to adapt its operations to changes of the modulation and coding format of the transmitted signal.

c) *Adaptive coding and modulation (ACM) configuration*

Scope of the analysis of this configuration is to verify the equipment capability to adapt its operations to the channel variation, the target being interactive point-to-point applications.

3 Methodology used

Essentially, the main objective of the laboratory tests was the validation of the hardware equipment performance against the simulation results as reported in EN 302 307 (ETSI standard) and TR 102 376 (User guidelines). The reference test configurations and set-up and the procedures adopted for each of the performance measurements listed above are described in the following sections.

Target performance for DVB-S2 had been established in a PER equal to 10^{-7}, corresponding to less than one erroneous MPEG-TS packed per hour per program at a bit rate of 5 Mbit/s. This is a very stringent target, that requires long measures[2]. Since a large number of modems and configurations have been tested, each measure could not last longer than about 10-15 min.

Assuming that the total transmitted stream is analysed and that at least 50 erroneous packets must be computed for each measure, to guarantee the reliability of the result, PER measurement validity stops at about 10^{-5} to 10^{-6}. Therefore BER/PER curves have been evaluated versus E_s/N_0 with a step in E_s/N_0 of 0.1 dB down to PER of about 10^{-5} to 10^{-6} and the E_s/N_0 value for the target PER of 10^{-7} has been extrapolated. To confirm the extrapolation at PER of 10^{-7}, E_s/N_0 has then been increased of 0.1 dB and a new 10 min measure started, to verify the absence of errors. Finally for some selected configurations the target PER of 10^{-7} has been validated by means of longer measures, to confirm the results of the extrapolation.

4 System configurations under test

The DVB-S2 system encompasses 28 different modulation and coding options (MODCOD), two different frame sizes, and many other options to choose from, for the maximum flexibility.

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[2] It is not possible to follow the procedure used in the evaluations of first generation modems, where a concatenation of codes was used and performance could be measured after inner Viterbi decoding at a BER of 2×10^{-4}.

In order to allow for an effective validation work of the DVB-S2 system performance, a selection of modes was adopted for the lab tests, with the objective to cover all the application areas and profiles targeted by DVB-S2.

Main attention was devoted to the CCM configuration, with constant frame size of 64 800 bits (Normal FECFRAME, forward error correction frame). The presence/absence of pilot sequences has been selected as required by the measure. The following modulations and coding rates have been selected for an in-deep analysis[3]:

– QPSK 1/2
– 8-PSK 2/3
– 16-APSK 3/4
– 32-APSK 4/5.

Secondly, VCM/ACM configurations have been tested, without any constraints on the MODCOD configurations and frame size to be adopted.

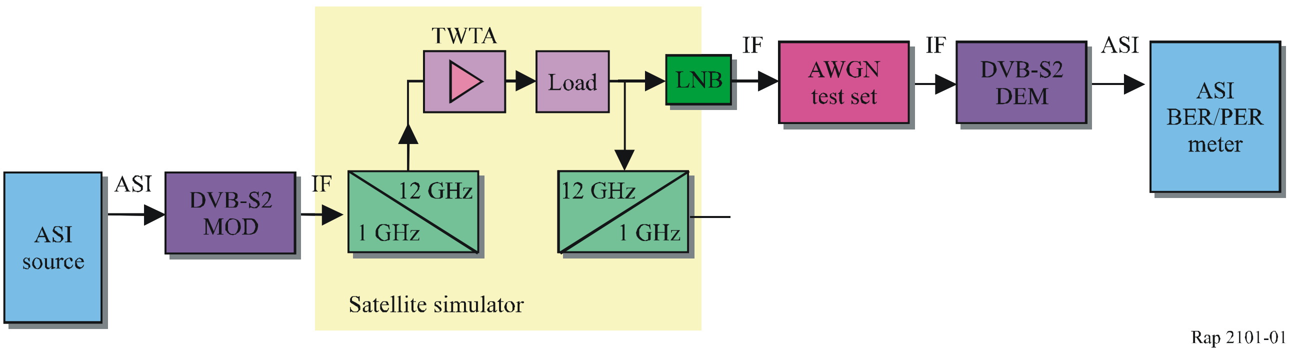
5 Laboratory set-up and basic test procedure

The laboratory performance evaluation of the DVB-S2 system is carried out by changing the parameters of the channel impairments (noise, nonlinearity, phase noise, interference) and measuring the PER at the receiver side. Additional observations on the decoded picture are carried out to verify the results.

Figure 1 shows a simplified scheme of the RAI Laboratory set-up, simulating the channel impairments. The detailed set-up for the different tests is given in Annex 1.

FIGURE 1

Block diagram of the RAI Laboratory set-up



6 Test results

6.1 AWGN test

Figures 2 to 5 show the system performance on the AWGN channel respectively for QPSK, 8-PSK, 16-APSK and 32-APSK in the normal FECFRAME configuration. The symbol rate is of 27.5 MBd,

3 In some specific cases other modulations and coding rates have been considered, and are indicated in the Report.

except for 32-APSK where it is 20 MBd[4], and the roll-off 35%. The curves are an average of the results obtained in the measurements. Implementation loss, calculated as the $\Delta E_s/N_0$@PER=10^{-7} with respect to the simulation results indicated in [1], Table 13, are in the range 0.2 to 0.6 dB for QPSK, 0.2 to 0.9 dB for 8-PSK, 0.3 to 1.3 dB for 16-APSK, 1.3 to 1.7 dB for 32-APSK.

FIGURE 2

QPSK performance on the AWGN channel (IF loop). Normal frame size and no pilots

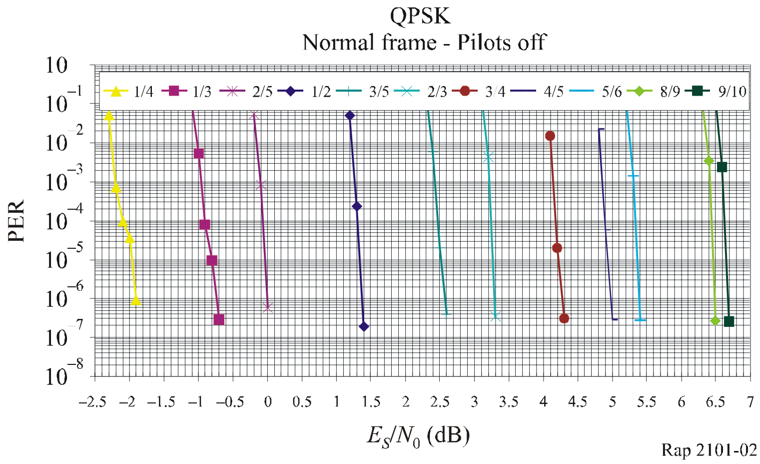


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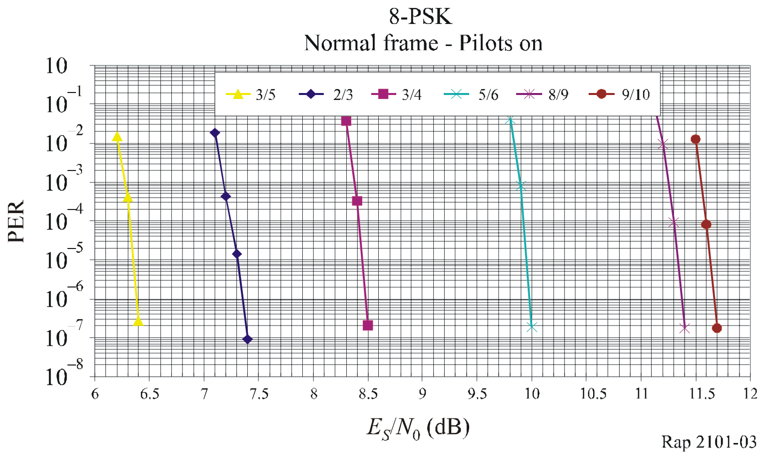
FIGURE 3

8-PSK performance on the AWGN channel (IF loop). Normal frame size and pilots



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4 Maximum symbol rate available for the 32-APSK configuration. Above 20 MBd, the equipment performance is for the time being not guaranteed, since the clock speed and/or the FPGA density do not allow to perform the required number of LDPC decoder iterations. It can be expected that improvements of FPGA technology could in the near future allow to cover at full performance extreme baud rates.

FIGURE 4

16-APSK performance on the AWGN channel (IF loop). Normal frame size and pilots

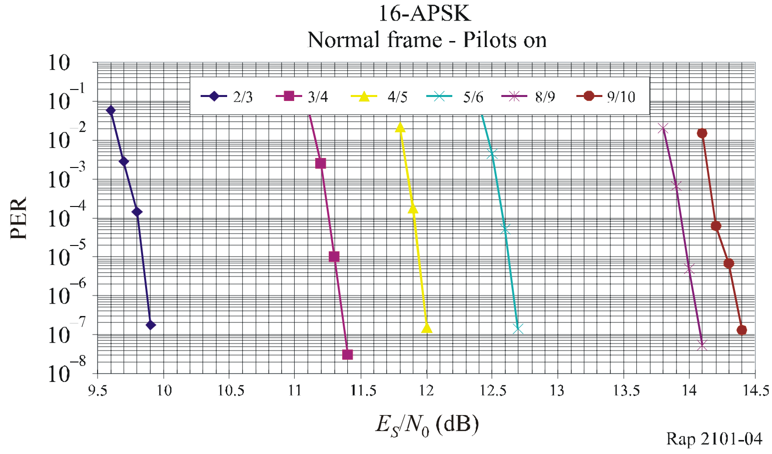
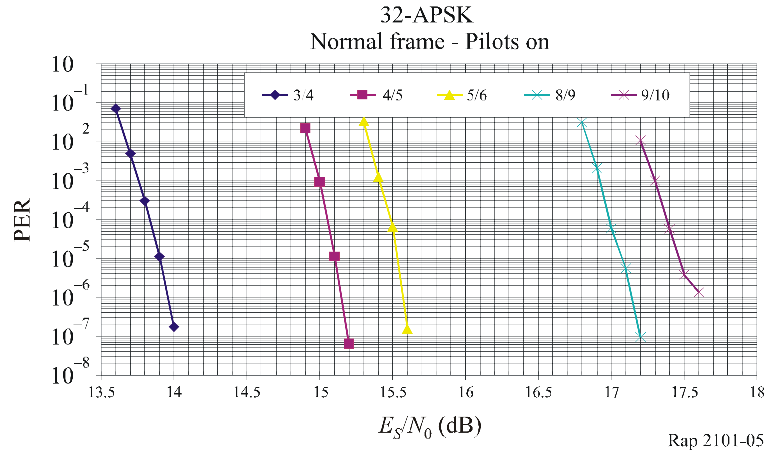


FIGURE 5

32-APSK performance on the AWGN channel (IF loop). Normal frame size and pilots



Figures 6 to 8 give the system performance in AWGN channel in the short frame mode, for the same symbol rate of the normal frame measurements. The results indicate comparable values of the implementation loss to those obtained for the normal frame case.

FIGURE 6

QPSK performance on the AWGN channel (IF loop). Short frame size and no pilots

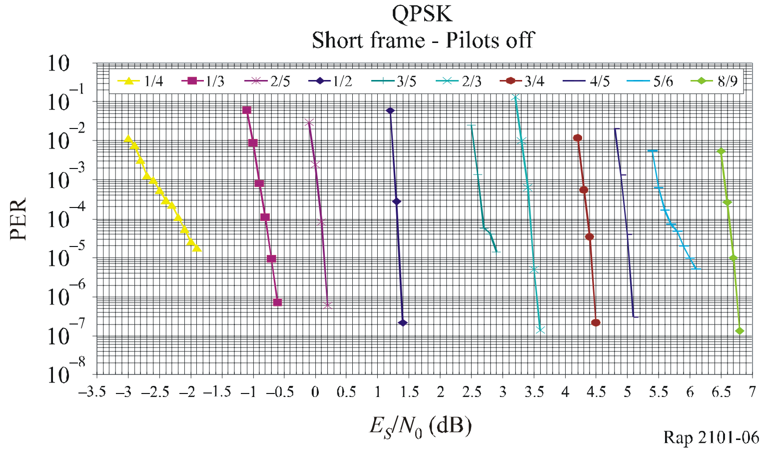


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FIGURE 7

8-PSK performance on the AWGN channel (IF loop). Short frame size and pilots

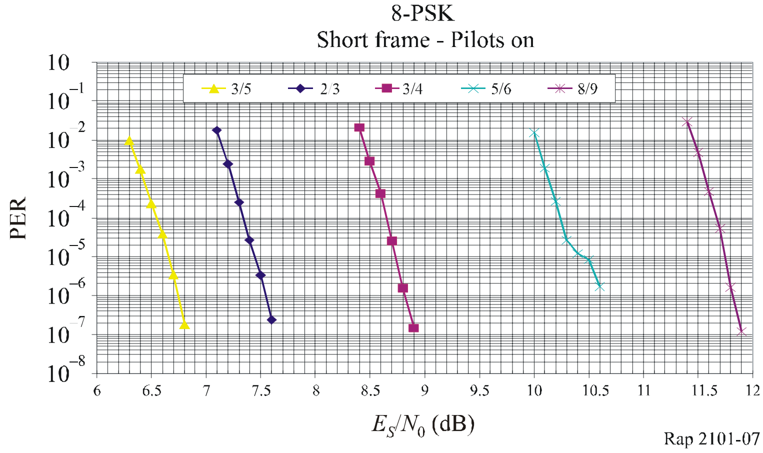

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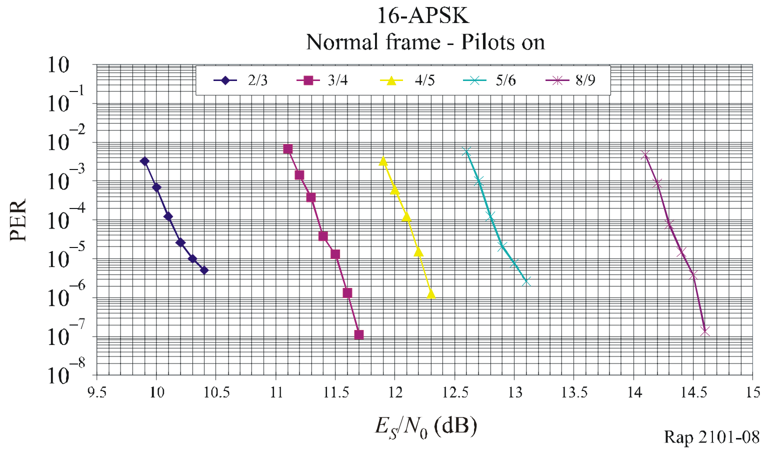
FIGURE 8

16-APSK performance on the AWGN channel (IF loop). Short frame size and pilots



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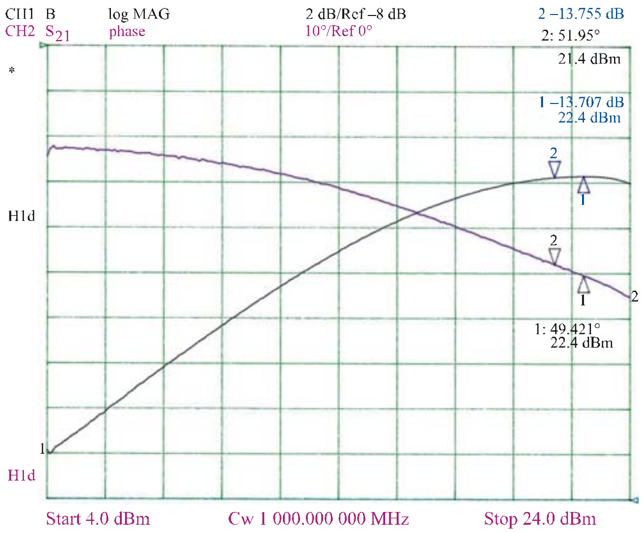
6.2 SAT test

FIGURE 9

AM/AM (amplitude/amplitude) and AM/PM (amplitude/phase) curves of the satellite simulator



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Figures 10 to 13 show the DVB-S2 system performance over the satellite transponder with the non-linear characteristics of Fig. 9, respectively for QSPK rate 1/2, 8-QPSK rate 2/3, 16-APSK rate 3/4 and 32-APSK rate 4/5. The measured symbol rate R_s is 27.5 MBd, except for 32-APSK, where it is 20 MBd, the roll-off 35% and E_{sSAT} refers to an un-modulated carrier at saturation. The figures report the measured results for the system configurations without pilots in QSPK, 8-PSK and 16-APSK, and with pilots for 32-ASPK. The lab test results confirm the simulation results as reported in [1], Table H.1. The optimum operating point is 0 dB IBO (input back-off) for QPSK1/2, corresponding to an OBO (output back-off) of 0.3 dB, and giving a performance degradation of about 0.5 dB with respect to the AWGN channel. For 8-PSK the optimum operating point is 1 dB IBO, corresponding to an OBO of 0.4 dB, and giving a performance degradation of about 0.6 dB. For 16-APSK the optimum operating point is 4 dB IBO, corresponding to an OBO of 1.6 dB, and giving a performance degradation of about 3.0 dB. For 32-APSK the optimum operating point is 7 dB IBO, corresponding to an OBO of 3.2 dB, and giving a performance degradation of about 5.4-dB. If pilots are inserted in the transmitted signal, the performance improves of about 0.3 dB for 8-PSK and 1.0 dB for 16-APSK.

FIGURE 10

QPSK rate 1/2 performance on the satellite channel for different values of the input back-off. Normal frame size without pilots

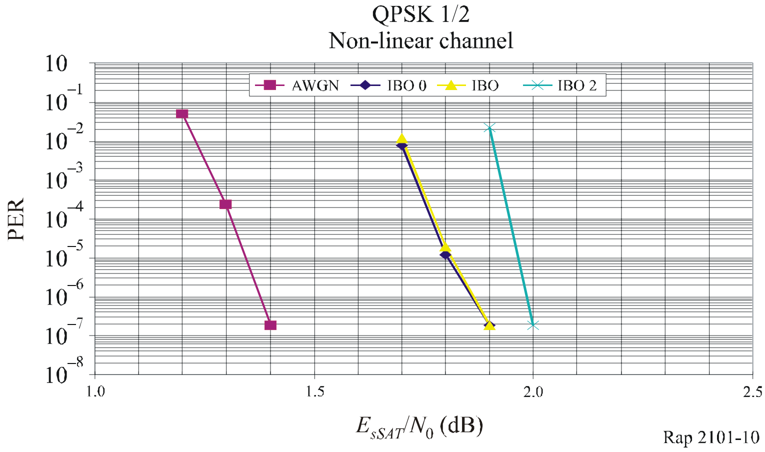

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FIGURE 11

8-PSK rate 2/3 performance on the satellite channel for different values of the input back-off. Normal frame size without pilots

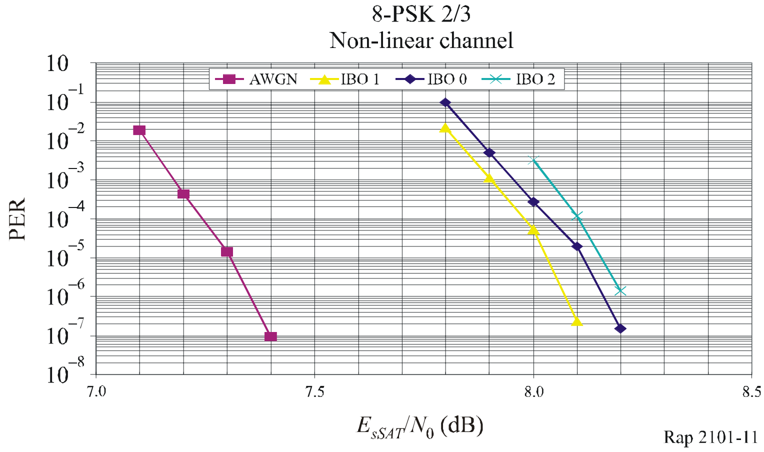

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FIGURE 12

16-APSK rate 3/4 performance on the satellite channel for different values of the input back-off. Normal frame size without pilots

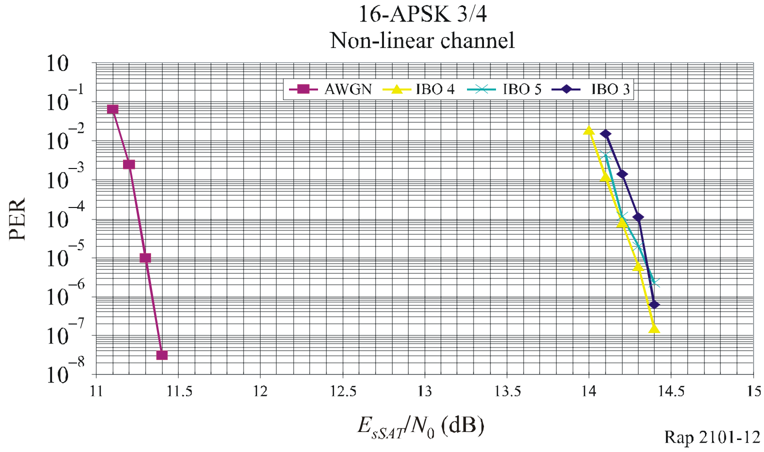

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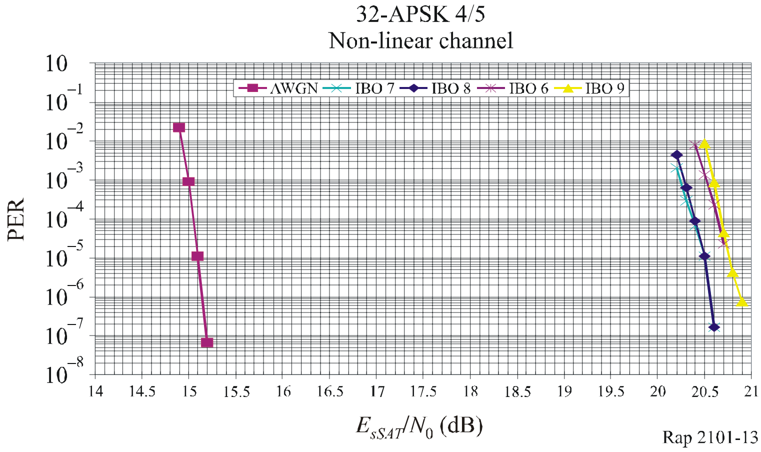
FIGURE 13

32-APSK rate 4/5 performance on the satellite channel for different values of the input back-off. Normal frame size with pilots



Figures 14 to 17 show the signal spectrum for the 4 configuration at the optimum operating point.

FIGURE 14

QPSK rate 1/2 signal spectrum at optimum operating point (IBO = 0 dB, OBO = 0.3 dB)

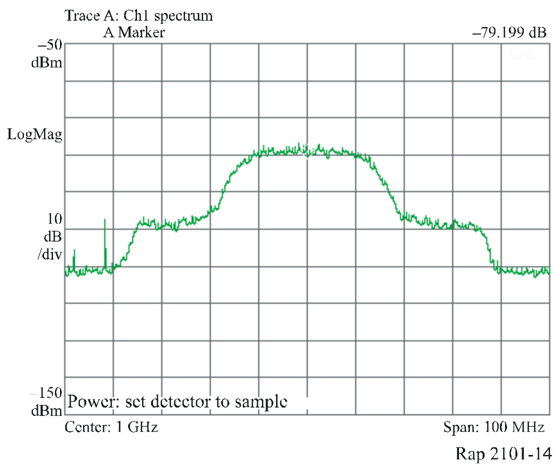


FIGURE 15

8-PSK rate 2/3 signal spectrum at the optimum operating point (IBO = 1 dB, OBO = 0.4 dB)

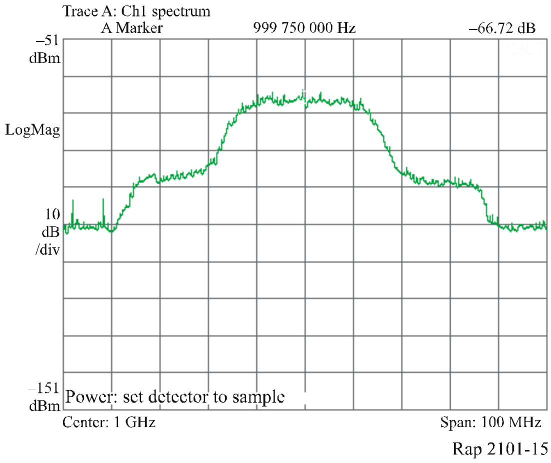


FIGURE 16

16-APSK rate 3/4 signal spectrum at the optimum operating point (IBO = 4 dB, OBO = 1.6 dB)

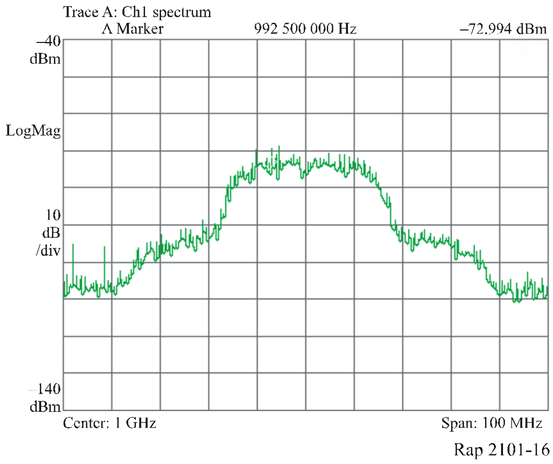
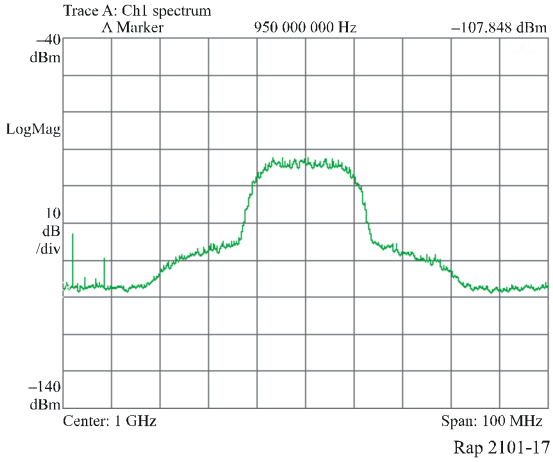


FIGURE 17

32-APSK rate 4/5 signal spectrum at the optimum operating point (IBO = 7 dB, OBO = 3.2 dB)



Additional tests have been carried out using signal precorrection in the modulator to reduce the non-linear effects on the demodulated signal and allow the system to work closer to the saturation point, also for higher order modulations, i.e. 16 and 32-APSK. Figure 18 indicates the results obtained for 16-APSK rate 3/4 for a symbol rate of 27.5 MBd and 35% roll off: the use of precorrection in the modulator allows the system to operate optimally at saturation, with a decrease of the satellite OBO of about 1.3 dB and a performance loss with respect to AWGN channel of about 1.5 dB, i.e. allowing a gain in performance with respect to the non-precorrected signal of about 1.5 dB. Figure 19 shows instead the 32-APSK received constellation after non-linear precompensation (the symbol rate is in this case of 15 MBd).

FIGURE 18

16-APSK rate 3/4 performance over the non-linear channel in presence of non-linear precorrection at the modulator side. Normal frame size and pilots

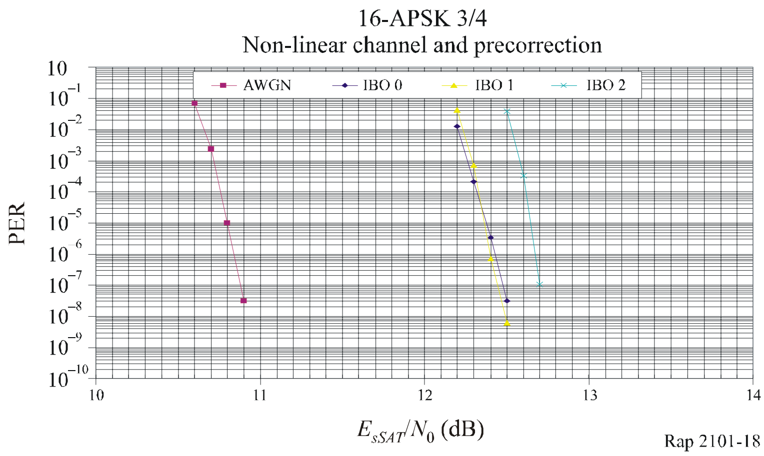
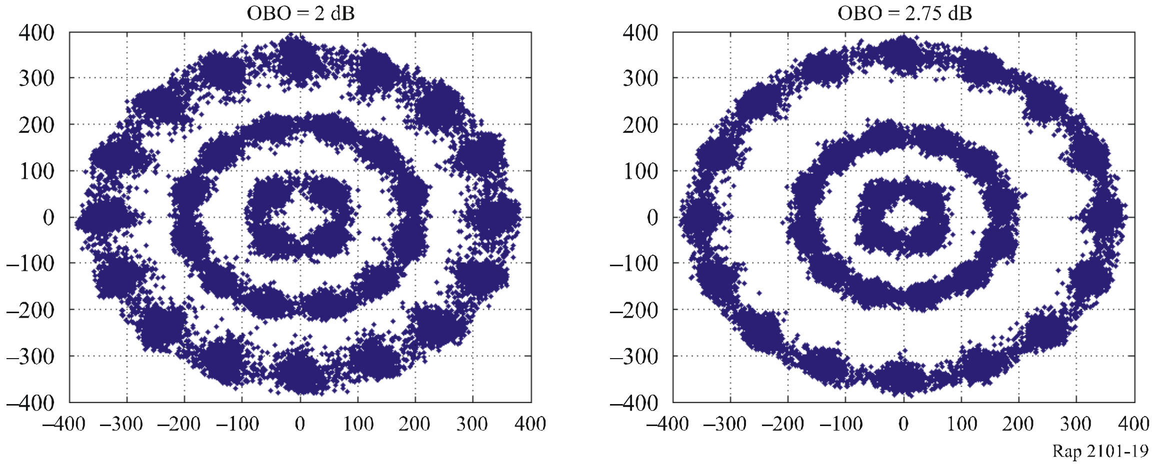


FIGURE 19

32-APSK received constellation after nonlinearity precorrection



Comparative examples of DVB-S and DVB-S2 for broadcast applications has been investigated and correspondingly tested, according to the configurations given in Table 1. The satellite channel included the travelling wave tube amplifier (TWTA) and the output multiplexer (OMUX) filter, with transfer function as shown in Fig. 20.

TABLE 1

Comparative DVB-S/DVB-S2 scenarios for broadcast applications

System	DVB-S	DVB-S2	DVB-S	DVB-S2
Channel bandwidth BW (MHz)	36	36	36	36
Modulation and coding	QPSK 2/3	QPSK 3/4	QPSK 7/8	8-PSK 2/3
Roll-off α	0.35	0.20	0.35	0.25
Symbol-rate (MBd) = 1.03 BW/(1 + α)	27.5	30.9	27.5	29.7
Useful bit-rate (Mbit/s)	33.8	46 (gain = 34%)	44.4	58.8 (gain = 32%)
C/*N* (in 27.5 MHz) (dB)@PER=10^{-7}	4.7	4.9	7.6	7.6

FIGURE 20

OMUX filter transfer function

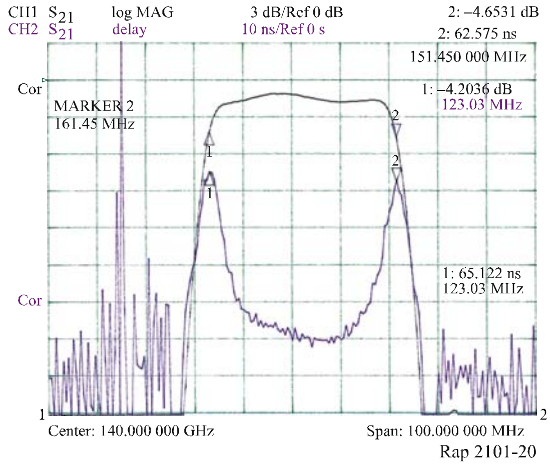


Table 1 indicate the *C*/*N* in 27.5 MHz required by the investigated systems to achieve the target PER of 10^{-7}. The results in Table 1 indicate that at the expense of a marginal increase of the *C*/*N* requirements (0 to 0.2 dB), the DVB-S2 system allows to increase the transmitted capacity, dependent upon the mode, to up to and beyond 30%.

Multiple carrier per transponder configurations have also been tested, in the following configuration: 3 carriers at 10 MBd using mode QPSK rate 1/2, 8-PSK 2/3, 16-APSK 3/4 and 32-APSK 4/5 on a linear transponder (IBO = 17 dB, OBO = 10.5 dB) in the normal fecframe configuration with pilots. The results (Fig. 21) show that for a ratio D_f/R_s (Channel spacing / symbol rate) larger that about 1.1, the performance loss due to the adjacent signal interference is of about 0.2 dB for QPSK and 8-PSK, 0.5 dB for 16-APSK and 0.8 dB for 32-APSK. If $D_f/Rs = 1$, than the degradation increases to 0.5 dB for QPSK, 1 dB for 8-PSK and 3.5 dB for 16-APSK. When moving towards the saturation the transponder operating point, the degradation increases: with QPSK rate 1/2 for 6 dB IBO (OBO = 1.6 dB), the performance loss with respect to AWGN is of about 6 dB (Fig. 25).

FIGURE 21

QPSK rate 1/2 performance in the multiple carrier per transponder configuration for different values of the frequency spacing between the carriers. Linear operating point of the transponder

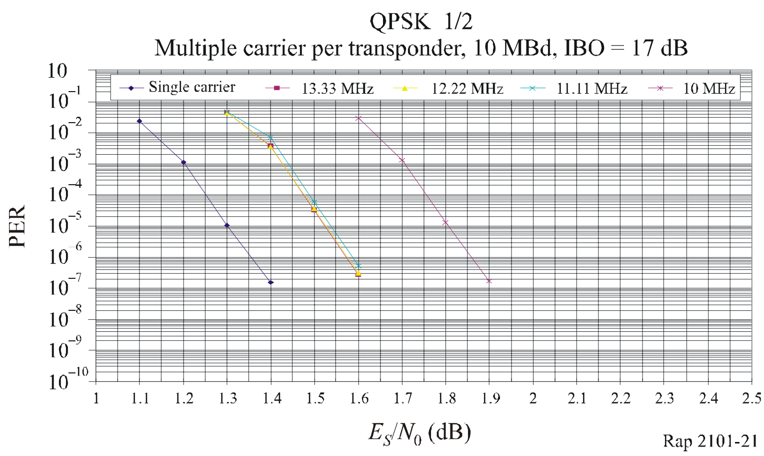


FIGURE 22

8-PSK rate 2/3 performance in the multiple carrier per transponder configuration for different values of the frequency spacing between the carriers. Linear operating point of the transponder

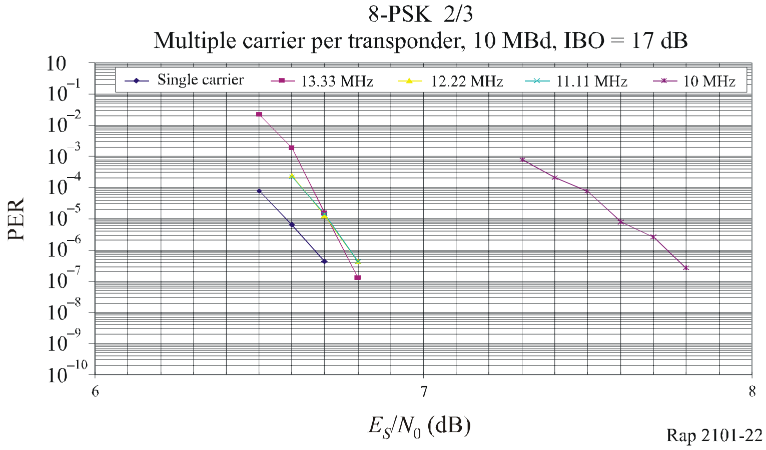


FIGURE 23

16-APSK 3/4 performance in the multiple carrier per transponder configuration for different values of the frequency spacing between the carriers. Linear operating point of the transponder

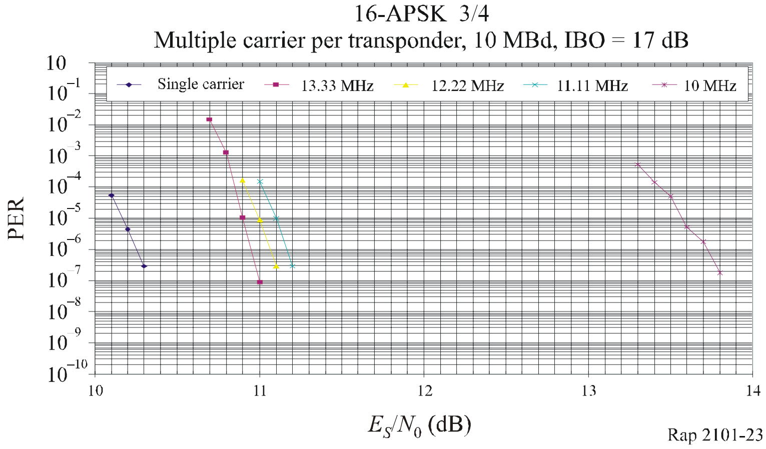


FIGURE 24

32-APSK 4/5 performance in the multiple carrier per transponder configuration for different values of the frequency spacing between the carriers. Linear operating point of the transponder

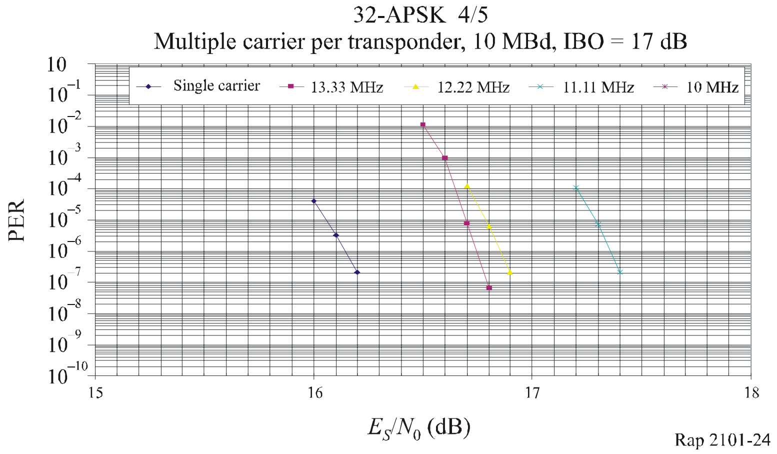
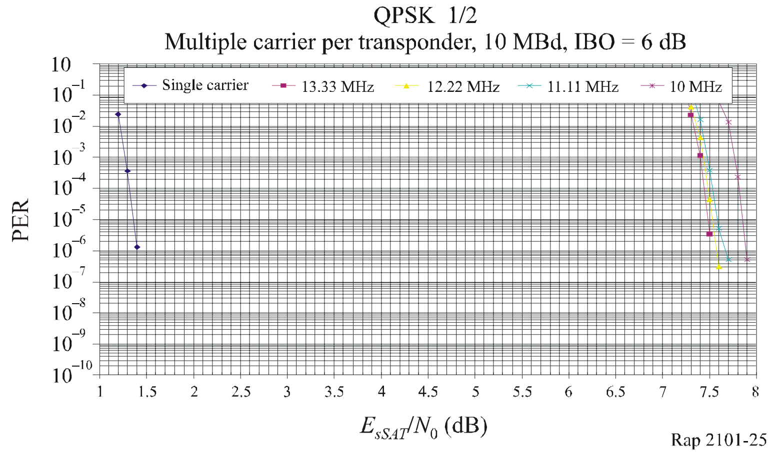


FIGURE 25

QPSK rate 1/2 performance in the multiple carrier per transponder configuration for different values of the frequency spacing between the carriers. Operating point of the transponder IBO = 6 dB



6.3 Phase noise test

Two different configurations have been considered for the phase noise tests:

– A contribution scenario, with a symbol rate of the transmitted signal of 5 MBaud and the satellite amplifier operating in linearity. In this case the SMW WDL digital type B LNB has been inserted in the test chain, with Phase noise characteristics as shown in Table 2.

– A satellite broadcasting scenario, with a symbol rate of the transmitted signal of 27.5 MBd and the satellite amplifier operating at the optimum back-off. In this case the Norsat 1000 PLL LNB has been inserted in the test chain, with Phase noise characteristics as shown in Table 2.

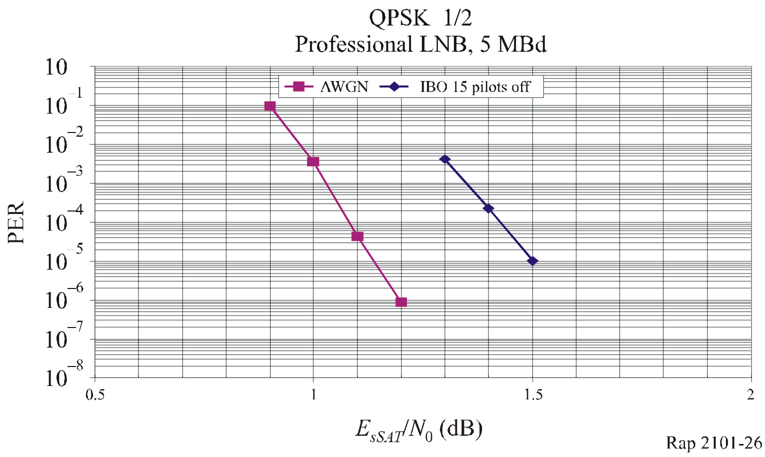
TABLE 2

Aggregate satellite simulator and receiver LNB phase noise masks

Frequency (kHz)	SMW WDL digital type B (contribution) (dBc/Hz)	Norsat 1000PLL (satellite broadcasting) (dBc/Hz)
1	–75	–65
10	–95	–75
100	–110	–85

FIGURE 26

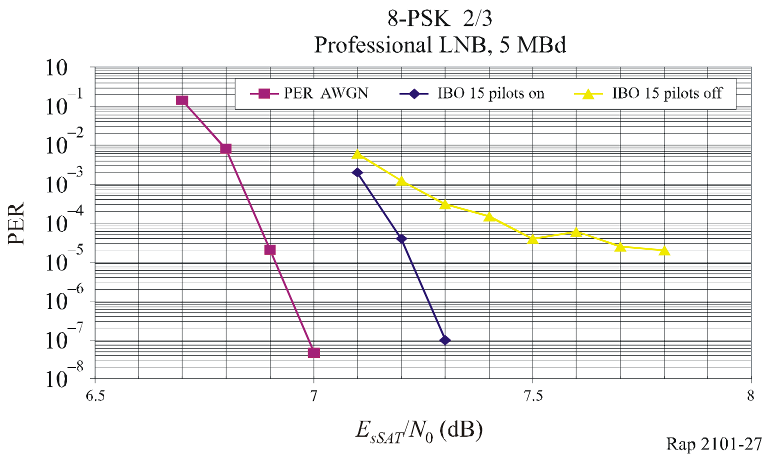
QPSK rate 1/2 performance on the satellite channel with phase noise. Contribution LNB, Symbol rate of 5 MBd, linear operating point (IBO = 15 dB)



Rap 2101-26

FIGURE 27

8-PSK rate 2/3 performance on the satellite channel with phase noise. Contribution LNB, Symbol rate of 5 MBd, linear operating point (IBO = 15 dB)



Rap 2101-27

FIGURE 28

16-APSK rate 3/4 performance on the satellite channel with phase noise. Contribution LNB, Symbol rate of 5 MBd, linear operating point (IBO = 15 dB)

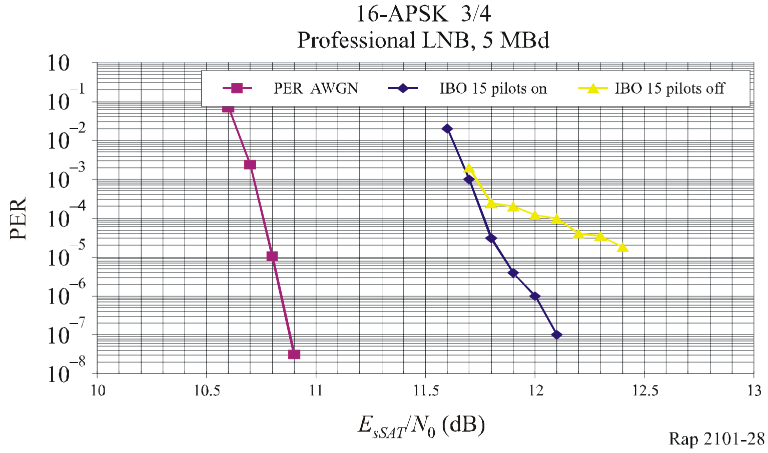
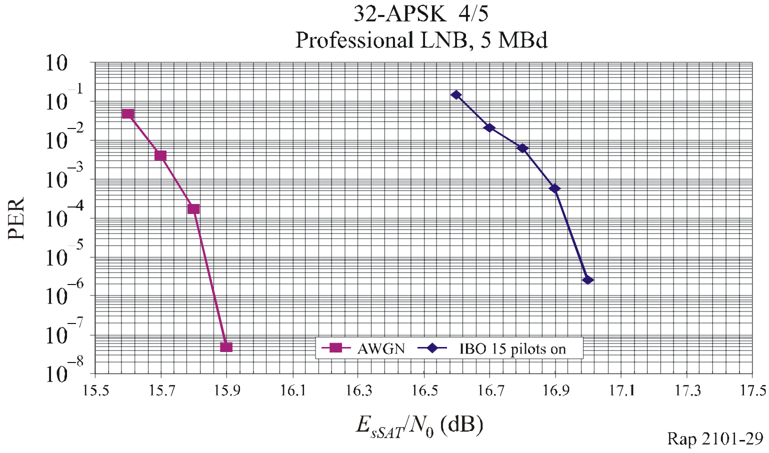


FIGURE 29

32-APSK rate 4/5 performance on the satellite channel with phase noise. Contribution LNB, Symbol rate of 5 MBd, linear operating point (IBO = 15 dB)



Results obtained for the contribution scenario indicate that the degradation introduced by the LNB Phase noise is in the order of 0.3 dB for QPSK and 8-PSK, 1.2 dB for 16-APSK and 32-APSK. Furthermore pilots are not required for QPSK, while they start to be beneficial for 8-PSK; 16-APSK and 32-APSK need pilots to give good results.

FIGURE 30

QPSK rate 1/2 performance on the satellite channel with phase noise. Satellite brodcasting scenario, Symbol rate of 27.5 MBd, optimized non-linear operating point (IBO = 0 dB)

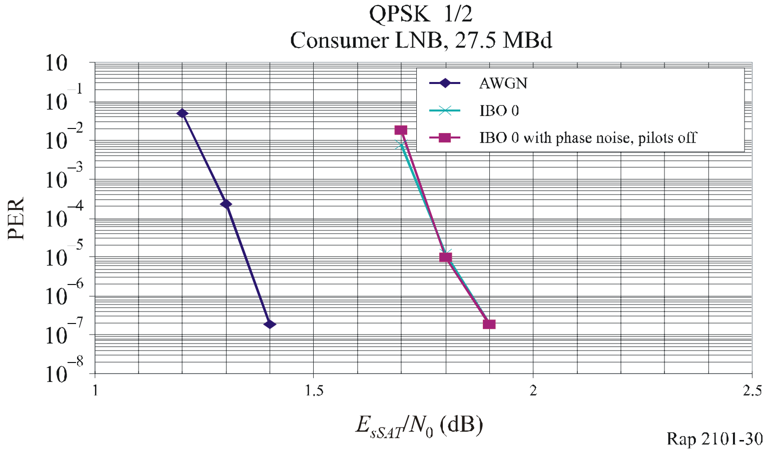


FIGURE 31

8-PSK rate 2/3 performance on the satellite channel with phase noise. Satellite brodcasting scenario, Symbol rate of 27.5 MBd, optimized non-linear operating point (IBO = 1 dB)

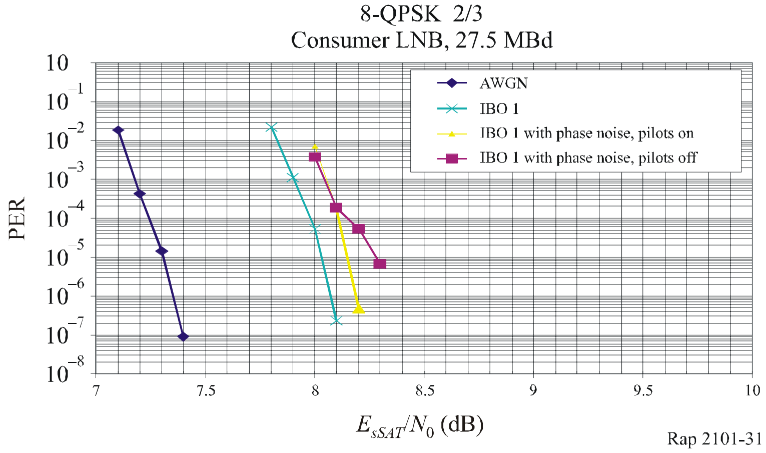
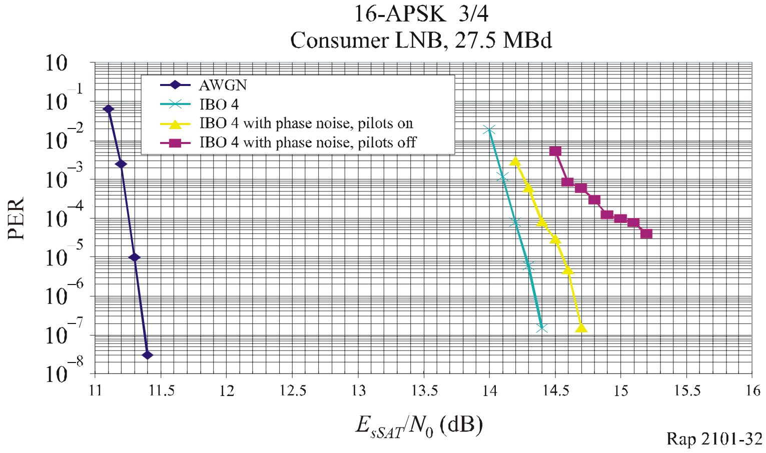


FIGURE 32

16-APSK rate 3/4 performance on the satellite channel with phase noise. Satellite brodcasting scenario, Symbol rate of 27.5 MBd, optimized non-linear operating point (IBO = 4 dB)



The satellite broadcasting scenario, with a larger symbol rate is instead much less critical with respect to phase noise. The results in Figs. 30 to 32 indicate that the degradation introduced by the LNB Phase noise is negligible for QPSK even without pilots, in the order of 0.1 dB for 8-PSK and 0.3 dB for 16-APSK with the use of pilots.

6.4 VCM and ACM tests

VCM tests have been carried out, demonstrating the receivers capability to adapt to the change of the transmission configuration. A sequence of FECFRAMEs has been generated and stored on an Arbitrary Waveform Generator. Noise was then inserted to give different values of signal to noise ratio. Provided that the signal to noise ratio was larger than the minimum requested by a specific modulation and coding, the receiver was able to decode the corresponding FECframe.

Finally ACM functionality was tested, to investigate the receivers capability to estimate the experienced signal to noise ratio, and the corresponding adaptivity of the modulator to change the modulation and coding. The results show that in a point-to-point connection the equipment is able to follow the signal to noise ratio variations and to adapt correspondingly.

7 Use of DVB-S2 by the Eurovision contribution network for HDTV transmissions of the FIFA World Cup

7.1 Background

The EBU's Eurovision network distributed the HDTV feed to Europe for the host broadcaster for the FIFA World Cup 2006. A provision of a 36 MHz space capacity (for each of the two feeds) was made on Eutelsat W3A (AB36 within TP B1, and QR36 within TPB4).

7.2 Eurovision tests and investigations

The picture format used by HBS to produce the pictures was 1050i/25. HDTV tests have been conducted by Eurovision between 29/11/2005 and 7/12/005, to determine the most appropriated parameters for the video compression.

No ITU-T H-264 encoder was available to meet the Eurovision contribution quality requirements and particularly no equipment was available on the market was able to produce MPEG-4 AVC (advanced video coding) with a 4:2:2 sampling.

Finally, the MPEG2 HL@422P profile was chosen. However, a bit rate exceeding 55 Mbits/s for the video was found to be necessary to avoid impairments on picture for critical football sequences.

7.3 Transmission parameters

In addition to the video, it was necessary to transmit a stereo sound, plus a DolbyE multiplex.

Because of the high data rate requirements, it was impossible to use DVB-S or even DVB-DSNG modulation in a 36 MHz satellite channel capacity.

Finally, DVB-S2 was adopted, with the following parameters:

Video 1080i/25	56 217 kbit/s
Audio1 (stereo)	384 kbit/s
Audio2 (Dolby E SMPTE 302M)	2 304 kbit/s
Info bitrate (188)	60 416 kbit/s
DVB-S2 MODCOD	8-PSK FEC3/4, P
Channel rate	27.7456 Msymbol/s
Roll-off factor	25%
Occupied bandwidth	34.68 MHz
Allocated bandwidth	36 MHz.

7.4 Results

Thanks to DVB-S2, the EBU has been able to increase the available bit-rate by about 40%, compared to our usual DVB-S transmission parameters. This allowed transmitting HDTV signal at contribution quality in a 36 MHz transponder, which would not otherwise have been possible. DVB-S2 equipment will continue to be extensively used on our Eurovision satellite network, using equipment from various manufacturers.

8 Other relevant information for the use of DVB-S2

Additional information regarding the use of DVB-S2 could be found in ETSI TR 102376 "Digital Video Broadcasting (DVB) – User guidelines for the second generation system for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2)". The report gives an overview of the technical and operational issues relevant to the system specified in EN 302 307 [2] "Digital Video Broadcasting (DVB): Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications", including service quality and link availability evaluation for typical DSNG and fixed contribution links, with the purpose to facilitate its interpretation.

Furthermore, in [12] a simplified analysis method is reported in order to allow the estimation of a satellite system link budget under different operating conditions (e.g. up-link EIRP, nominal TWTA input back-off, noise power density levels etc.), without the need to perform complete computer simulations or laboratory measurements.

9 Conclusions of Annex 1

This Annex reports on the results of the laboratory tests carried out by Rai-CRIT on several DVB-S2 equipments. The tests investigated the ruggedness of the system in presence of a variety of typical channel distortions, such as Gaussian, nonlinearity, receiver phase noise. Furthermore the VCM/ACM capability of the equipment has been verified.

The test results are largely in line with the performance predicted by computer simulations, and allow to gain an important insight on the characteristics of the sophisticated modulation, channel coding, framing and synchronisation techniques of the DVB-S2 system. In spite of the fact that the equipment being tested represents a first generation of equipment, and consequently some improvement of the receiver algorithms is certainly expected which will offer further enhancement in the performance, as an average, the results indicate that DVB-S2 is an excellent system, not only on paper, but also in the real hardware.

The comparison with the performance of DVB-S in operative configurations, indicate that DVB-S2 offers the promised appreciable gain in capacity both in single carrier and in multiple carrier per transponder configuration.

Finally, tests have been carried out by coupling modulators and demodulators of different manufacturers with the results that the equipment show excellent interoperability.

In addition the text describes the EBU experience with DVB-S2 in the implementation of the HDTV contribution network for the FIFA World Cup. Thanks to DVB-S2, the EBU has been able to increase the available bit-rate by about 40%, compared to our usual DVB-S transmission parameters. This allowed transmitting HDTV signal at contribution quality in a 36 MHz transponder, which would not otherwise have been possible.

Finally this Annex lists further texts giving useful guidelines for the use of the DVB-S2 system.

References

[1] ETSI. EN 302 307 (V1.1.2) – Digital Video Broadcasting (DVB). Second generation framing structure, channel coding and modulation systems for Broadcasting. Interactive Services, News Gathering and other broadband satellite applications.

[2] ETSI. TR 102 376 – Digital Video Broadcasting (DVB). User guidelines for the second generation system for Broadcasting. Interactive Services. News Gathering and other broadband satellite applications (DVB-S2).

[12] MORELLO, A. and MIGNONE, V. [Autumn, 1998] The New DVB Standard for Digital Satellite News Gathering and other contribution applications by satellite. *EBU Techn. Rev.*, http://www.ebu.ch/trev_277-morello.pdf.

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[3] *Internat. J. on Sat. Com. Networks* [May-June 2004] Vol. 22, **3**. Special issue on The DVB-S2 standard for Broadband Satellite Systems.

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[5] http://www.advantech.ca/files/534.pdf.

[6] http://www.comtechefdata.com/datasheets/ds-cdm710.pdf.

[7] http://www.eccincorp.com/ECC3100EP.pdf.

[8] http://www.newtec.be/index.php?id=119; http://www.newtec.be/index.php?id=50.

[9] http://www.scopus.net/pdf/products/UE%209217-8.pdf;
http://www.computermodules.com/pdf/IRD-2900.pdf.

[10] http://www.space.it.

[11] http://www.tandbergtv.com/public/site/Primary/productdocs62/SM6620_v5.pdf.

Appendix 1
to Annex 1

Detailed test set-up and test procedure

Performance with AWGN

Test identifier:	**AWGN** (IF-loop, L-band)
Scope:	BER/PER versus E_s/N_0 curves
Channel impairment:	AWGN

Test set-up:

IF modulator output → AWGNtestset input

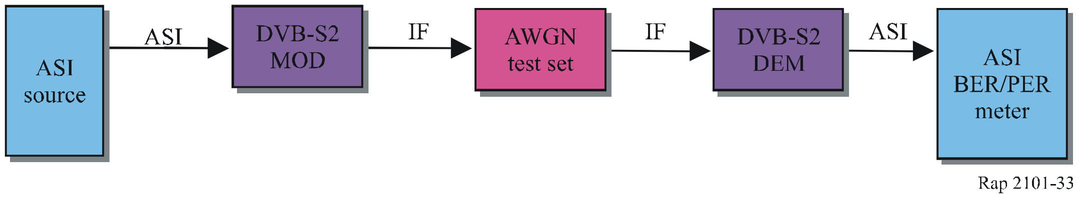
AWGNtestset output → Demodulator IF input

BER/PER meter at the demodulator output

Step	Procedure
1	Increase the E_s/N_0 ratio (measured in a bandwidth equal to the symbol rate) in 0.1 dB steps
2	Measure BER/PER
3	Draw the BER/PER versus E_s/N_0 curves (repeat Steps 1 to 2)
4	Identify $\eta_T = E_s/N_0$ @PER = 10^{-6}
5	Verify 10 min absence of errors for $E_s/N_0 = \eta_T + 0.1$

FIGURE 33

Experimental set-up for AWGN test



Performance on the satellite channel

Test identifier:	**SAT**
Scope:	BER/PER versus E_s/N_0 curves in presence of the satellite nonlinearity, for different values of the satellite operating point
Channel impairment:	AWGN and satellite nonlinearity (AM/AM and AM/PM curves in Fig. 9)

Test set-up:

IF modulator output → SatSim IF input

SatSim IF output → AWGNtestset input

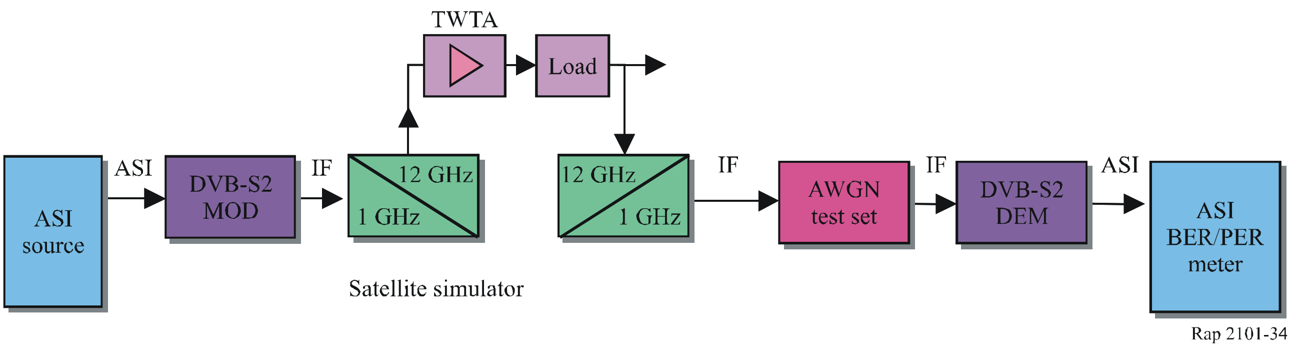
AWGNtestset output → Demodulator IF input

BER/PER meter at the demodulator output

Step	Procedure
1	Set the satellite simulator operating point at saturation with an input un-modulated carrier (IBO = 0 dB); set AWGNtestset in the track inhibit mode
2	Replace the modulated signal to the un-modulated carrier
3	Increase the E_s/N_0 ratio (measured in a bandwidth equal to the symbol rate) in 0.1 dB steps
4	Measure BER/PER
5	Draw the BER/PER versus E_S/N_0 curves (repeat Step 3 to 4)
6	Increase IBO; repeat Step 3 to 5
7	Identify opt. IBO
8	Identify $\eta_T = E_S/N_0$@PER = 10^{-6} for optimum IBO
9	Verify the absence of errors for $E_s/N_0 = \eta_T + 0.1$

FIGURE 34

Experimental set-up for SAT test



Influence of phase noise

Test identifier:	**Phase Noise**
Scope:	BER/PER versus E_s/N_0 curves in presence of different LNB phase noise profiles and satellite nonlinearity (optimum IBO, as derived from SAT test
Channel impairment:	AWGN, phase noise and satellite nonlinearity

Test set-up:

IF modulator output → SatSim IF input

SatSim RF output → LNB RF input

LNB IF output → AWGNtestset input

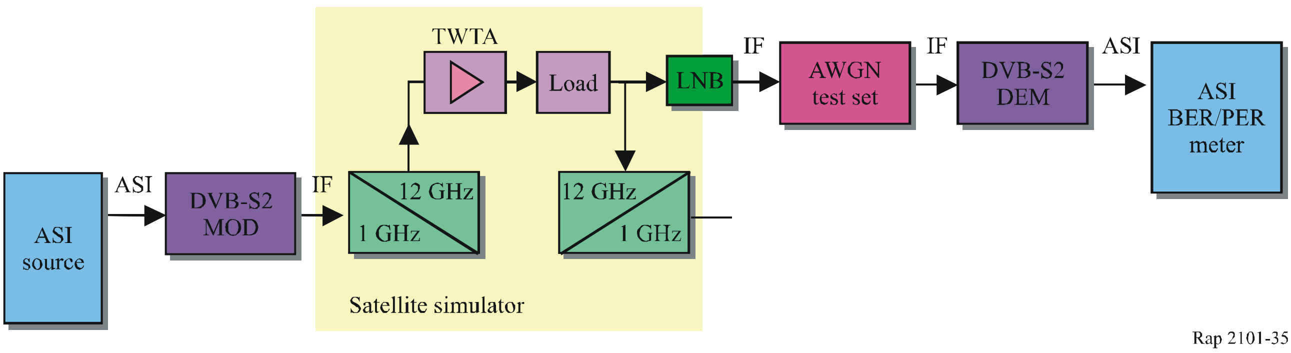
AWGNtestset output → Demodulator IF input

BER/PER meter at the demodulator output

Step	Procedure
1	Insert the LNB with desired phase noise profile (see Table 2)
2	Set the satellite operating point to optimum IBO of SAT test
3	Increase the E_s/N_0 ratio (measured in a bandwidth equal to the symbol rate) in 0.1 dB steps
4	Measure BER/PER
5	Draw the BER/PER versus E_s/N_0 curves (repeat Step 3 to 4).
6	Identify $\eta_T = E_s/N_0$ @PER = 10^{-6}
7	Verify the absence of errors for $E_s/N_0 = \eta_T + 0.1$

FIGURE 35

Experimental set-up for PhNoise test

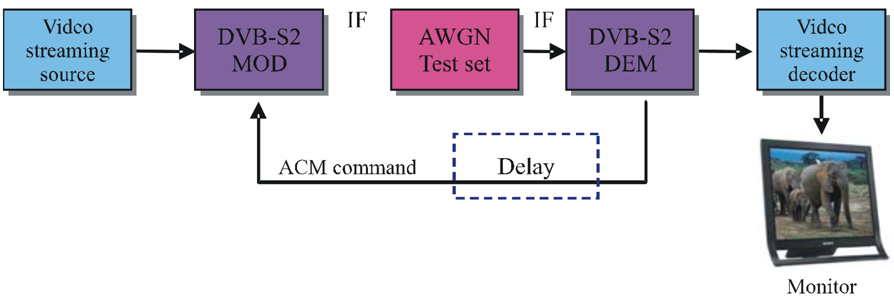


ACM performance

Test identifier		**ACM**
Scope		Equipment capability to adapt its operations to the channel variation
Channel impairment		AWGN + fading events
Test set-up: IF modulator output → AWGNtestset input AWGNtestset output → Demodulator IF input Demodulator Return channel → ACMcommand input BER/PER meter at the demodulator output		
Step	**Procedure**	
1	Set E_s/N_0 = 20 dB. The modulator is working with the higher available MODCOD	
2	Vary E_S/N_0	
3	Verify the absence of errored packets	

FIGURE 36

Experimental set-up for ACM test



Annex 2

Australian television broadcaster's tests

Australian television broadcasters have undertaken studies to investigate actual comparative performance and the implementation effects between DVB-S and DVB-S2. The tests focused on the system performance for broadcast contribution analysing DVB-SNG modem implementation margin and margin to threshold for each modulation mode.

1 Methodology used

To service television contribution requirements on the broadcasting satellite and fixed satellite systems and networks, common practice amongst the providers of satellite services is to divide a satellite transponder into a number of equal bandwidth 'slots' and apportion the transponder power accordingly, de-rated to suit the transponder characteristics for multi-carrier operation. Broadcasters or service providers then book and use these slots as required.

This study examines use of DVB-S2 modulation in this type of scenario. A 54 MHz bandwidth transponder is split into six slots of 9 MHz each. Adjacent slots may be combined for wider bandwidth / higher capacity links.

Three scenarios are investigated:

– the contribution of a high definition (HD) feed at approximately 60 Mbit/s;

– a contribution multiplex of standard definition (SD) feeds totalling approximately 40 Mbit/s; and

– the contribution of a single standard definition feed at approximately 20 Mbit/s.

Whereas both DVB-S and DVB-S2 support a variety of modulation FEC and roll-off options, to reduce these to a manageable quantity, firstly as many commercial products now offer a composite range of modulation roll-offs (alpha or excess bandwidth factor), the same factor is used for both modulation methods ($\alpha = 0.25$). Then, for each modulation and forward error correction option in each system the carrier to noise ratio in unit bandwidth and information rate were calculated. Then, the nearest options from each system were compared in each scenario.

2 System analysis

The results of the calculation of the threshold carrier to noise ratio (in unit bandwidth and in the channel noise bandwidth) and information rate for each modulation and FEC option in each system are provided in Annex A. The threshold points are defined in each standard for quasi error free (QEF) performance and calculations were derived from:

– For DVB-S, E_b/N_0 for BER = 2×10^{-4} after Viterbi decoding, and applying implementation margins as listed in Table 3 of ETSI EN 300 421 V1.1.2 [1].

– For DVB-SNG, E_b/N_0 for BER = 2×10^{-4} after Viterbi decoding and, and applying implementation margins as listed in Table 5 of ETSI EN 301 210 V1.1.1 [2].

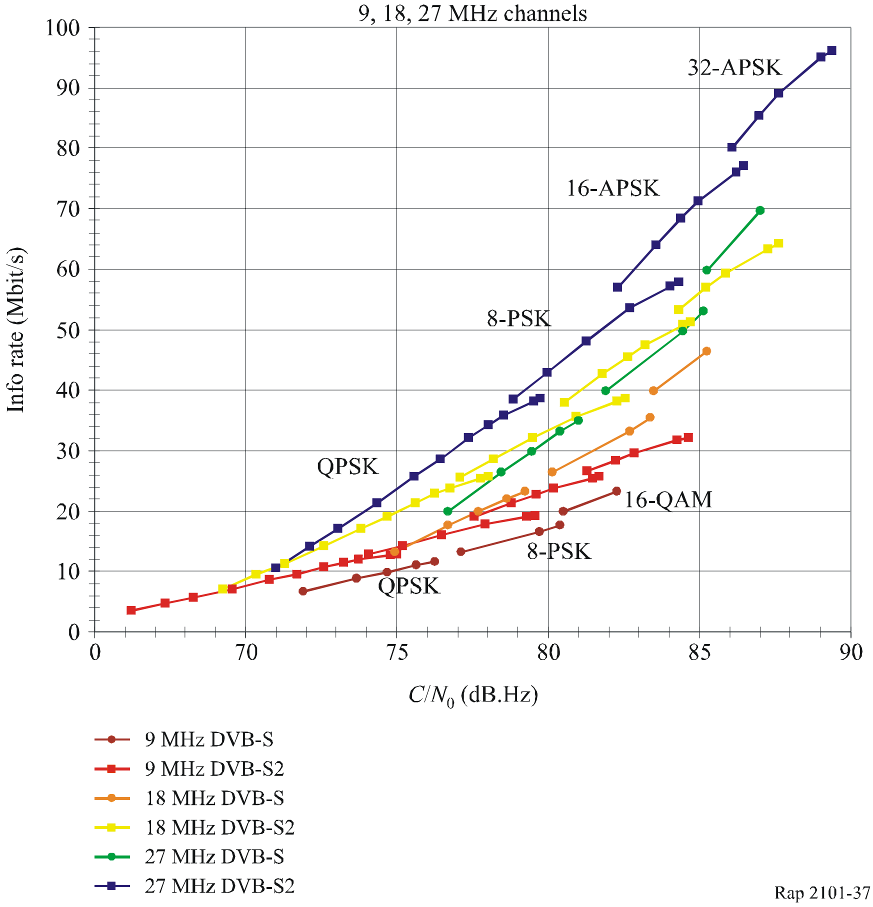
– For DVB-S2, E_s/N_0 for transport stream PER = 10^{-11} as listed in Table 13 of ETSI EN 302 307 V1.1.2 [3].

Implementation margins for DVB-S have been removed from the calculation of the threshold performance to make the comparison of systems on the same basis. The DVB-S2 option used was for normal frame size with no pilot tones.

The calculated results are illustrated in Figs. 37 and 38. It should be noted that when plotting C/N_0 the systems overlap in the lower bit-rate regions, indicating that use of reduced transponder capacity might be possible. At higher bit-rates, the curves diverge, indicating that a link margin benefit is possible. The selection of the three scenarios aims to confirm if these benefits are realised in practical tests.

FIGURE 37

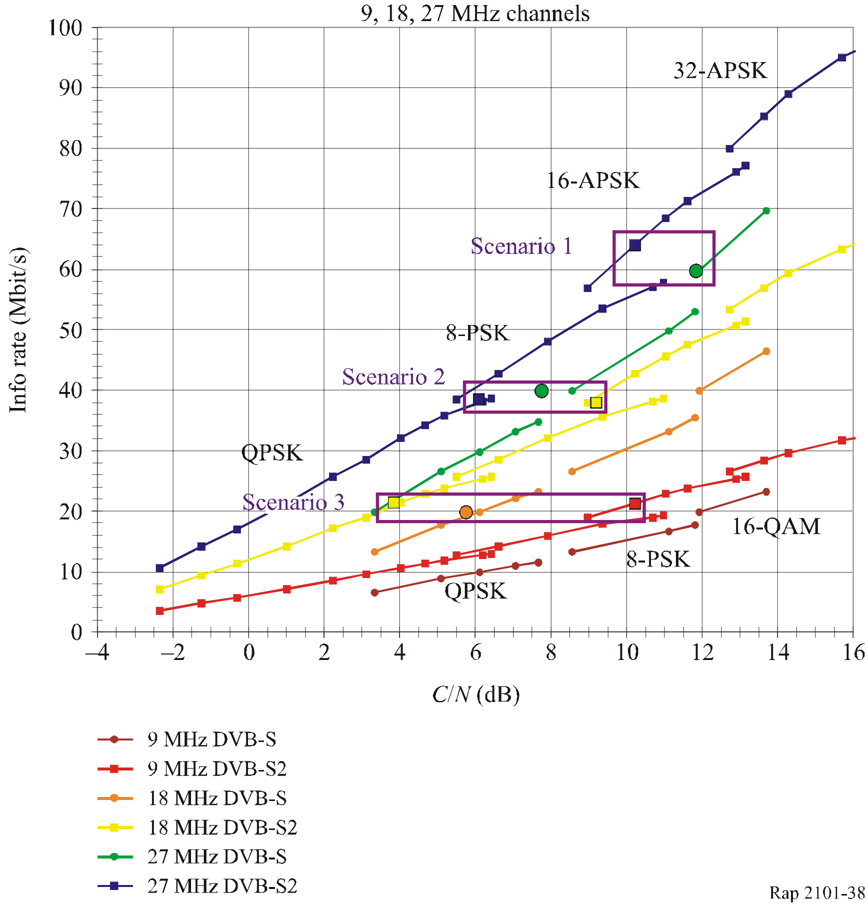
Calculated C/N_0 vs information rate



Measurement results from the intermediate frequency (IF) loop tests (refer § 4) are shown as individual points on the *C*/*N* plot, colour coded in the same manner as the specification curves. Refer to § 5 for a description of the scenarios.

FIGURE 38

Calculated *C*/*N* vs information rate and IF measured results



3 Intermediate frequency loop test results

3.1 Methodology

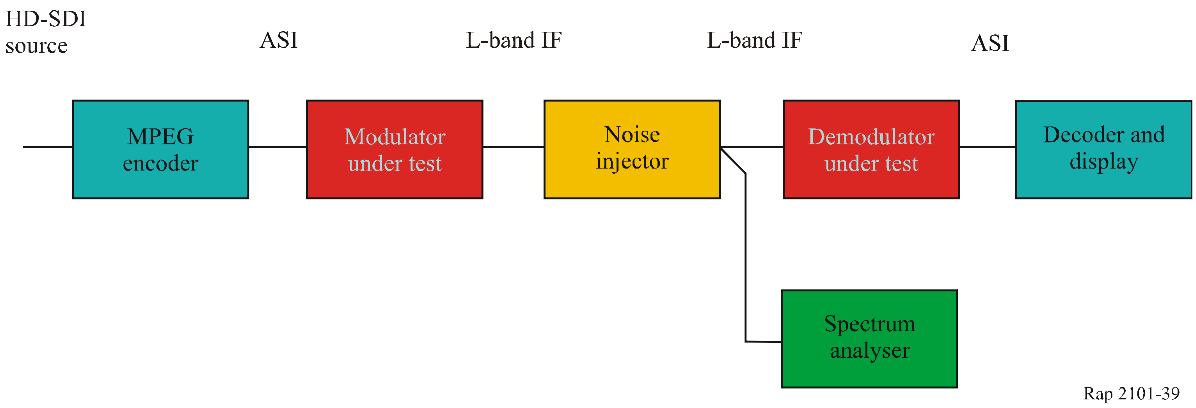
The modulators and demodulators under test were connected as shown in Fig. 39. It would have been preferable to use a pseudo random binary sequence generator and analyser to determine threshold performance, however these devices were not available when the tests were conducted. Therefore, in each case a single MPEG-2 service was passed through the system at a transport stream rate just below the maximum rate capable of the modulation mode. AWGN was injected in the L-band IF path and the video signal monitored for impairments. As noise levels were increased a spectrum analyser was used to note the noise and signal level of the carrier using the internal band power function and recordings from each demodulator were noted either as E_s/N_0, E_b/N_0 or C/N depending on the device under test (DUT).

In some instances, the demodulator readouts provided an estimation of BER or PER. In these cases, threshold performance was taken to be where the DUT estimated BER/PER corresponded to the QEF error rate from the relevant ESTI specification. Where this data was not available, threshold performance was taken to be the highest noise level where no video impairments were noticed after viewing for at least 30 s. Due to the large number of measurements to be taken, a longer viewing time was not possible in practice.

Therefore for each measurement, a result has been derived from spectrum analyser measurements and the DUT.

FIGURE 39

IF test setup



3.2 Test results

The results are plotted in Fig. 39 against their relevant computed specification whilst in Fig. 40 the differences of the measured results and demodulator readings against specification are plotted.

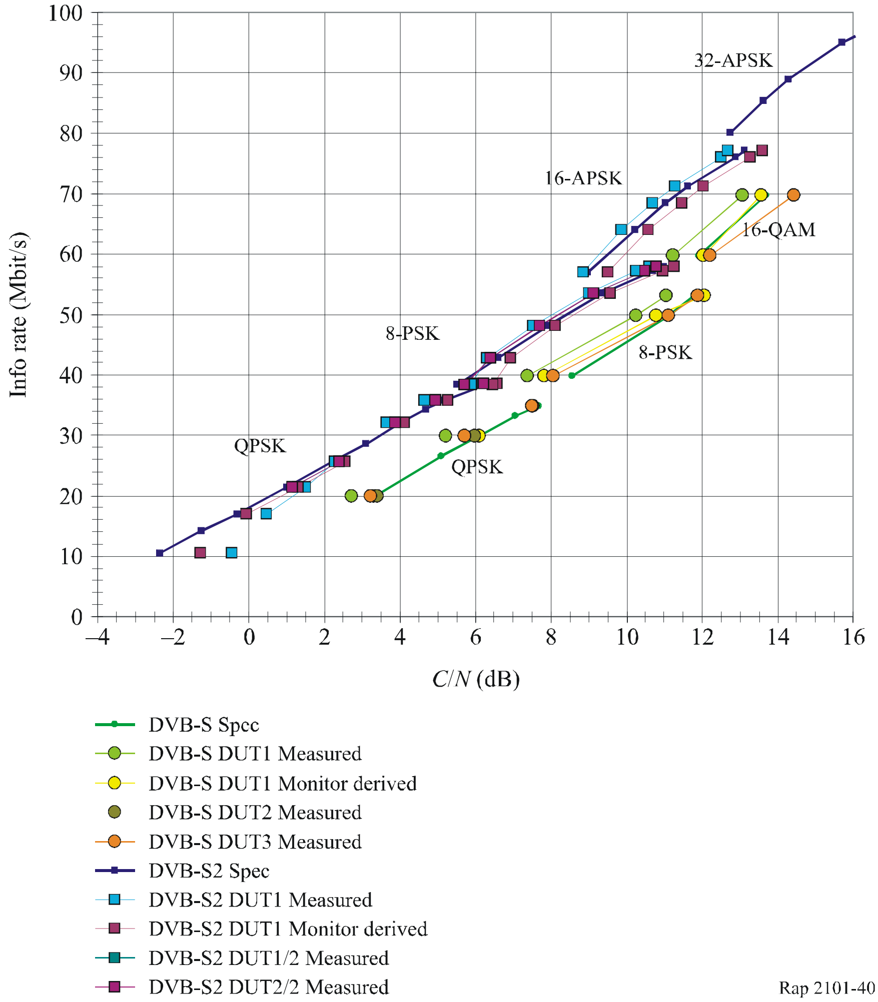
The average of measured results for DVB-S2 are generally 0 dB to 0.2 dB better than specification, except for cases where a low FEC (less than 3/5) was used. Results for QPSK 1/4, where the C/N is less than 0 dB, it was noted that the signal level had to be increased considerably more than other configurations to obtain an error free picture. Note should also be made that the results for the lowest FEC in each modulation scheme seemed to increase compared with other measurements (the curl effect in Fig. 40).

In general it was noted that the degradation region of C/N between a usable picture to total loss of signal was much less for DVB-S2 than DVB-S (i.e. the "digital cliff effect" is much steeper for DVB-S2). For DVB-S, from the first noticeable picture error to loss of signal was a C/N reduction of approximately 1 dB with a gradual increase in errors as the C/N reduced, providing an indication of an impending link failure. On recovery of the C/N, the picture recovered in the same manner. For DVB-S2, a C/N reduction of 0.2 dB reduced the signal from error free pictures to total loss of signal. On recovery, however it was noted that the C/N had to increase between 1 dB and 2 dB before the decoders recovered to lock and pictures restored. The anomalous results (for low FEC) mentioned above, the picture became slightly degraded (occasional line "flashing" noted) for an extended region before the rapid failure point, so the resultant threshold point was a higher C/N.

The anomaly for these low QPSK FEC cases was further investigated by turning on the pilot tones to see if this would assist demodulator performance at low C/N_s. However, the results were the same or slightly worse than with pilots off.

FIGURE 40

IF loop measured results in a 27 MHz channel*

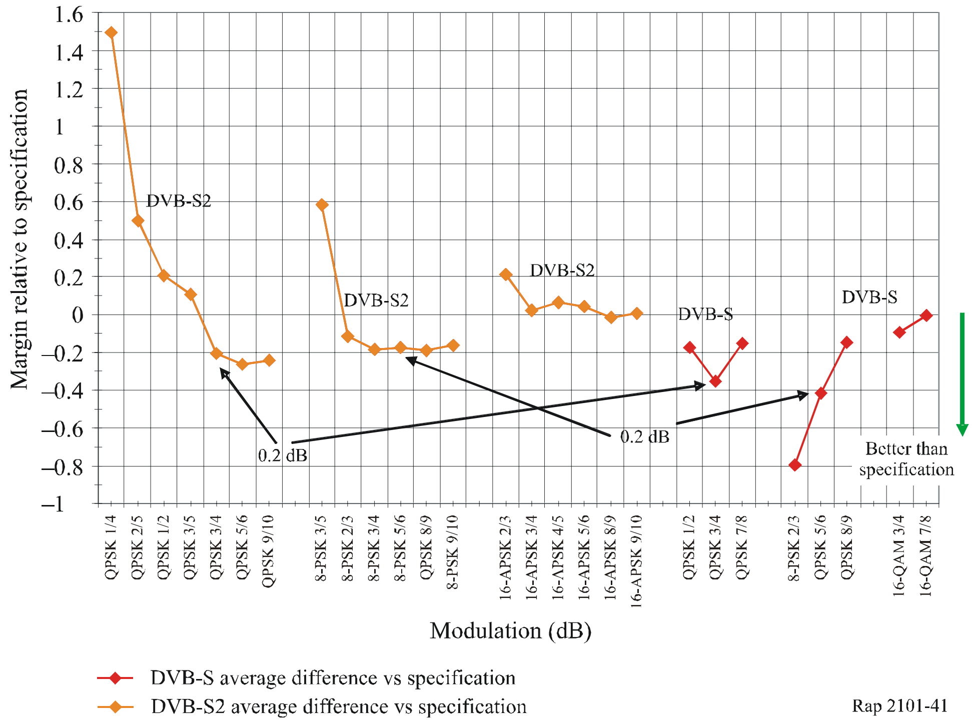


* "Measured" are results from spectrum analyser measurements, "Monitor derived" are based on readouts from the DUT display at QEF point.

Note that in Fig. 40, the measurements for DVB-S2 lie on or around the specification curve, while for DVB-S they are mostly to the left of their specification. As indicated in Fig. 41, the average of measured results for DVB-S varied up to 0.8 dB better than specification. It is important to note that for DUT1 the threshold point was estimated for the DVB-S2 measurements (based on a visual error free picture), but for DVB-S, it was based on the demodulator BER estimation for QEF. For other demodulators the DUT BER/PER estimation for QEF was used to determine the threshold point.

FIGURE 41

Measured margins vs specification



A comparison of DVB-S modulation/FEC with its nearest equivalent DVB-S2 modulation/FEC revealed the DVB-S demodulators were working approximately 0.2 dB better than their DVB-S2 counterparts when compared with their specified thresholds. This is indicative of a product which includes enhancements such as error concealment, whereas these enhancements may not yet have been developed for DVB-S2 product. Irrespective of how this difference is considered, as it is a relative measurement between the systems, the benefits of DVB-S2 over DVB-S are reduced by 0.2 dB.

Further investigation on this topic is recommended.

4 Multi-carrier occasional use scenario analysis

4.1 High bit rate scenario (HD)

Australian television broadcasters have commenced broadcasts in high definition of live sporting events, requiring high definition contribution circuits. Tests conducted on three sports, Australian Football League (“Australian Rules”), cricket and swimming championships have determined that the minimum acceptable contribution performance is a transport stream with MPEG-2 HL@422P profile video at approximately 56 Mbit/s, plus accompanying multi-channel audio Dolby E and Lt Rt mixdown audio components, in a transport stream totalling 60 Mbit/s. This aligns with investigations of the Eurovision tests and investigations as reported to ITU-R for the World Cup in 2006.

As DVB-S2 decoders capable of 32-APSK are not yet available, this preliminary study was undertaken starting with the 60 Mbit/s requirement, this is met by DVB-S operating in a 27 MHz channel at 16-QAM 3/4 FEC and DVB-S2 operating in a 27 MHz channel at 16-APSK 3/4 FEC. Key parameters are in Table 3.

TABLE 3

60 Mbit/s comparison

Carrier details					Specification/calculated					Average measured
System	Modulation	FEC	Band-width (MHz)	Info. rate (MBit/s)	QEF E_b/N_0 (dB.Hz)	Imple. margin (dB)	Ideal E_s/N_0 (dB.Hz)	C/N_0 (dB.Hz)	C/N See Note 1 (dB)	C/N See Note 1 (dB)
DVB-S	16-QAM	3/4	27	59.72	9.0	1.5		85.26	11.92	11.82
DVB-S2	16-APSK	3/4	27	64.08			10.21	83.55	10.21	10.24
S2 Adv.			0	4.36				–1.71	–1.71	–1.59

NOTE 1 – The calculated C/N values are taken from Tables 6 and 7 in the Appendix 1 to Annex 2. Average measured C/N values are from measured results.

As both systems use the same bandwidth, there will be no change in the transponder capacity required for the feed. DVB-S2 offers an additional 4.36 Mbit/s of information rate, but at these HD video encoding rates, this will offer no or imperceptible improvement in video performance. However DVB-S2 also offers 1.7 dB of additional margin. This will benefit situations where the link is constrained, for example a satellite news gathering uplink that is operating at its power limit, or where system intermodulation products limit performance. Based on the measured results, this margin benefit reduces slightly to 1.6 dB.

4.2 Mid bit rate scenario (SD multiplex)

At mid bitrates, parameter selections have been made where the carrier-to-noise ratios of each system are approximately the same with an information rate approximating 40 Mbit/s. Key parameters are in Table 4.

TABLE 4

40 Mbit/s comparisons

Carrier Details					Specification / Calculated					Average Measured
System	Modulation	FEC	Band-width (MHz)	Info. rate (MBit/s)	QEF E_b/N_0 (dB.Hz)	Imple. margin (dB)	Ideal E_s/N_0 (dB.Hz)	C/N_0 (dB.Hz)	C/N See Note 1 (dB)	C/N See Note 1 (dB)
DVB-S	8-PSK	2/3	27	39.81	6.9	1.0		81.90	8.56	7.76
DVB-S2	16-APSK	2/3	18	37.98			8.97	80.55	8.97	9.19
S2 Adv.			9	–1.84				–1.35	0.41	1.42
DVB-S	8-PSK	2/3	27	39.81	6.9	1.0		81.90	8.56	7.76
DVB-S2	8-PSK	3/5	27	38.45			5.50	78.84	5.50	6.08
S2 Adv.			0	–1.36				–3.06	–3.06	–1.68

NOTE 1 – The calculated C/N values are taken from Tables 6 and 7 in the Appendix 1 to Annex 2. Average measured C/N values are from measured results.

In this case, the first DVB-S2 link uses two thirds of the bandwidth of the DVB-S link and hence requires less transponder capacity. This benefit is at a slight penalty to the information rate, reducing by 1.84 Mbit/s of data rate, which if the multiplex was carrying two SD MPEG-2 video services would be an imperceptible change. DVB-S2 offers an additional C/N_0 margin, but after accounting for bandwidth, there is a slight increase required in C/N. In this mid bitrate region, all other factors being the same, the benefit is demonstrated by a bandwidth reduction. Based on the measured results, the C/N required increased to 1.4 dB.

The second DVB-S2 comparison uses the same bandwidth, but offers a 3.1 dB *C*/*N* improvement. Based on the measured results, the *C*/*N* improvement reduces to 1.7 dB. The anomaly here may be due to the curl effect noted above. Further investigation of this effect is required to confirm if this is due to phase noise at some point in the system.

4.3 Low bit rate scenario (SD)

At lower bitrates, in Fig. 37 the curves for DVB-S (18 MHz) and DVB-S2 (9 MHz) coincide, which leads to a comparison of performance at approximately 20 Mbit/s. Key parameters are in Table 5.

TABLE 5

20 Mbit/s comparisons

Carrier Details					Specification / Calculated					Average Measured
System	Modulation	FEC	Band-width (MHz)	Info. rate (MBit/s)	QEF E_b/N_0 (dB.Hz)	Imple. margin (dB)	Ideal E_s/N_0 (dB.Hz)	C/N_0 (dB.Hz)	C/N See Note 1 (dB)	C/N See Note 1 (dB)
DVB-S	QPSK	3/4	18	19.91	5.5	0.8		77.69	6.11	5.75
DVB-S2	16-APSK	3/4	9	21.36			10.21	78.78	10.21	10.24
S2 Adv.			9	1.45				1.09	4.10	4.48
DVB-S	QPSK	3/4	18	19.91	5.5	0.8		77.69	6.11	5.75
DVB-S2	QPSK	3/4	18	21.42			4.03	75.61	4.03	3.83
S2 Adv.			0	1.51				–2.08	–2.08	–1.93

NOTE 1 – The calculated *C*/*N* values are taken from Tables 6 and 7 in the Appendix 1 to Annex 2. Average measured *C*/*N* values are from measured results.

In this case, the first DVB-S2 link uses half the bandwidth of the DVB-S link and hence requires half the transponder capacity. DVB-S2 offers an additional 1.45 Mbit/s of data rate, but at these SD MPEG-2 video encoding rates, this will offer no or imperceptible improvement in video performance. However, DVB-S2 requires an additional C/N_0 margin of 1.1 dB, or 4.1 dB of link *C*/*N* as the use of half the bandwidth implies that half the transponder power is available for the link. Hence there is a significant benefit, but this may be realised only in situations where there is excess link margin already, for example where large uplink and downlink antennas are used. Based on the measured results, the *C*/*N* required increased to 4.5 dB.

The second DVB-S2 comparison uses the same bandwidth, but offers a *C*/*N* improvement of 2.1 dB. Based on the measured results, the improvement reduces slightly to 1.9 dB.

5 Conclusions of Annex 2

Tests have been undertaken (at an IF loop point) to determine the comparative performance of DVB-S and DVB-S2 systems. The performance of each system has been compared to specification, normalised on an equitable basis by removing the implementation margin from the DVB-S specification. Analysis of the systems providing occasional use feeds operating in a multi-carrier transponder has been completed.

The results indicate that DVB-S2 demodulators are able to operate at or near specification, but that DVB-S demodulators are able to operate on average comparatively 0.2 dB better than specification.

The comparison of a new modulation system indicate that the realisation of potential benefits for occasional use feeds vary depending upon the information rate of the desired contribution link. For low rate contribution links, transponder capacity may be considerably reduced, but this comes at a considerable cost of link margin. In the mid rate contribution links, theoretically it appears that savings may be made in transponder capacity whilst providing a similar information rate at a similar link margin, however based on the measured results this benefit is offset by lowering the available *C*/*N* margin. At higher rate links, no savings are made in transponder capacity, but margins are enhanced slightly offering a more robust link.

Given the varying degree of benefit, and the finding that DVB-S operates better than specification, where the benefit of a new modulation system is expressed in *percentage* terms it should be qualified by the set of bandwidth, modulation and error correction parameters of the comparison.

6 Further studies

Further studies are proposed by undertaking comparative tests on operational satellites to confirm that the measured differences are representative of actual systems with non-linearities in amplitude and phase.

References

[1] ETSI. EN 300 421 (V1.1.2) – Digital Video Broadcasting (DVB). Framing structure, channel coding and modulation for 11/12 GHz satellite services.

[2] ETSI. EN 301 210 (V1.1.1) – Digital Video Broadcasting (DVB). Framing structure, channel coding and modulation for Digital Satellite News Gathering (DSNG) and other contribution applications by satellite.

[3] ETSI. EN 302 307 (V1.1.2) – Digital Video Broadcasting (DVB). Second generation framing structure, channel coding and modulation systems for Broadcasting. Interactive Services, News Gathering and other broadband satellite applications.

Appendix 1
to Annex 2

Calculated results

1 DVB-S/SNG parameters

Table 6 lists the carrier to noise ratio (in unit bandwidth and in the channel noise bandwidth) and user information rate for each modulation option, calculated from Specifications ETSI EN 300 421 V1.1.2 [1] and ETSI EN 301 210 V1.1.1 [2], after removing the implementation margin listed in the specifications. Three channel bandwidth options are provided and the modulation roll-off factor set to $\alpha = 0.25$.

TABLE 6

DVB-S

Channel bandwidth			9 MHz		18 MHz		27 MHz	
Symbol rate			7.2 Msymbol/s		14.4 Msymbol/s		21.6 Msymbol/s	
Modulation	FEC	*C*/*N* (dB)	*C*/*N*$_0$ (dB.Hz)	Info. rate (Mbit/s)	*C*/*N*$_0$ (dB.Hz)	Info. rate (Mbit/s)	*C*/*N*$_0$ (dB.Hz)	Info. rate (Mbit/s)
QPSK	1/2	3.35	71.92	6.635	74.93	13.271	76.69	19.906
QPSK	2/3	5.09	73.67	8.847	76.68	17.694	78.44	26.541
QPSK	3/4	6.11	74.68	9.953	77.69	19.906	79.45	29.859
QPSK	5/6	7.06	75.64	11.059	78.65	22.118	80.41	33.176
QPSK	7/8	7.68	76.25	11.612	79.26	23.224	81.02	34.835
8-PSK	2/3	8.56	77.13	13.271	80.14	26.541	81.90	39.812
8-PSK	5/6	11.12	79.70	16.588	82.71	33.176	84.47	49.765
8-PSK	8/9	11.80	80.38	17.694	83.39	35.388	85.15	53.082
16-QAM	3/4	11.92	80.49	19.906	83.50	39.812	85.26	59.718
16-QAM	7/8	13.69	82.26	23.224	85.27	46.447	87.03	69.671

2 DVB-S2 parameters

Table 7 lists the carrier to noise ratio (in unit bandwidth and in the channel noise bandwidth) and user information rate for each modulation option, calculated from Specifications ETSI EN 302 307 V1.1.2 [3] for a normal frame with no pilots. Three channel bandwidth options are provided and the modulation roll-off factor set to $\alpha = 0.25$.

TABLE 7

DVB-S2

Channel bandwidth			9 MHz		18 MHz		27 MHz	
Symbol rate			7.2 Msymbol/s		14.4 Msymbol/s		21.6 Msymbol/s	
Modulation	FEC	*C*/*N* (dB)	*C*/*N*$_0$ (dB.Hz)	Info. rate (Mbit/s)	*C*/*N*$_0$ (dB.Hz)	Info. rate (Mbit/s)	*C*/*N*$_0$ (dB.Hz)	Info. rate (Mbit/s)
QPSK	1/4	–2.35	66.22	3.530	69.23	7.060	70.99	10.589
QPSK	1/3	–1.24	67.33	4.726	70.34	9.453	72.10	14.179
QPSK	2/5	–0.30	68.27	5.684	71.28	11.368	73.04	17.051
QPSK	1/2	1.00	69.57	7.120	72.58	14.240	74.34	21.359
QPSK	3/5	2.23	70.80	8.556	73.81	17.112	75.57	25.667
QPSK	2/3	3.10	71.67	9.520	74.68	19.040	76.44	28.561
QPSK	3/4	4.03	72.60	10.710	75.61	21.420	77.37	32.129
QPSK	4/5	4.68	73.25	11.428	76.26	22.856	78.02	34.283
QPSK	5/6	5.18	73.75	11.914	76.76	23.827	78.52	35.741
QPSK	8/9	6.20	74.77	12.718	77.78	25.437	79.54	38.155

TABLE 7 (*end*)

Channel bandwidth			**9 MHz**		**18 MHz**		**27 MHz**	
Symbol rate			**7.2 Msymbol/s**		**14.4 Msymbol/s**		**21.6 Msymbol/s**	
Modulation	**FEC**	***C/N* (dB)**	**C/N_0 (dB.Hz)**	**Info. rate (Mbit/s)**	**C/N_0 (dB.Hz)**	**Info. rate (Mbit/s)**	**C/N_0 (dB.Hz)**	**Info. rate (Mbit/s)**
QPSK	9/10	6.42	74.99	12.878	78.00	25.756	79.76	38.634
8-PSK	3/5	5.50	74.07	12.816	77.08	25.632	78.84	38.448
8-PSK	2/3	6.62	75.19	14.261	78.20	28.521	79.96	42.782
8-PSK	3/4	7.91	76.48	16.042	79.49	32.085	81.25	48.127
8-PSK	5/6	9.35	77.92	17.846	80.93	35.691	82.69	53.537
8-PSK	8/9	10.69	79.26	19.051	82.27	38.103	84.03	57.154
8-PSK	9/10	10.98	79.55	19.290	82.56	38.581	84.32	57.871
16-APSK	2/3	8.97	77.54	18.988	80.55	37.976	82.31	56.964
16-APSK	3/4	10.21	78.78	21.360	81.79	42.721	83.55	64.081
16-APSK	4/5	11.03	79.60	22.792	82.61	45.585	84.37	68.377
16-APSK	5/6	11.61	80.18	23.761	83.19	47.523	84.95	71.284
16-APSK	8/9	12.89	81.46	25.367	84.47	50.733	86.23	76.100
16-APSK	9/10	13.13	81.70	25.685	84.71	51.370	86.47	77.055
32-APSK	3/4	12.73	81.30	26.664	84.31	53.327	86.07	79.991
32-APSK	4/5	13.64	82.21	28.451	85.22	56.903	86.98	85.354
32-APSK	5/6	14.28	82.85	29.661	85.86	59.321	87.62	88.982
32-APSK	8/9	15.69	84.26	31.665	87.27	63.329	89.03	94.994
32-APSK	9/10	16.05	84.62	32.062	87.63	64.124	89.39	96.185

References

[1] ETSI. EN 300 421 (V1.1.2) – Digital Video Broadcasting (DVB). Framing structure, channel coding and modulation for 11/12 GHz satellite services.

[2] ETSI. EN 301 210 (V1.1.1) – Digital Video Broadcasting (DVB). Framing structure, channel coding and modulation for Digital Satellite News Gathering (DSNG) and other contribution applications by satellite.

[3] ETSI. EN 302 307 (V1.1.2) – Digital Video Broadcasting (DVB). Second generation framing structure, channel coding and modulation systems for Broadcasting. Interactive Services, News Gathering and other broadband satellite applications.