

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 Internet 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-CRIT¹ 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 measures². 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.

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 analysis³:

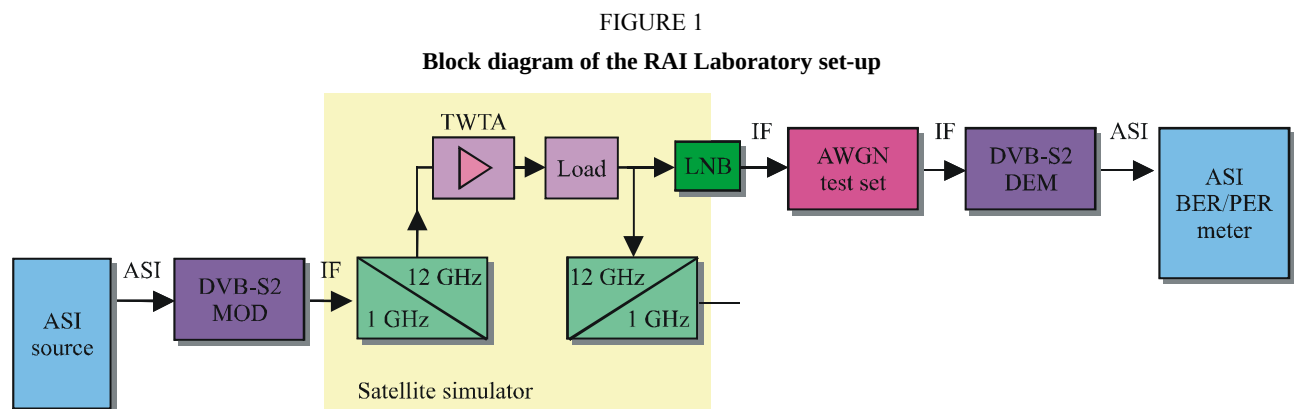
- QPSK 1/2
- 8-PSK 2/3
- 16-APSK 3/4
- 32-APSK 4/5.

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.



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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 MBd⁴, 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

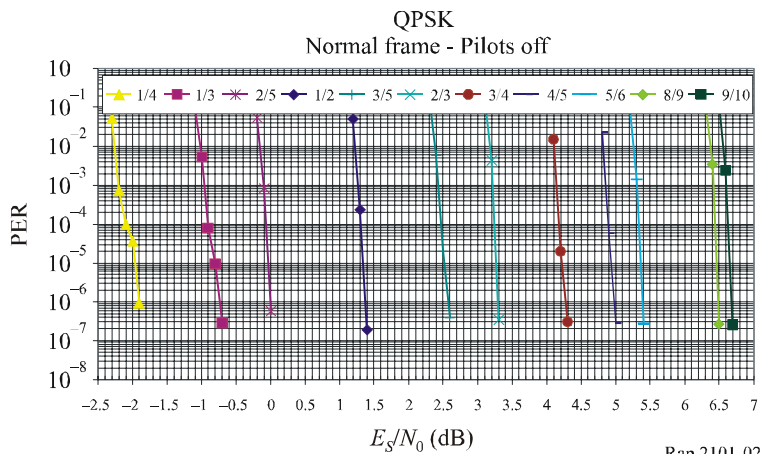
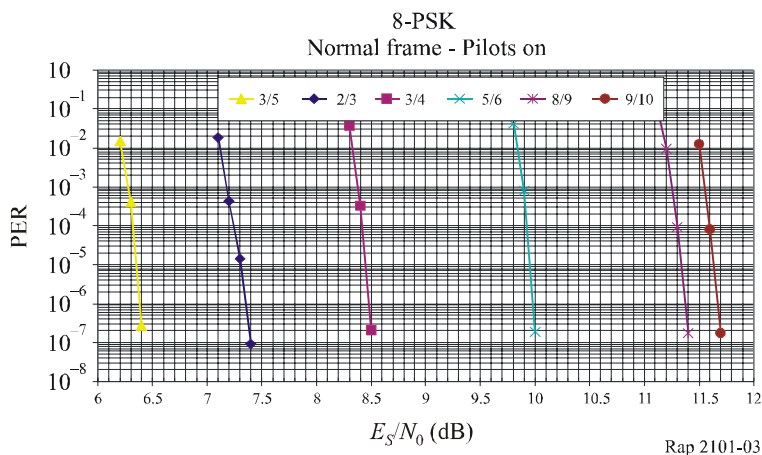


FIGURE 3

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



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 band rates.

FIGURE 4
16-APSK performance on the AWGN channel (IF loop).
Normal frame size and pilots

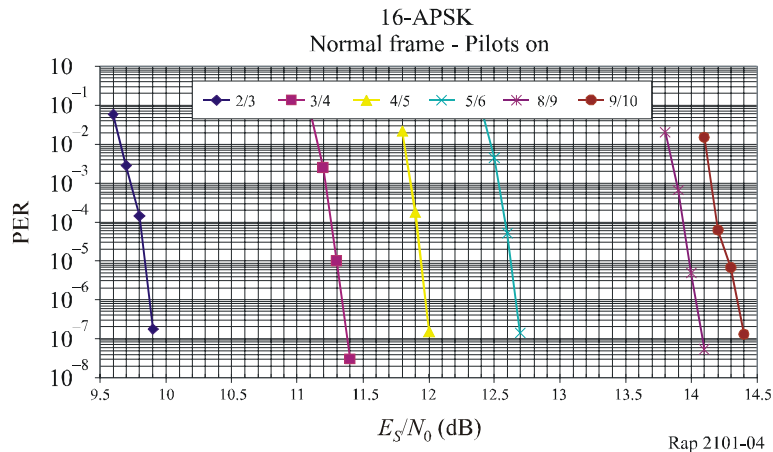
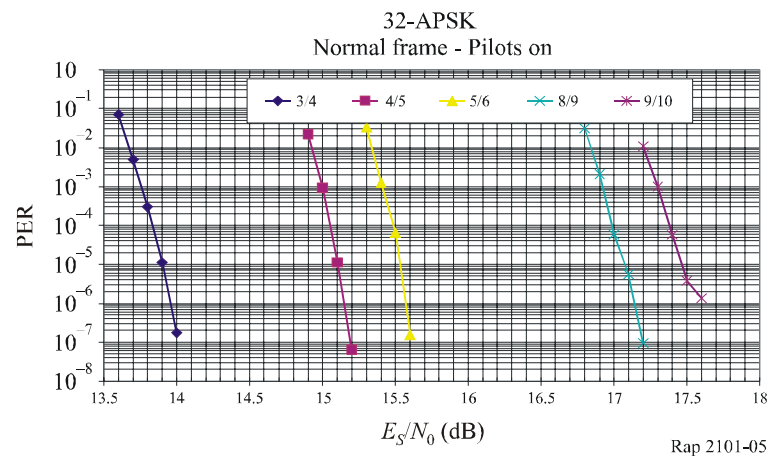


FIGURE 5
32-APSK performance on the AWGN channel (IF loop).
Normal frame size and pilots



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

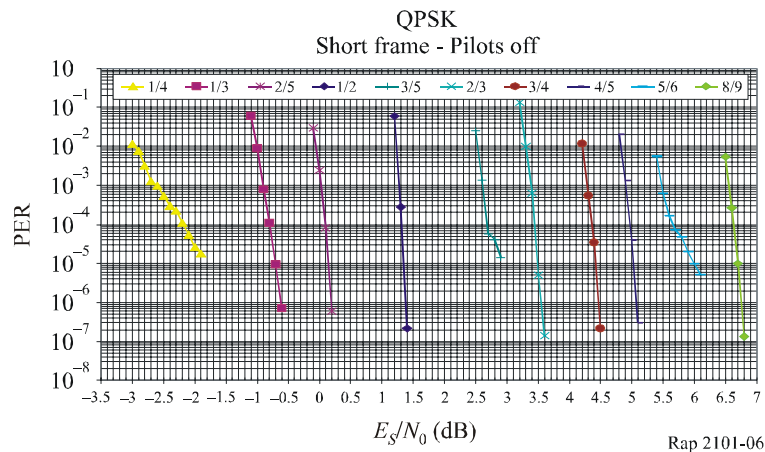


FIGURE 7

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

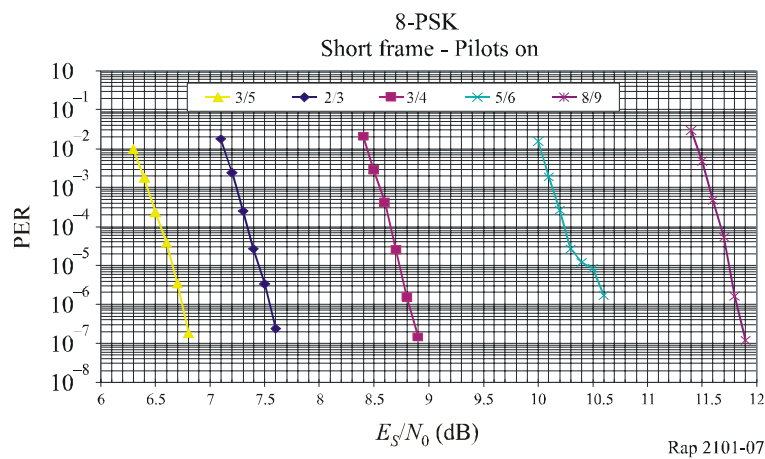
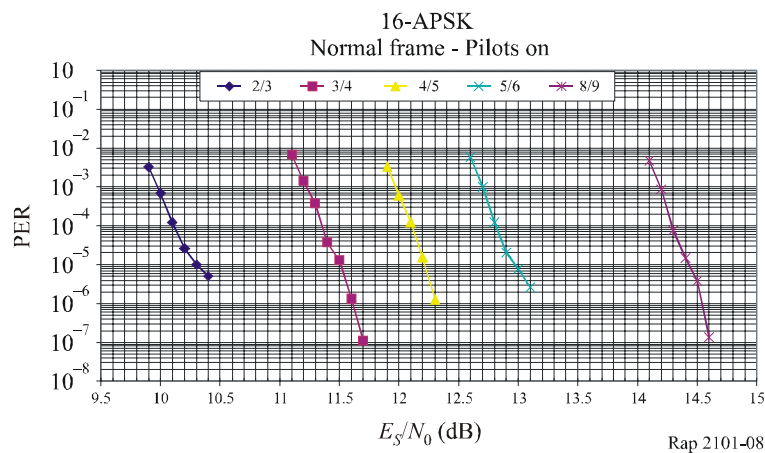


FIGURE 8

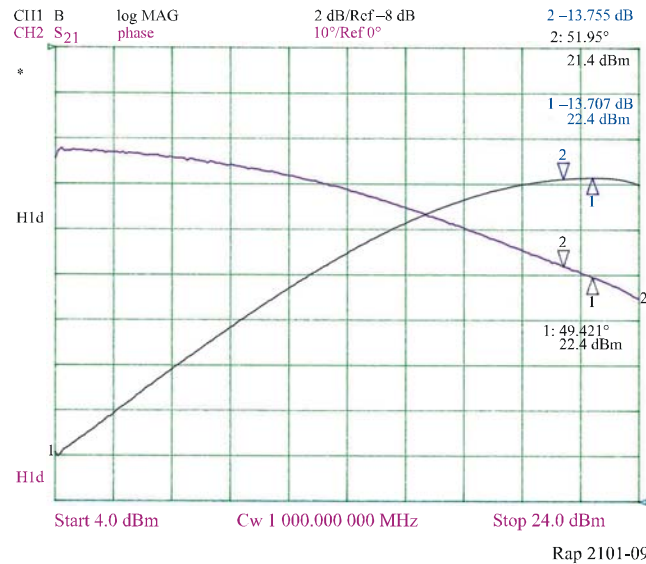
16-APSK performance on the AWGN channel (IF loop).
Short frame size and pilots



6.2 SAT test

FIGURE 9

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



Figures 10 to 13 show the DVB-S2 system performance over the satellite transponder with the non-linear characteristics of Fig. 9, respectively for QPSK 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 QPSK, 8-PSK and 16-APSK, and with pilots for 32-APSK. 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

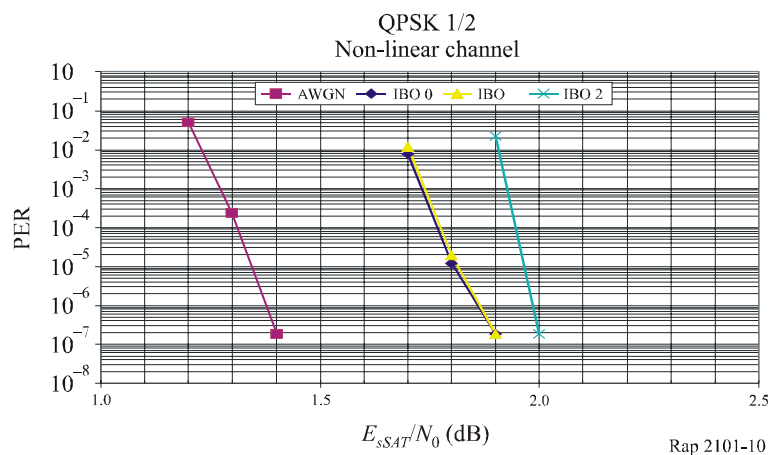


FIGURE 11

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

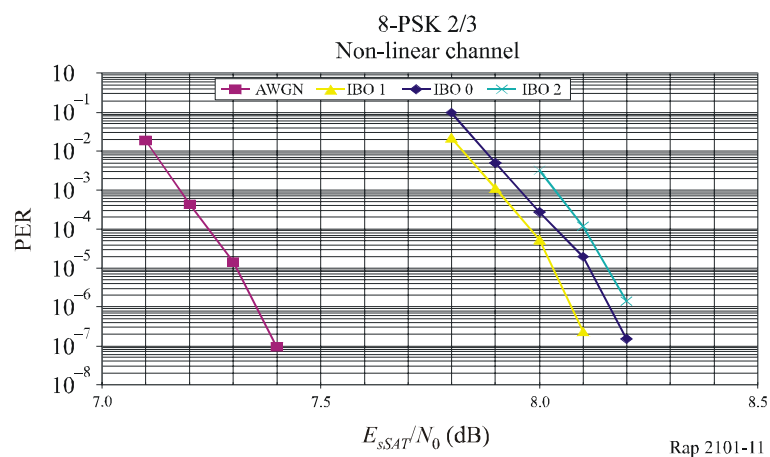


FIGURE 12

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

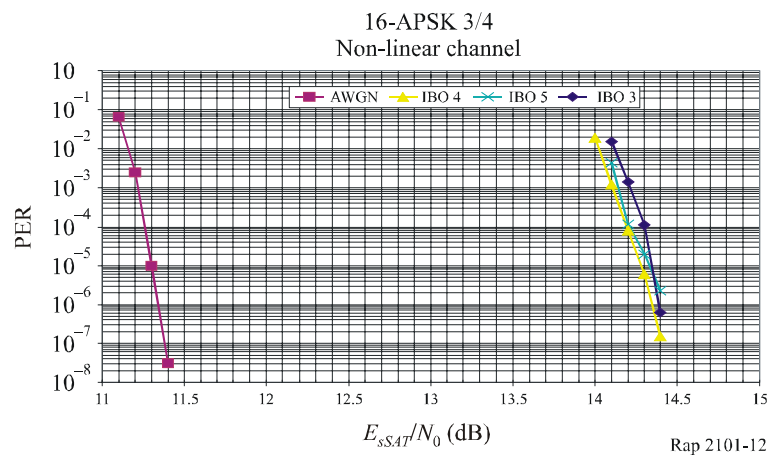
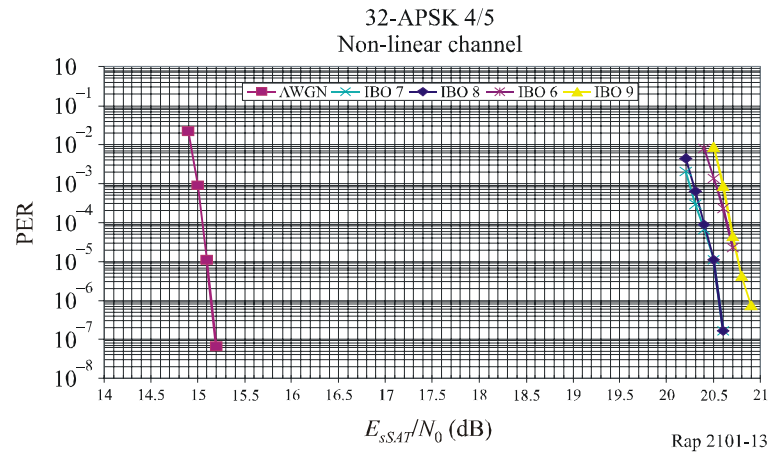


FIGURE 13

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)**

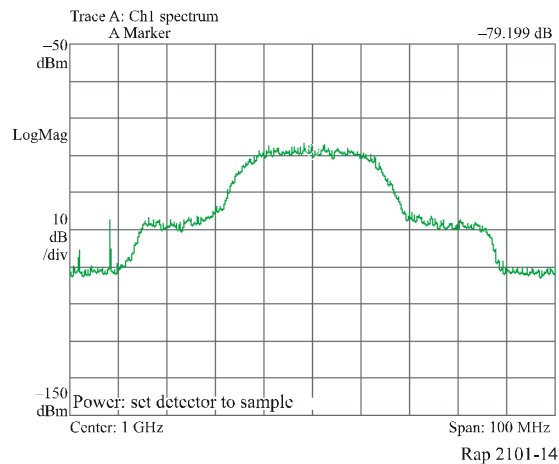


FIGURE 15
8-PSK rate 2/3 signal spectrum at the optimum operating point
(IBO = 1 dB, OBO = 0.4 dB)

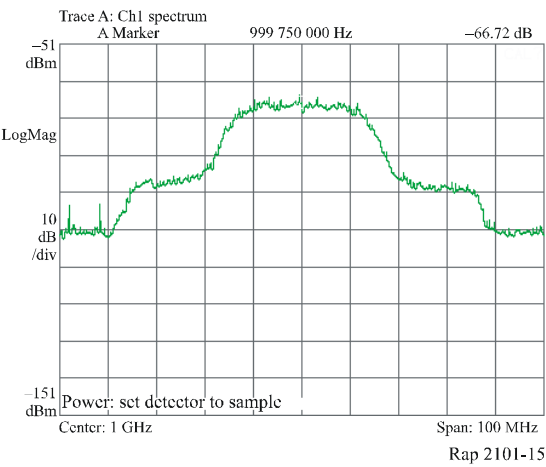
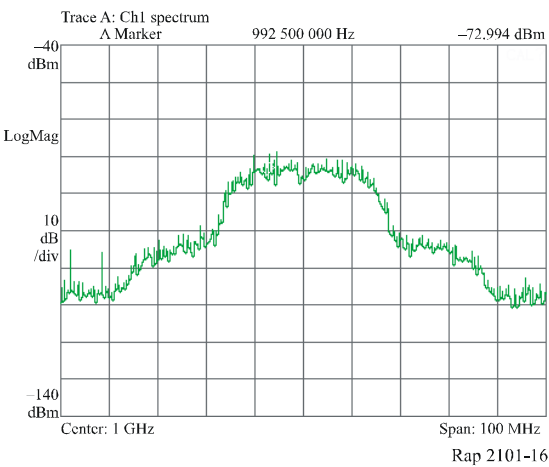


FIGURE 16
16-APSK rate 3/4 signal spectrum at the optimum operating point
(IBO = 4 dB, OBO = 1.6 dB)



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