Presentation

The work here shown constitutes the first part of the final report, that refers to the tests in Digital Television Systems, carried on accordingly to the Resolution #69, of 23rd November 1998, as well as to the Act #4609, of 30th august 1999, both approved by Board of Directors of Anatel.

On 14th January, during the first meeting between Anatel and the group of sound and image broadcasting consentees which had solicited the authorization for the trials on Digital Television Systems, the group expressed its will in, besides the technical evaluation of the systems performance, include an Brazilian market analysis, from the point of view of the Digital receivers introduction.

This part of this report consists in a technical analysis of the performance of the tested systems. Although the tests are not concluded yet, we believe that the data gathered so far is enough for a very confident evaluation about the performance of each system, whether from the viewpoint of its current stage or from the viewpoint of the evolution potential and its limitations.

As is has been already reported in the previous reports, besides the field tests authorized by Anatel, there were rigorous laboratory tests, covering a number of situation much bigger than it is possible to verify in the field, putting the field results as a verification of what is expected from the results obtained in the laboratory.

People from both ATSC and DVB, who came to visit the installations and analyzed the procedures, producing comments and suggestions that were considered pertinent validated the tests.

We consider this work carried out by this group, with the supervision and orientation of Anatel and its technical consultants, the CPqD, of extreme importance for Brazil, for it has been done within the particularities and characteristics of the country. The DVB-T system, developed to operate in an 8MHz bandwidth, was adapted to the Brazilian 6 MHz channels, thus making possible the very first scientific test in the world aimed to evaluate such system in the Brazilian conditions. The tests station was installed in the city of São Paulo, with is characteristic urban structure, allowing the proper evaluation of reception in real cases of multipath. This consideration is fundamental to allow the introduction of the Digital Technology in the Brazilian Television, what will be, undoubtedly, pushed and headed by the city of São Paulo.

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Chapter I - Introduction

I-1) History

In December 1998 the works of identification and description of the lab tests begun.

In January 1999, the first list of equipment that had to import was ready. At the same time the import process for the transmission and reception related equipment from NEC was getting started. Among that equipment, there was a power transmitter for HDTV, with 2 modulators, one for the ATSC system and the other for the DVB-T system. It was also a part of the batch a 6-MHz NDS receiver for DVB-T and a Zenith receiver for ATSC.

During the first half of 1999, it was built, at the Mackenzie, one cage of Faraday so to avoid any electromagnetic external interference over the reception devices. It was also at that time that the shelter for the transmission equipment was built.

In July 1999 the first equipment from NEC arrived. In August 1999 these equipment were already operational, while the last batch of imported equipment arrived.

In August 1999 the lab tests for the two available systems begun.

In January 2000 all the necessary equipment for transmission and reception using for ISDB-T system evaluation was delivered and put operational.

The tests for the ATSC standard were practically over by November 1999. The DVB-T and ISDB-T standards are still being done.

I-2) Aim of the tests

The main goal of the lab tests was to measure the performance of the DTV standards currently available for DTTB.

First, only the American and the European systems were available. Later, the tests were extended, now with the availability of the Japanese standard (ISDB-T).

The general goal for these measures, as far as the activities at the Mackenzie Institute are concerned, was to provide Set and Abert, accordingly to a technological cooperation agreement, technical elements so to the group of authorized broadcasters compare the systems and subsidize Anatel in its decision taking process of choosing the most adequate DTV system for Brazil.

I-3) Tested standards

There were 3 international standards, namely:

a) American standard, known as ATSC (United States Advanced Television Systems Committee) in its version for DTTB, using the modulation method known as 8VSB (8 Vestigial Side Band) and using a 6 MHz channel bandwidth.
b) European standard, known as DVB-T (Digital Video Broadcasting – Terrestrial), using the modulation method known as COFDM (Coded Orthogonal Frequency Division Multiplex) and using a 6 MHz channel bandwidth. The DVB-T allows several modulator configurations. The ones chosen for the tests were:

Configuration	FEC	Guard Interval	Mode	Net bit rate	QAM levels
1	3/4	1/16	2K	19,76	64
2	3/4	1/16	8K	19,76	64
3	2/3	1/32	8K	18,10	64
4	3/4	1/8	2K	18,66	64

c) Japanese standard, known as ISDB-T (Integrated Services Digital Broadcasting – Terrestrial), using the modulation method COFDM (Coded Orthogonal Frequency Division Multiplex) and using a 6 MHz channel bandwidth.

This standard was tested in the following configuration:
FEC: 3/4;
Guard Interval: 1/16;
Mode: 4K;
Carrier modulation: 64QAM;
Net bit rate: 19,329 Mbps.

During some tests different configurations from the above were tested.

I-4) Tests phases identification

We can distinguish the following main functional phases of executing the tests:

A. Identification of the tests to be applied;
B. Elaborating the lists of equipment/devices to be acquired and the acquisition itself;
C. Lab Implantation;
D. Description of the trials methods; for this phase there were 5 versions, each new version absorbing improvements from analysis made by the whole group and by the results of the physical implantation;
E. Execution of the trials;
F. Writing the Final Report.

I-5) presenting the results

With the description of each test, at the end of it, one can find the results as either tables or charts, or both. Preference was given to the presentation in charts so to make easier the visualization and allow a faster comparison among the standards.

I-6) Identification of the tests phases

During the period of the tests some members from international groups, representing the systems being tested, visited São Paulo.
The ATSC representatives visited the group in October 1999. In December 1999 it was the DVB representatives turn, and in January 2000, the ISDB group. The main goal of those visits was the validation of the methods of trial and of the equipment being used for the generation of results that may be internationally recognized as elements of comparison among the systems being tested.

Chapter II – General Description of the Lab tests

II-1) Identification and classification of the tests

1) Introduction

The tests were grouped in families, characterized by its functionality and numbered from 1 to 6.
Thus, we have the functional families and the tests that correspond to each family, namely:

2) Interference Behavior

2.1 – Digital into PAL-M Interference
2.2 – PAL-M into digital Interference
2.3 – Digital into digital Interference (co-channel, adjacent and “Taboo” channels)
2.4 – Interference by a Continuous Signal (CW)
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4.1 Carrier-to-noise Ratio Threshold
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4.4 BER as function of C/N
4.5 C/N threshold as function of the signal level

5) Characteristics of transmission performance

5.1 Transmitters set-up and spectral analysis of the transmitted signal
5.2 “Peak Power Level” / “Average Power Level” ratio
5.3 Emission of out of band spurious signals

6) **Characteristics of Digital TV systems in the presence of reflections caused by moving objects (Doppler effect)**

II-2 Set-up General Description

The general test set-up can be split into 3 segments, namely:

1 – Transmitters room;
2 – Reception room;
3 – Interconnection;

II-2.1) Transmitter room

Physical location: The transmitters room can be found at the Joao Calvino building ground level, which belongs to the Mackenzie Institute, located at Rua da Consolação, 896.

Dimensions: The transmitters room is an ensemble of two contiguous rooms. The larger one has an area of 15 m^2 (4.2x3.6) and shelters the power transmitters. The smaller one has an area of 3 m^2 (approximately 2x1.5) and shelters the cooling system (“blower”).

Equipment: The following are the main equipment that can be found at the transmitters room:

a) PAL-M Generation:

a1) Video
- Programmable Generator TSG1001, Tektronix
- Digital Variacomb Coder V4238, Vistek
- Modulator Pulsar, Barco
- Power Transmitter 1Kw, UHF, channel 34, Linear

a2) Sound
- Programmable Generator TSG 95, Tektronix
- Stereo generator MTS, Leaming Industries
- BTSC SAP Generator

b) HDTV signal generation

b1) Video
- Programmable generator TSG1001, Tektronix
- Encoder MPEG2, MH1000, Mitsubishi + RF Generator, Rhode & Schwarz - SMY-02
- Modulator 8VSB NEC or Modulator COFDM NEC or Modulator ISDB NEC OFM2000-02-07 TS Multiplexer MPEG2, NEC
- HDTV transmitter, 1 Kw, UHF, channel 35 with modulators alternating among 8VSB, COFDM or ISDB
- Monitor Plasmasync 4200W, NEC

b2) Sound
- Programmable generator TSG95, Tektronix
- 2 CH AD Converter AD2X Yamaha
- ZX Resound Audio Encoder (AC3 Dolby), Zapex
- Encoder MPEG2 - MH1000, Mitsubishi

II-2.2) Reception room

- *Physical Location*: The reception room can be found at the Joao Calvino building 1st floor, which belongs to the Mackenzie Institute, located at Rua da Consolação, 896.
- *Dimensions*: The reception room has an area of 24,80 m^2 (3.6x6.9) and shelters the equipment and devices for reception.
- *Faraday's Cage*: The main component in the reception room is a "Faraday's Cage" built by the ITM (Technological Mackenzie Institute) and the purpose of building such an apparatus is to avoid that external electromagnetic fields may disturb the measures on the reception devices. This cage has an area of 7m^2 (2,0 X 3,5) and shelters almost all the reception equipment.
- *The cage external part*: Outside the cage there is a "Patch Panel" which provides the terminations and pass-through to the signals within the interconnecting coaxial cables between the reception room and the transmission room. This "Patch Panel" is docked into the cage and allows that high frequency signals go in and out the cage without compromising the electromagnetic insulation. The capability of this "Patch Panel" is to terminate in both sides (external and internal sides of the cage) 4 coaxial cables RG213, through connectors type N and 8 coaxial cables RG58, through connectors type N and 8 coaxial cables RG58, through BNC connectors. The RG213 cables are used for signal interconnection between the transmitters room and the reception room, while the RG58 cables are generally used for connecting the devices outside the cage.
- *The cage internal part*: the main equipment and devices used inside the cage

were:

a) Reception equipment:

- 1 Zenith ATSC receiver model: Prodemod
- 1 NDS DVB receiver system 3000
- 1 ISDB receiver (prototype)
- 1 decoder SDTV-NEC240
- 3 PAL-M commercial receivers PAL-M
- 1 decoder Dolby AC3 Harman-Kardon
- parallel/serial interfaces

b) Measurement devices:

- 1 signal analyzer HP89441V
- 1 TAS noise generator model TAS420
- 1 bit error rate analyzer, Tektronix PB200
- 1 Digital Transmission Analyzer 3764 da HP (ISDB)
- 1 TAS - RF Channel Emulator TAS 4500
- 2 TELONIC filters12Mhz TT600
- 1 Advantest U3641 spectrum analyzer
- 1 HP amplifier, model HP8347A
- 1 Rhode & Schwarz attenuator 0-110dB, 0,1dB model RSP

- 2 Attenuators HP, 0-120dB, model 355D
- 2 Attenuators HP, 0-12dB, model 355C
- 2 coupler circuits HP, model HP0955-0751
- 2 HP signal splitter, model HP0955-0751
- 2 Mini-circuit Mixer model ZLW186MH
- 2 R&S RF Generator, model SMY02
- 1 R&S RF Generator, model SMH
- 1 Oscilloscope Tektronix 4 channels, model TDS754D
- Frequency measurer Advantest model 5361B
- 1 coaxial RF key, 1 pole 2 positions

II-2.3) *Interconnection*

The interconnection between the transmitters room and the reception room is made by coaxial cables approximately 80 meters long. There is a total of 5 coaxial cables type RG213 that is intended for:

- Cable 1: coaxial cable with N terminators in both ends, transporting the data signal (TX data) constituted by a sequence PRBS 2^{15} -1. This sequence is generated by the Tektronix error rate data generator circuit PB200 and inserted in the coaxial cable through a "line-driver" circuit.
  In the other end, the spoken sequence is inserted in a TTL serial/parallel converter, which parallel data is converted from the TTL mode to the LVDS through an appropriate interface, before being injected at either the ATSC or DVB modulator.
  Note: in the ISDB case, the modulator itself generates internally the sequence PRBS 2^{23} -1 used in the tests.

- Cable 2: coaxial cable with N terminations in both ends, relaying the "clock" signal (TX clock) to which is synchronizing the TX DATA signal. This "clock" signal is generated by the PB200 and inserted in the coaxial cable through one "line driver" circuit. In the other end, the TX Clock signal is inserted in the series/parallel converter, which parallel clock output clock is converted into the TTL mode to LVDS before getting into the ATSC or DVB modulator.

Cable 3: The coaxial cable with N termination in both ends carrying the “synch” signal (TX Synch). This "synch" signal is generated by the PB200 and it is supposed to mark the beginning of the transport packet by indicating the position of the synchronism byte. This signal is inserted into the coaxial cable trough a "line driver" circuit. In the other end of the coaxial cable, the TX Synch signal is inserted into the modulator ATSC or DVB using one serial/parallel converter and the TTL/LVDS converter.

- Cable 4: Coaxial Cable with N termination in both ends, carrying the signal originated in a "pesca" (sample taker) located in the power output of the digital transmitter. In the other end of the coaxial cable, the digital signal is inserted é into the "Patch Panel" of the Faraday's cage and then to the reception "set-up".

- Cable 5: Coaxial cable with N terminations in both ends transporting the analog signal from the "pesca" in the RF load of the PAL-M analog transmitter. In the other end of the coaxial cable, the analog signal is inserted into the "Patch panel" of the Faraday's cage and then to the reception "set-up".

II-3) Measurements Set-up

II-3.1) Interconnection cables measurements

In the measure shelters located in the transmission and reception rooms, all the interconnection cables were constituted and measured accordingly their characteristics of attenuation and return loss.
For each experiment, it was possible to identify the cable set that was used.

II-3.2) Mixers and Couplers measurements

The couplers and splitters used in the tests had their attenuation and return losses evaluated.
In the mixers, besides the attenuation measurements and return loss, it was evaluated the amplitude feed back curve, with the identification of the saturation point.

II-3.3) PAL-M power measurements

The power measure of the PAL-M signal is taken during the synchronism peak by using the HP Vector Signal Analyzer - model 89441V, which allows the direct reading of this power.

II-3.4) Power measurements of the digital signal and gaussian noise power.

Both powers were measured by the HP Vector Signal Analyzer - model 89441V, which measures directly the signal average power within the 6MHz band.

II-4) Auxiliary equipment designed and developed

To solve the interface problems between the modulation and reception equipment and the measurement equipment, it was needed design and develop the following devices:

1) serial/parallel interface: inserted between the PRBS sequence generated by the Tektronix PB200 and the input of the ATSC or DVB modulator.
2) Parallel/serial interface: inserted between the NDS DVB receiver output and the PB200 PRBS signal input.
3) Line Driver: inserted in the reception room between the PB200 signal outputs and the 3 coaxial cables that carry those signal to the transmitters room.

II-5) Standards adopted

Several image, sounds and digital sequences were used during the trials. They are:

II-5.1) Image standards

- To the digital into analog interference tests , the image interfered used in the PAL-M receivers was the 8 bar "Color-bar".
- To the analog into digital interference tests it was used, in the interfering analog system, the "Zone Plate" image.

II-5.2) Sound standards

To the generation of the PAL-M system sound channel, it was used a audio generator with a sweeper from 20 Hz to 20kHz, causing maximum deviations to the 12,5kHz modulation frequency of :

- Mono: 25kHz
- Stereo: 55khz
- Stereo + SAP: 75kHz

II-5.3) Digital sequences standards and error rate

- To the digital sequence of transmission it was used a pseudo-random sequence (PRBS) of 2^{15} -1 bits to the ISDB system.
  The fact that the standard 2^{23}-1 was not used to the ATSC and DVB is due the difficulties experimented with the Tektronix PB200 that wasn't able to synchronize with this long sequence. Since the ISDB was using another error rate measurement device, there was no difficulty with the 2^{23}-1 sequence.
  To use the 2^{15} -1 sequence, a detailed analysis was made, so to verify the differences related to the use of this shorter sequence, in relation to the longer sequence 2^{23}-1. There were no reports on any significant problem with the shorter sequence.

- Error Rate Threshold: It was used the same reference of error rate threshold to all systems, or, $3X10^{-6}$, measured at the receivers data output.

II-6) Interface description

The interfaces for the receivers are, to the laboratory tests, the most significant, for they define the interface of the main measurement equipment. In short, these interfaces have the following characteristics:

II-6.1) Receiver Zenith to the ATSC standard

- Parallel output, 208 bytes, output type LVDS, and DB25 connector. This output is connected to the Nucom's interface adapter LVDS/TTL, which output is then connected to the Mitsubishi's MPEG-2 decoder.
- Data/clock serial output, TTL standard, BNC connector. This output is connected directly to the Tektronix PB200 error rate measurer data input.
- Interface RS232 for receiver set-up

II-6.2) NDS DVB receiver

- Parallel output (204 data bytes) standard DVB SPI (output LVDS, connector DB25). This output is connected to the Nucom's interfaces adapter LVDS/TTL which output is, by its turn, connected to the Mitsubishi's MPEG-2 Decoder.
  To measure the error rate, this parallel output is connected to the Tektronix PB200 serial data input.

- Interface RS232 for receiver set-up.

II-6.3) NEC ISDB receiver

- Parallel output (204 data bytes) DVB SPI standard (LVDS output, connector DB25). This output is connected to the Nucom's interfaces adapter LVDS/TTL, which output is then connected to the Mitsubishi's MPEG-2 Decoder.

II-7) Final Remarks

To the accomplishment of the laboratory tests, all the cares were take to insure the results reliability.

Among the problems faced during the tests, the 2 larger ones were related to error rate measuring and to the interfacing between the receivers and the error rate measurer and the MPEG-2 demodulator, that have been already mentioned in the text above.

We are absolutely sure that the results mirror, as trustfully as possible, the performance of the various parameters analyzed, which will allow a correct comparison among the 3 considered standards.

2.1 Digital into PAL- M Interference

2.1.1 Aim

This measurement method aims to evaluate the degradation produced in a PAL-M signal interfered by a Digital signal, ATSC, DVB-T and ISDB.

This interference is determined by the "protection ratio", which is the ratio in dB between wanted signal power and the interfering signal power.

Protection ratio = D/U(dB)

With D = wanted signal and U = interfering signal

The protection ration will be evaluated in two different situations:

a) Upper digital channel into PAL-M interference: this experiment will be carried out with both wanted and interfering signals coming from the transmitter output stages, allocated in adjacent channels.

Simulated digital into PAL-M interference: this experiment will be carried out by removing the interfering signal from the digital transmitter's IF. This will allow varying the digital channel frequency (frequency shifting/displacement), shifting the digital channel over the analogue channel, measuring in each case the protection ratio. This measurement would be evaluating the protection ratio of the co-channel and its adjacencies, including upper and lower adjacent channels. In the case of upper adjacent channel, which we consider more critical, the difference in relation to item a) is due to the fact that we are not considering the effects of the digital transmitter final stage (filter) and therefore we are carrying out a less realistic evaluation.

The co-channel analysis will allow us to study the feasibility of re-using the analogue channel by the digital TV, in a nearby town.

It also will be made measurements of the "protection ratio" for offsets near the frequency of the channel.

2.1.2 Basic parameters characteristics

The basic parameters used to determine the protection ratio would be subjective image evaluation, carried out by people observing the images coming from the PAL-M receiver. Despite the image being the parameter chosen as a reference to obtain the protection ratio, it is also necessary that the observers notice what happens to the sound, in the protection ratio measurement points.

There are methods of subjective evaluation to be used:

- Subjective comparison method UIT-R level 3 (white noise graded UIT-R level 3).
- Subjective comparison method UIT-R level 4 (white noise graded UIT-R level 4).
- Limit of Perceptibility (LOP).

The figures resulting from methods with UIT-R levels 3 and 4 provide approximately video quality equivalent to Grades 3 and 4.

2.1.3 Initial values and characteristics

2.1.3.1 PAL-M receivers: 3 receivers with less than 5 years of use and fitted with varactor tuner.

2.1.3.2 Initial frequency shifting: 0 MHz (co-channel interference).

2.1.3.3 Number of trained observers: 3, each observer individually analyse the receiver in test - the final result will be the average of the 3 analysis.

2.1.3.4 PAL sound signal: the PAL-M video signal generator should have the sound channel adjusted to transmit in stereo, with 1 kHz modulation frequency and frequency shifting of 50 kHz.

2.1.3.5 The HDTV interfering signals, being either from DVB-T, ATSC or ISDB, should be provided by HDTV transmitters, via attenuators coupled to the output stages.

2.1.3.6 The initial input levels of the PAL-M receivers should be adjusted to around 1mV.

2.1.3.7 The PAL-M signal should be transmitter generated.

2.1.3.8 The power of the digital TV and PAL-M signals must be measured in dBm over a 50 ohm load using the HP 89441 vector analyser.

2.1.3.9 The PAL-M image to be used as a reference to aid the subjective analysis is the colour bar test card.

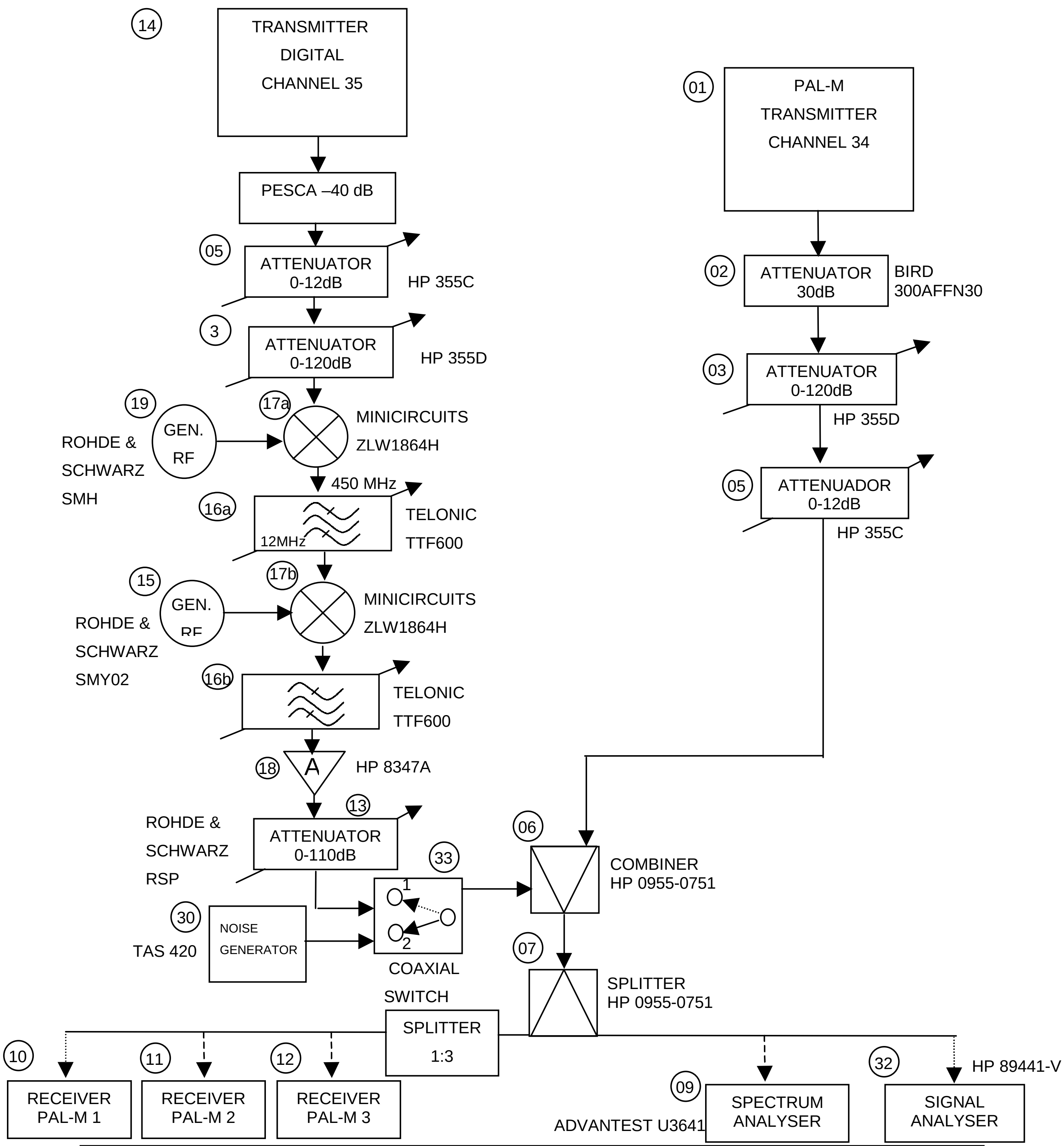
2.1.4 Measurement general description

The observer should vary the protection ratio until the image seen by the observer shows a quality level nearest possible to levels defined by UIT-R and LOP.

2.1.5 Equipment used

(1) PAL-M transmitter tuned to channel 34
(2) Bird 30dB attenuator, model 300AFFN30
(3) HP 0-120dB attenuator, model 355D
(5) HP 0-12dB attenuator, model 355C
(6) HP combiner, model 0955-0751
(7) HP splitter, model 0955-0751
(9) ADVANTEST spectrum analyser, model U3641
(10) PAL-M receiver 1
(11) PAL-M receiver 2
(12) PAL-M receiver 3
(13) R&S 0-110dB 0.1dB step attenuator, model RSP
(14) Digital transmitter tuned to channel 35
(15) R&S RF generator, model SMY02
(16A & B) Telonic 12 MHz filter, model TTF600
(17A & B) Mini-Circuits mixer, model ZLW186MH
(18) HP Amplifier model 8347A
(19) R&S RF generator, model SMH
(30) TAS noise generator, model 420
(32) HP 89441 V Vector signal analyser
(33) RF coaxial switch 1 pole, 2 positions
(45) Thevear 1:3 75 ohm Splitter

2.1.6 *Measurement Block Diagrams*



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2.1.7 Tests Procedures

Initial Observations: The procedures described below should be done to the following frequency offsets:

A) Frequency offset around the channel frequency

Δf = -558,04 Hz + n .1674,11 Hz (n integer positive or negative) for DVB-T system.

Δf = (496,03 Hz + n .992,06)Hz (n integer positive or negative) for ISDB system.

Δf = $\pm$10 KHz, for ATSC system.

B) Co-channel; Δf=0 kHz.

C) Adjacent channels; $\pm$6 MHz.

D) Frequency channels "taboo":

$\pm$7 BW, $\pm$8 BW, +14 BW, +15 BW, where BW = 6MHz.

The mentioned frequency offsets will be obtained by varying the generator's RF frequency (15), through the mixer circuit (17b) and through the band filter (16b).

The frequency of the first RF generator (19) will be always 1049 MHz generating a 450 MHz fixed channel.

The frequency of the second RF generator (15) will be 450 MHz plus the wanted interference channel frequency.

The first Telonic filter (16a) should be adjusted to 50 MHz.

The second Telonic filter (16b) should be adjusted to the chosen interference channel frequency.

2.1.7.1) With the coaxial switch (33) in position 1 and digital system attenuators set to max attenuation, adjust the PAL-M system attenuators until a -40dBm power level is reached at the receiver 1 input (10) and read by (32). Take this level as a reference.

2.1.7.2) With the coaxial switch (33) in position 2 and PAL-M system attenuators set to max attenuation, adjust the noise generator (30) level to give 33dB below the reference level (item 2.1.7.1) at the receiver input and read by (32). Turn the PAL-M attenuators back to the reference level determined by 2.1.7.1. This gives to the PAL-M receiver 1 a video quality corresponding to UIT-R level 3.

2.1.7.3) Turn the coaxial switch (33) back to position 1 and adjust the digital system attenuators so that the video quality seen in the PAL-M receiver 1 (10) is the closest possible to the image seen in item 2.1.7.2. This is a convergent process, and carrying out successive comparisons between the reference (switch (33) in position 2) and the digital (switch in position 1) images must achieve such convergence. For each comparison, the person carrying out this test must manipulate the digital system attenuators until the images are equal.

2.1.7.4) Record the PAL-M attenuators position level and subsequently adjust them to maximum attenuation. Turn the switch (33) to position 1. Read from (32) the interfering digital signal power level in $dBm_{i.}$

2.1.7.5) Calculate the protection ratio by using the following expression:

Protection Ratio = (reference level read in 2.1.7.1) - dBm_i .

Where dBm_i is the interfering signal level.

2.1.7.6) Repeat tests 2.1.7.1 to 2.1.7.5 with receivers 2 (11) and 3 (12) and take notes of the results in the tables 2.1.8.1 (ATSC - UITR3), 2.1.8.2 (DVB-T - UITR3) and 2.1.8.2 (ISDB - UITR3).

2.1.7.7) Repeat tests 2.1.7.1 to 2.1.7.5 for subjective comparison method UIT-R level 4. The only difference is that the level of the noise generator (30) must be adjusted to produce a level of 37.5 dB below the level of reference obtained in the item 2.1.7.1. Use as evaluating reference the PAL-M receiver 1 (10).

2.1.7.8) Repeat the item 2.1.7.7 for receivers 2 (11) and 3 (12), calculate the average protection ratio and register the results in the tables 2.1.8.1 (ATSC - UITR 4), 2.1.8.2 (DVB-T - UITR 4) and 2.1.8.3 (ISDB - UITR4).

2.1.7.9) To evaluate the interference using the method "Limit of Perceptibility" (LOP), repeat the item 2.1.7.1.

2.1.7.10) With the coaxial switch (33) in the position 1, adjust the attenuator of the digital system until the observers reach the threshold of perception of the interference in the image and/or in the sound.

2.1.7.11) Take note of the position of the PAL-M attenuators and then adjust them for the max attenuation. Read the power of the interfering signal in dBm_i using the method already explained in the item 2.1.7.5, Take notes of the results in the tables 2.1.8.1 (ATSC - LOP), 2.1.8.2 (DVB-T - LOP) and 2.1.8.3 (ISDB - LOP).

2.1.7.12) Repeat the item 2.1.7.10 with the receivers 2 (11) and 3 (12) and take note of the results in the tables A1 (8VSB) and A2 (COFDM).

NOTE: All the subjective tests described above must be made by 3 observers and the final result is going to be the average of the 3 results.

2.1.7.13) Repeat the procedures described in items 2.1.7.1 until 2.1.7.6 using the following frequency offsets (Δf) described in item A) at Initial Observations of this procedure, taking notes of the results in tables 2.1.8.4 (ATSC - UITR3), 2.1.8.5 (DVB-T - UITR3) and in 2.1.8.6 (ISDB - UITR3).

2.1.7.14) Repeat the procedures described in items 2.1.7.7 until 2.1.7.8 to the following frequency offsets (Δf) described in item A) at Initial Observations of this procedure, taking notes of the results in tables 2.1.8.4 (ATSC - UITR4), 2.1.8.5 (DVB-T - UITR4) and in 2.1.8.6 (ISDB - UITR4).

2.1.7.15) Repeat the procedures described in items 2.1.7.9 until 2.1.7.12 to the following frequency offsets (Δf) described in item A) at Initial Observations of this procedure, taking notes of the results in tables 2.1.8.4 (ATSC - LOP), 2.1.8.5 (DVB-T - LOP) and in 2.1.8.6 (ISDB - LOP).

2.1.8 Results tables

2.1.8.1 Interference Level and Protection ratio, for adjacent/Co-channel/"Taboo", simulated digital interference into PAL-M channel, ATSC system.

	OFF-SET FREQUENCY	PROTECTION RATIO AVERAGE VALUE (DB)		
BWs	MHZ	UITR 3	UITR 4	LOP
0	0	32,34	36,89	44,63
1	+6	-13,19	-7,77	0,84
+7	+42	-25,94	-21,49	-11,77
+8	+48	-26,69	-22,64	-11,94
+14	+84	-24,67	-20,80	-11,12
+15	+90	-22,99	-19,07	-9,25
-1	-6	-12,71	-9,15	-2,07
-7	-42	-25,85	-21,68	-11,27
-8	-48	-26,10	-21,93	-10,51

Reference Level: -47 dBmr

2.1.8.2 Interference Level and Protection ratio, for adjacent/Co-channel/"Taboo", simulated digital interference into PAL-M channel, DVB-T system.

	OFF-SET FREQUENCY	PROTECTION RATIO AVERAGE VALUE (DB)		
BWs	MHZ	UITR 3	UITR 4	LOP
0	0	33,30	38,05	48,11
1	+6	-10,83	-7,78	0,77
+7	+42	-25,50	-20,75	-9,57
+8	+48	-26,36	-21,93	-12,06
+14	+84	-24,28	-19,93	-10,47
+15	+90	-23,02	-18,52	-8,30
-1	-6	-12,13	-9,11	-2,55
-7	-42	-25,76	-21,20	-9,75
-8	-48	-25,10	-20,98	-8,92

Reference Level: -47 dBmr

2.1.8.3 Interference Level and Protection ratio, for adjacent/Co-channel/"Taboo", simulated digital interference into PAL-M channel, ISDB system.

	OFF-SET FREQUENCY	PROTECTION RATIO AVERAGE VALUE (DB)		
BWs	MHZ	UITR 3	UITR 4	LOP
0	0	32,06	37,28	48,04
1	+6	-14,28	-11,75	-2,67
+7	+42	-28,30	-24,38	-14,20
+8	+48	-27,69	-23,29	-13,61
+14	+84	-26,41	-21,51	-12,13
+15	+90	-25,38	-21,28	-11,96
-1	-6	-12,74	-9,56	-1,09
-7	-42	-27,71	-23,31	-14,36
-8	-48	-28,04	-24,61	-15,59

Reference Level: -46,0 dBmr

2.1.8.4 Protection Ratio and Interference Level for offsets frequency around the channel.

- Modulation: ATSC System

OFF-SET FREQUENCY	PROTECTION RATIO AVERAGE VALUE (DB)		
MHZ	UITR 3	UITR 4	LOP
0	32,34	36,89	44,63
+10	32,44	37,05	45,85
-10	32,17	36,79	45,26

Reference level: -32,75 dBmr

2.1.8.5 Protection Ratio and Interference Level for offsets frequency around the channel.

- Modulation: DVB-T System

OFF-SET FREQUENCY	PROTECTION RATIO AVERAGE VALUE (DB)		
HZ	UITR 3	UITR 4	LOP
0	33,30	38,05	48,11
1116,07	34,19	38,15	47,29
2790,18	34,07	38,71	50,77
4464,29	34,11	38,17	51,02
6138,40	33,50	37,79	50,80
-558,04	33,86	38,05	45,55
-2232,15	33,38	37,88	47,30
-3906,26	34,31	38,88	48,13
-5580,37	33,45	37,47	47,52

Reference level: -36,90 dBmr

2.1.8.6 Protection Ratio and Interference Level for offsets frequency around the channel.

- Modulation: ISDB System

FREQUENCY OFF-SET	PROTECTION RATIO AVERAGE VALUE (DB)		
HZ	UITR 3	UITR 4	LOP
0	32,06	37,28	48,04
496,03	32,81	36,58	46,70
1488,09	32,08	36,83	47,08
2480,15	32,05	36,42	46,50
3472,21	31,76	35,67	45,61
4464,27	32,64	36,24	42,81
-496,03	32,23	36,86	47,04
-1488,09	32,20	36,97	46,82
-2480,15	32,88	36,88	46,68
-3472,21	32,12	36,78	45,90
-4464,27	32,21	36,96	46,96

Reference Level: -36,70 dBmr

2.2 PAL- M into Digital Interference

2.2.1 Aim

This measurement method aims to evaluate the degradation produced in a digital channel with ATSC, DVB-T or ISDB modulation standard when interfered by a PAL-M modulated analogue channel.
This interference is measured by the evaluation of the parameter called "protection ratio". This is the ratio in dB between the wanted signal and the interfering signal power.

Protection Ratio = D/U$_{(dB)}$

D = wanted signal
U = interfering signal

The protection ratio will be evaluated for lower adjacent channel, upper adjacent channel, co-channel, "Taboo" Channels, and near of the interfered channel.

2.2.2 Basic parameters characteristics

The basic parameter to be used to determine the protection ratio is the Bit Error Rate Threshold.

2.2.3 Initial values and characteristics

2.2.3.1 The PAL-M interfering signal is obtained from a broadcasting transmitter with output tuned to channel 34 UHF.

The PAL-M interfering signal is obtained by using two generator mixers and two Telonic variable bandpass filters to the refered interfered channel frequency band.

2.2.3.2 The interfered digital channels, be it either ATSC, DVB-T or ISDB, is provided by the digital transmitter tuned to channel 35 UHF.

2.2.3.3 The PAL-M signal level at the digital receiver input must be set to -30 dBm. This is the synchronism peak power level and the HP signal analyser (32) must measure it.

2.2.3.4 The signal level originating from the digital transmitter must be set to -30 dBm at the digital receiver input and should be measured by the HP signal analyser (32). Note that for this level, the PAL-M power at the receiver input is equal to the signal power originating from the digital transmitter. We call it the calibration level, i.e. 0 dB.

2.2.3.5 The RF generator (19) frequency should be initially set to 0 Hz offset.

2.2.3.6 The PAL-M transmitter should have its sound channel stereo modulated by 1 kHz tones with 50 kHz frequency deviation.

2.2.3.7 The PAL-M video channel should be modulated with 100% modulation index and by a "Zone Plate" signal (with movement).

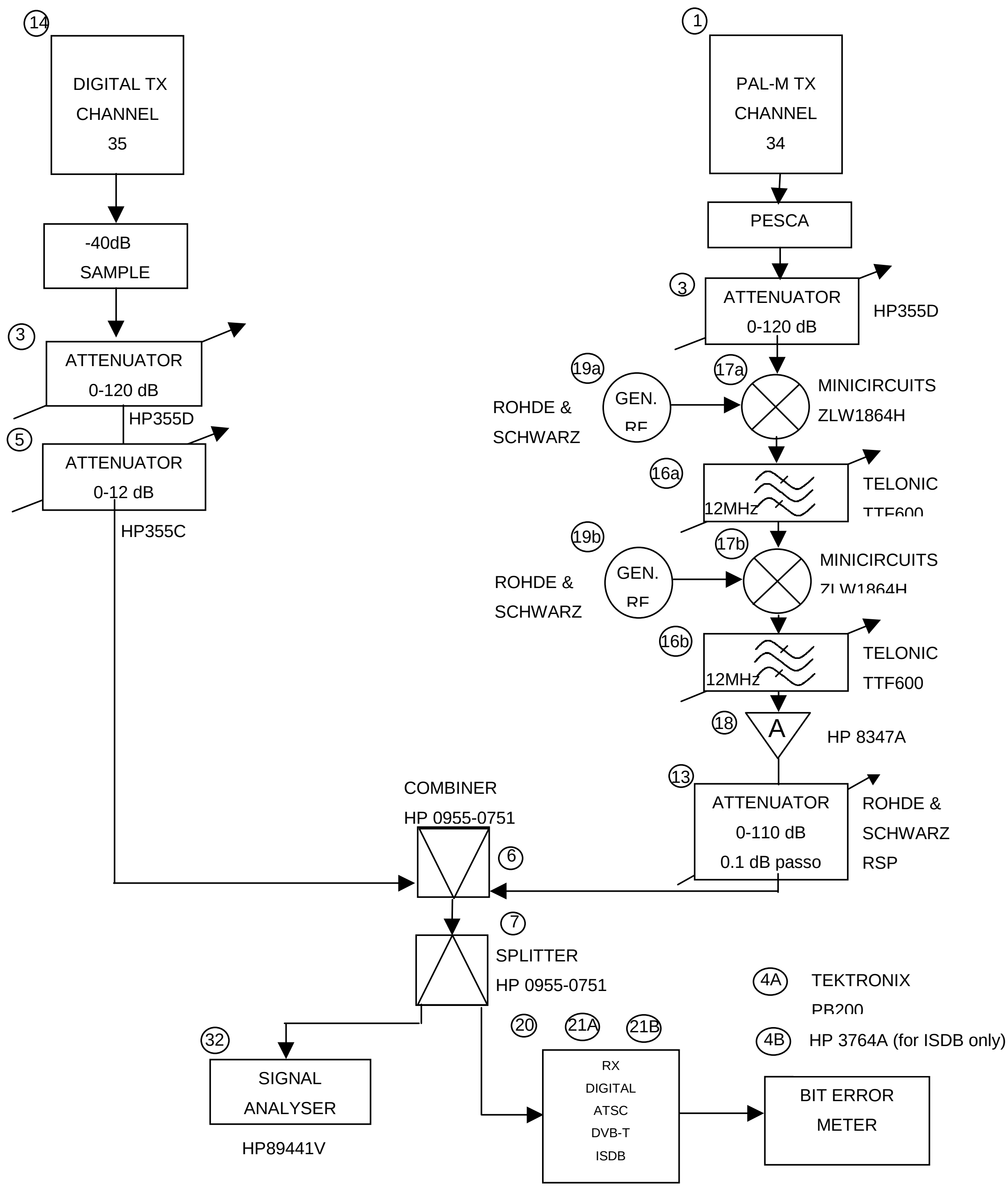
2.2.4 Measurement general description

For each one of the digital receivers used and for each frequency shifting between interfering and interfered signals, the protection ratio must be adjusted until the respective receiver bit error rate threshold is reached.

2.2.5 Equipment used

(1) PAL-M transmitter tuned to channel 34
(3) HP 0-120dB attenuator, model 355D
(4A) Tektronix PB200 BER measurement kit
(4B) HP3764A measurement kit (for ISDB only)
(5) HP 0-12dB attenuator, model 355C
(6) HP combiner, model 0955-0751
(7) HP splitter, model 0955-0751
(13) R&S 0-110dB, 0.1dB step attenuator, RSP.
(14) Digital transmitter tuned to channel 35
(16a/b) Telonic 12 MHz filter, model TTF600
(17a/b) Mini-Circuits mixer, model ZLW186MH
(18) HP amplifier, model 8347 A
(19a/b) R&S RF generator, model SMH
(20) ATSC digital receiver
(21A) DVB-T digital receiver
(21B) ISDB digital receiver
(32) HP 89441 V signal analyser

2.2.6 Measurement Block Diagrams



2.2.7 Tests Procedures

A) Lower adjacent PAL-M into digital interference (see fig. 2.2.6.1)

2.2.7.1) Adjust the RF generator's (19) frequency to produce, in the receiver input, the lower interference channel condition.

2.2.70.2) With the PAL-M and Digital 's channel attenuators, adjust the level signals at the receiver's input to the value indicated in items 2.2.3.3 and 2.2.3.4. These are considered as reference level.

2.2.7.3) Adjust the digital channel attenuators to obtain a 20dB attenuation level in relation to the reference level (i.e. -50dBm).

2.2.7.4) Through the PAL-M channel attenuator, increase the interfering signal level until BER (4) threshold is reached. To calculate the protection ratio, add the respective increase in signal level to 20dB, as shown below:

Protection Ratio$_{dB}$ = -(20$_{dB}$ + increase in signal level) dB

Record the results in table 2.2.8.1.

2.2.7.5) Repeat the procedures described in items 2.2.7.1 to 2.2.7.5 for the following frequency shifts:

a) Co-channel, offset=0Hz
b) For DVB-T system: Offset = +558,04Hz + n . 1674,11Hz (n integer positive and negative) until the offset approaches ±50KHz in the neighborhood of the channel frequency
c) Adjacent channels, ±6MHz
d) "Taboo" channels:

d1) ATSC System: ±7 BW, ±8 BW, +14 BW, +15 BW, where BW = 6MHz.

d2) DVB System: ±6 BW, +12 BW, where BW = 6MHz.

d3) ISDB System: ±6 BW, ±7 BW, +11BW, +12BW, +13BW

NOTES:

1) The TELONIC (16B) filter must be adjusted so that for any required shift the wanted signal corresponding to the interfering RF channel falls within the filter pass band.

2) Referring to the protection ratio calculations explained in item 2.2.7.4, there will be cases when it is necessary to attenuate the PAL-M signal level instead of increasing it. In this case the level variation must have a negative value in the protection ratio expression.

3) For all the values of frequency shift noticed in 2.2.7.5, record the protection ratio results in tables: 2.2.8.1, 2.2.8.2, 2.2.8.3 and 2.2.8.4.

2.2.8 Results tables

Observation: The items in red should be redone.

FREQUENCY OFFSETS (MHz)	PROTECTION RATIO (dB)					
	ATSC	DVB-T				ISDB
		3/4;1/16;2K	3/4;1/16;8K	3/4;1/8;2K	2/3;1/32;8K	3/4; 1/16; Mode 2 (4K); INT2 (0,1s)
0	3,80	6,15	6,20			6,35*
+6	-40	-26,51	-31,44			-28,71
-6	-33,3	-27,03	-25,93			-27,80

Table 2.2.8.1 (continued)

) OBS: This result was got with the "Comb filter" off. When the "Comb filter" is on, the result was **5,31.*

Table 2.2.8.1: PAL-M into Digital interference (co-channel and adjacent channel).

Frequency OFF-SET (Hz)	Protection Ratio (dB) DVB-T System **(3/4;1/16;2K)**
-1.116,07	6,77
-2.790,18	6,77
-4.464,29	6,77
-6.138,40	6,67
-7.812,50	6,87
-9.486,62	6,67
-11.160,73	6,77
-12.834,84	6,47
-14.508,95	6,77
-16.183,06	6,67
2.232,15	6,87
3.906,26	6,36
5.580,37	6,87
7.254,48	6,47
8.928,59	6,87
10.602,70	6,67
12.276,81	6,87
13.950,92	6,57
15.625,03	6,95
17.299,14	6,57

Table 2.2.8.2: Interference for small frequency offsets.

Table 2.2.8.3: Interference of PAL-M system into digital ATSC system for "taboo" channels.

BWs	FREQUENCY OFFSETS MHz	PROTECTION RATIO (dB)
+7	+42	-46,21
+8	+48	-48,23
+14	+84	-44,61
+15	+90	-46,51
-7	-42	-48,45
-8	-48	-43,95

Table 2.2.8.4: Interference of PAL-M system into digital ATSC system for "taboo" channels.

BWs	FREQUENCY OFFSETS MHz	PROTECTION RATIO (dB)	
		3/4;1/16;2K	**3/4;1/16;8K**
+6	+36	-29,59	-36,75
+12	+72	-26,47	-34,12
-6	-36	-33,57	-33,75

Table 2.2.8.5: Interference of PAL-M system into digital ISDB system for "taboo" channels.

BWs	FREQUENCY OFFSETS MHz	PROTECTION RATIO (dB)
+6	+36	-26,14
+7	+42	-25,86
+11	+66	-31,14
+12	+72	+1,3*
+13	+78	+14,86*
-6	-36	-23,9
-7	-42	-24,26

*) Observation: These results occurred because the ISDB receiver did not have "RF Filter" in its input (the FI frequency in the ISDB input is 37,15MHz).

2.2.9 - Comments

To evaluate the interference grade into lower adjacent channel, with the presence of sound channel into PAL-M signal, we measures the protection ratio under many sound's channel conditions and the values are shown in the tables below:

Sound channels condition	Protection Ratio D/U (dB)		
	ATSC	DVB 3/4; 1/16; 2K	ISDB 3/4; 1/16; Modo 2 (4K); INT 2 (0,1s)
Stereo + SAP off-set: 0Hz	-32,70	-30,10	-27,75
Stereo off-set: 0Hz	-33,30	-30,15	-27,80
Mono off-set: 0Hz	-33,30	-31	-27,72
No modulation	-38,82	-38,82	Not measured

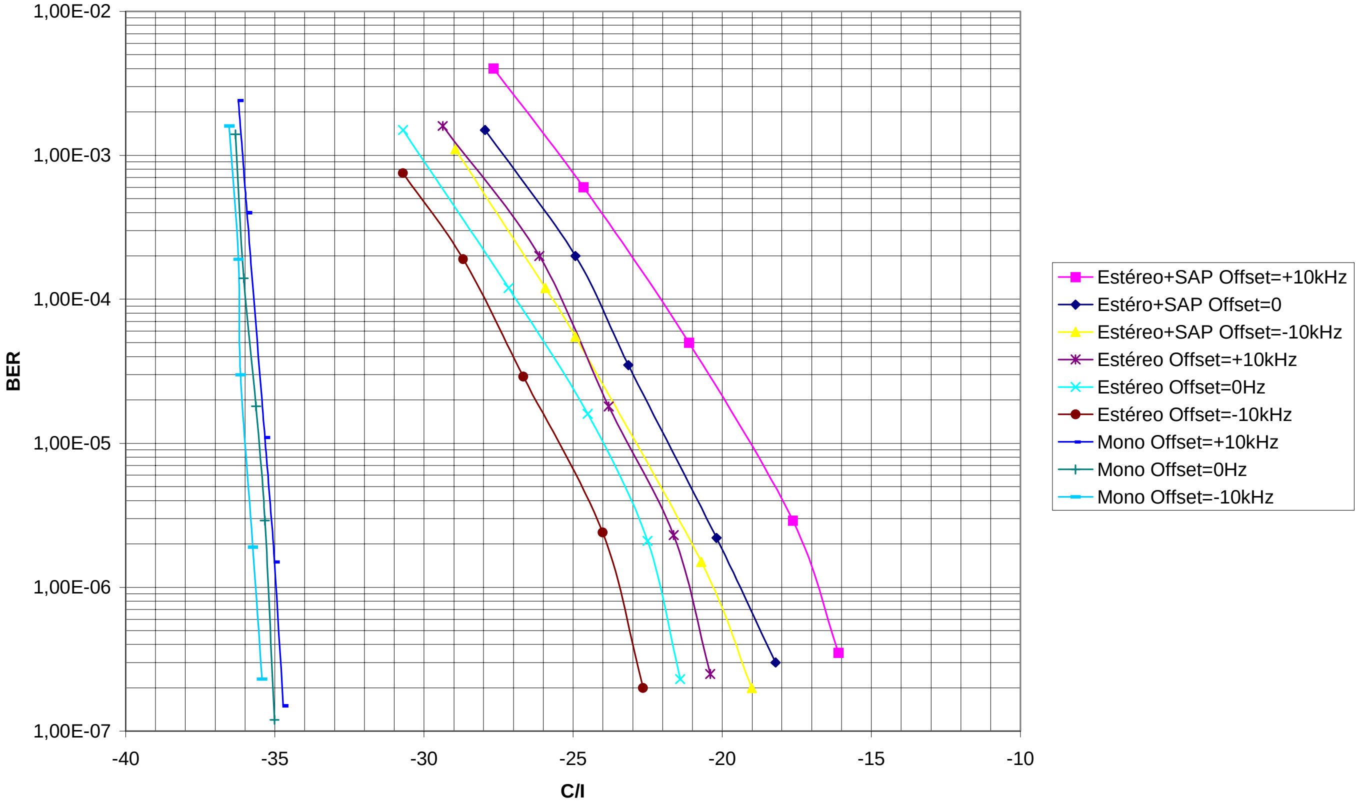
Sound channels condition	Protection Ratio D/U (dB)	
	ATSC	DVB 3/4; 1/16; 2K
Stereo + SAP off-set: +10kHz	-17,50	-29,80
Stereo off-set: +10kHz	-21,90	-29,90
Mono off-set: +10kHz	-35	-30,45

Sound channels condition	Protection Ratio D/U (dB)	
	ATSC	DVB 3/4; 1/16; 2K
Stereo + SAP off-set: -10kHz	-21,50	-30,30
Stereo off-set: -10kHz	-24,60	-30,70
Mono off-set: -10kHz	-35,90	-31

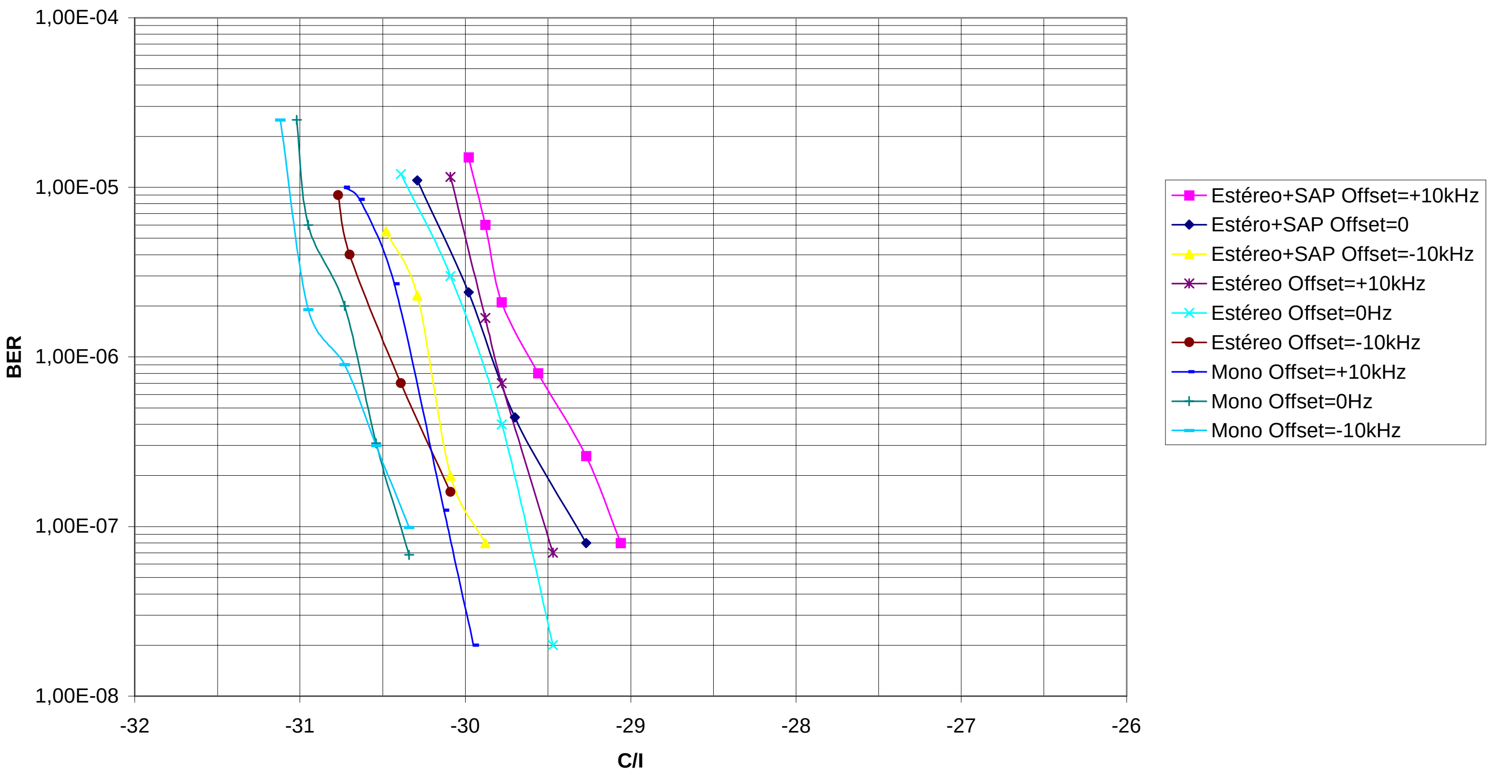
Note 1: The protection ratio values are for $3x10^{-6}$ error rate threshold.

Note 2: For others error rates threshold, see the graphs below:

Graph 2.2.8.1: BER vs. Interference signal relation
Interference: Lower adjacent channel - ATSC



Graph 2.2.8.2: BER vs. Interference signal relation
Interference: Lower adjacent channel
DVB 64 QAM FEC 3/4 GI 1/16 2K



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2.3 Digital into digital interference (co-channel, adjacent and "Taboo" channels)

2.3.1 Aim

This test main purpose is to verify, in a laboratory environment, the DVB-T and ATSC behaviours when a digital TV channel is interfered by another digital TV channel. This could be in the form of co-channel, upper/lower adjacent and taboo channel interference.

This interference can be measured by evaluating the protection ratio parameter. This is the ratio (in dB) between the wanted signal power (D) and the interfering signal power (U):

Protection Ratio = D/U_{db}

Where: D= wanted signal

U = interfering signal

In this analysis the wanted signal will be originating from a digital transmitter and the interfered signal will be also obtained of the same digital transmitter after introducing, the original digital signal, with a 1600 us delay, and a frequency offset = 100Hz.

This procedure is necessary to separate the "wanted signal" of the "interference signal".

2.3.2 Basic parameters characteristics

2.3.2.1 D= wanted signal power level (in dBm) at the receiver input.

2.3.2.2 U= interfering signal power level (in dBm) at the receiver input.

2.3.2.3 D/U= protection ratio (in dB).

D/U= D (dBm) - U (dBm)

2.3.2.4 BER = Bit Error Rate

2.3.3 Initial values and characteristics

2.3.3.1 Wanted signal power level D= -60dBm (at the receiver input)

2.3.3.2 Wanted signal to noise ratio = D/N = greater than 50dB.

2.3.3.3 Protection ratio = D/N= greater than 50dB.

2.3.4 Measurement general description

Keeping the wanted channel signal level constant, vary the interfering channel signal level until it reaches the BER threshold, measured in the BER test set.

2.3.5 Equipment used

(3) HP 0-120dB attenuator, model 355D

(4A) Tektronix PB200 BER test set

(4B) HP 3764A BER Test set (for ISDB only)

(6) HP combiner, model 0955-0751

(7A) HP splitter, model 0955-0751

(7B) HP splitter, model 0955-0751

(13) R&S 0-110dB 0.1dB step attenuator, model RSP

(16A) Telonic 12 MHz filter, model TTF600

(16B) Telonic 12 MHz filter, model TTF600

(17A) Mini-Circuits mixer, model ZLW186MH

(17B) Mini-Circuits mixer, model ZLW186MH

(18) HP amplifier, model 8347 A

(19A) R&S RF generator, model SMH

(19B) R&S RF generator, model SMH

(20) ATSC digital receiver

(21A) DVB-T digital receiver

(21B) ISDB digital receiver

(25) NEC digital transmitter (ATSC, DVB-T or ISDB) tuned on channel 35

(15) R&S SMY02 RF Generator

(32) HP 89441 V signal analyser

(04) HP 0-12dB attenuator, model HP355C

(46) BIRD attenuator model ATT (2 units of 20 dB)

(31) TAS Echo Simulator, model 4500

	DIGITAL INTO DIGITAL INTERFERENCE (CO-CHANNEL, ADJACENT AND "TABOO" CHANNELS)	CÓDE: MNAS222	
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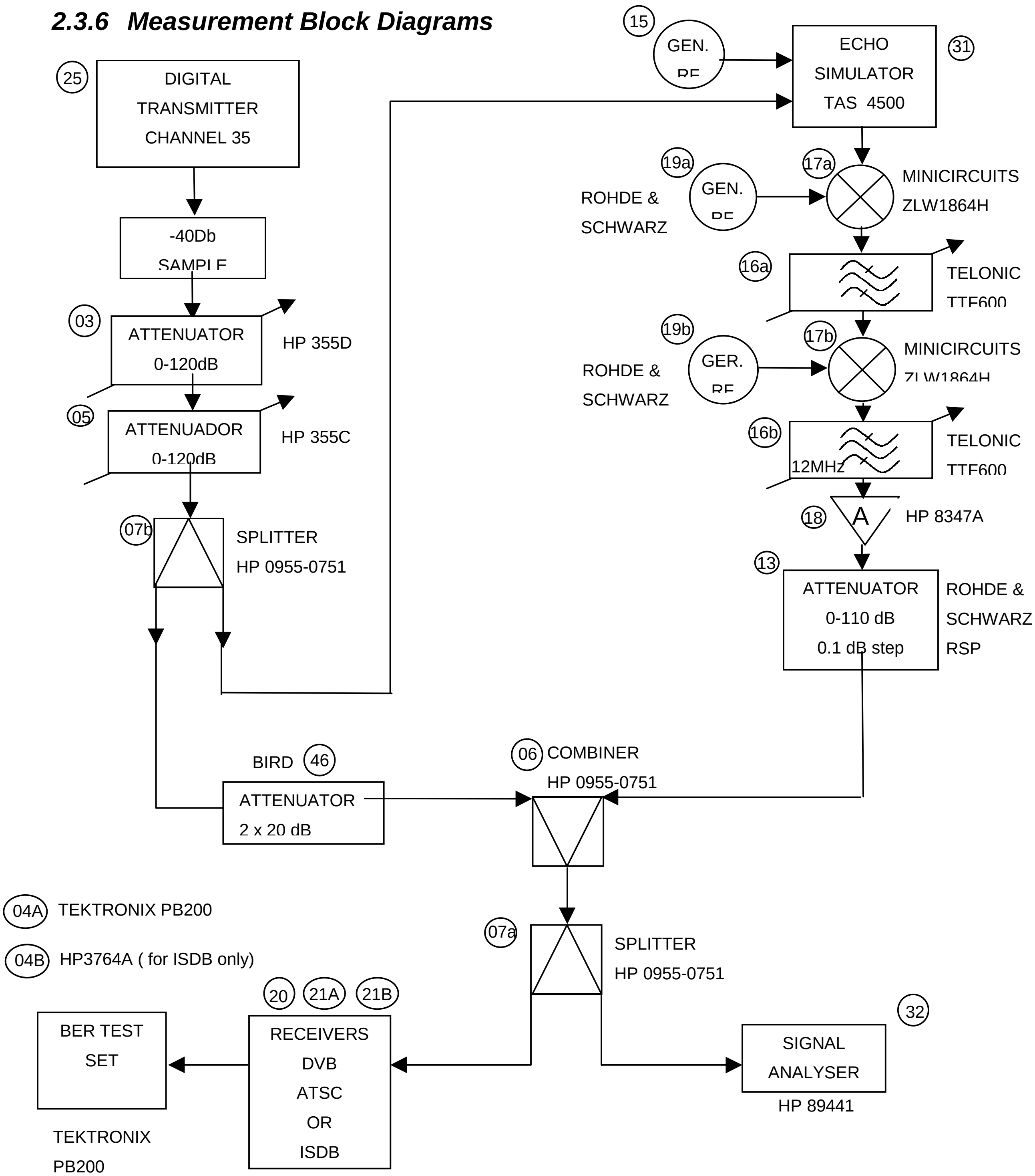
2.3.6 Measurement Block Diagrams



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2.3.7 Test procedures

2.3.7.1) With the attenuator (13) at the maximum position, adjust the attenuators (3) and (5) to obtain in the receivers input an approximately level of -60dBm. This is the reference level to the wanted signal (interfering signal) i.e. D level in dBm.

2.3.7.2) Adjust the echo delay time in the echo simulator (31), to the value of 1600us. Also adjust to a 100Hz 0ffset.

2.3.7.3) Adjust the RF generator (15) frequency to 739Hz. The echo simulator (31) needs this reference to generate in its output the delayed (1600us and 100Hz offset) 35 channel (599MHz).

2.3.7.4) Adjust the RF generator (19a) frequency to obtain a modulated digital signal around the 450MHz (450MHz ±3MHz) frequency in the Telonic (16a) filters output.

2.3.7.5) Adjust the RF generator (19b) frequency to obtain in the Telonic (16a) filter output, the interference signal with the wanted frequency. The central frequency should be adjusted, in each case, to the central frequency of the interference signal.

2.3.7.6) Adjust the attenuator (13) so that the BER test set (4) indicates the BER threshold ($3x10^{-6}$).

2.3.7.7) Through the attenuators (3) and (5), attenuate the wanted channel signal to the maximum and read in the Signal analyser (32) the interference signal channel. This is the value of U (dBm).

2.3.7.8) Calculate the Protectio ratio by using the following expression:

(D-U)dB = D(dBm) - U(dBm)

Set the results in tables 2.3.8.1 (ATSC), 2.3.8.2 (DVB) and 2.3.8.3 (ISDB).

2.3.8 Results

Table 2.3.8.1: ATSC

Interference Channel		Protection Ratio D/U (dB)
Designation	Frequency (N X BW)	
Upper adjacent	+ BW	-27
Lower adjacent	- BW	-27
Co-channel	0 X BW	15
"Taboos"	+15 BW	-37,90
	+14 BW	-38,70
	+8 BW	-40,70
	+7 BW	-39,20
	-7 BW	-40,70
	-8 BW	-38,10

BW = Bandpass = 6 MHz.

Table 2.3.8.2: DVB

Interference Channel		Protectio Ratio D/U (dB)			
Designation	Frequencies N X BW	3/4;1/16;2K	3/4;1/16;8K	3/4;1/8;2K	3/4;1/32;8K
Upper adjacent	+ BW	-25,90	-24,10		
Lower adjacent	- BW	-25,60	-25		
Co-channel	0 X BW	20	19,80		
“Taboos”	+6 BW	-37	-38,90		
	+12 BW	-34,50	-36,60		
	-6 BW	-36,60	-38,70		

BW = Bandpass = 6 MHz.

Table 2.3.8.3: ISDB

Interference Channel		Protection Ratio D/U (dB)
Designation	Frequencies N X BW	
Upper adjacent	+ BW	-24,2
Lower adjacent	- BW	-23,8
Co-channel	0 X BW	18,7
"Taboos"	+13 BW	15,6(*)
	+12 BW	17,8(*)
	+11 BW	-28,3
	+7 BW	-21,6
	+6 BW	-21,5
	-6 BW	-19,9
	-7 BW	-19,4

BW = Bandpass = 6 MHz.

(*) These results occurred because the ISDB receiver did not have "RF filter" in its input (The FI frequency of the ISDB receiver is 37,15MHz).

2.4 - Interference by a continuos Signal (CW)

2.4.1 Aim

At the beginning the aim of this measurement method was to evaluate the degradation in the ATSC, DVB-T or ISDB digital signals interfered by a continuos (CW) narrow band signal. After this, we got the conclusion that it was also interesting to modulate the continuos signal with a 1kHz senoidal interference and a 25kHz deviation.

This interference is measured by the evaluation of the "protection ratio", which is the ratio, in dB, between the desired signal power and the interference signal power.

Protection ratio = D/U(dB)

With D = wanted signal and U = interfering signal

The measurement is done with a signal in the same frequency of the digital center frequency channel and in frequencies presenting shifting.

2.4.2 Basic parameters characteristics

The main parameter, to be used for the "protection ratio" determination, will be the BER threshold.

2.4.3 Initial values and characteristics

2.4.3.1 - The "CW interference signal" or the "modulated FM signal" must be provided from the RF SMH R&S Generator (19) and must be injected into R&S attenuator - step 0.1dB (13).

2.4.3.2 - Real transmitters, through attenuators, must provide the interference digital channel for ISDB, DVB or ATSC system.

2.4.3.3 - Initial adjusts of the reference level for interference signal measurements:

Turn the digital channel signal off in the point A and replace for a 50-ohm load (44).

The interference CW level in the receiver input must be adjusted to +1,5 dBm, measured by the HP signal Analyser (32), acting on attenuator (13). Take note of the interference channel position of the attenuator (13). This will be the reference value.

2.4.3.4 - Initial adjusts of the digital signal level at the receiver's input

For this measurement, the interference channel attenuators must be adjusted to its maximum attenuation position. The 30dB attenuator (44) should be taken out and the signal from attenuator (05) should be directly on A point. Under these conditions, the attenuators (03) and (05) shold be adjusted to -25dBm, which will be the reading in HP signal analyzer (32). After this, the 30dB attenuator (44) should be replaced at the circuit, and the signal level at the receiver's input can be calculated by:

D (dBm) = (value read by signal analyzer)dBm - 30dB

Take note of this D value, it will be used as reference for all measurements.

2.4.4 Measurement general description

For each used digital receiver and for each frequency offset between the interference signal and the digital channel central frequency, the protection ratio must be adjusted until obtain the respective receivers error threshold.

2.4.5 Equipment used

(3) HP 0-120dB attenuator, model 355D

(4A) Tektronix PB200 BER test set

(4B) HP 3764A BER Test set (for ISDB only)

(5) HP0-12dB attenuator, model HP355C

(6) HP combiner, model 0955-0751

(7) HP splitter, model 0955-0751

(13) R&S 0-110dB 0.1dB step attenuator, model RSP

(14) NEC channel 35 Digital transmitter

(19) R&S RF generator, model SMH

(20) ATSC digital receiver

(21A) DVB-T digital receiver

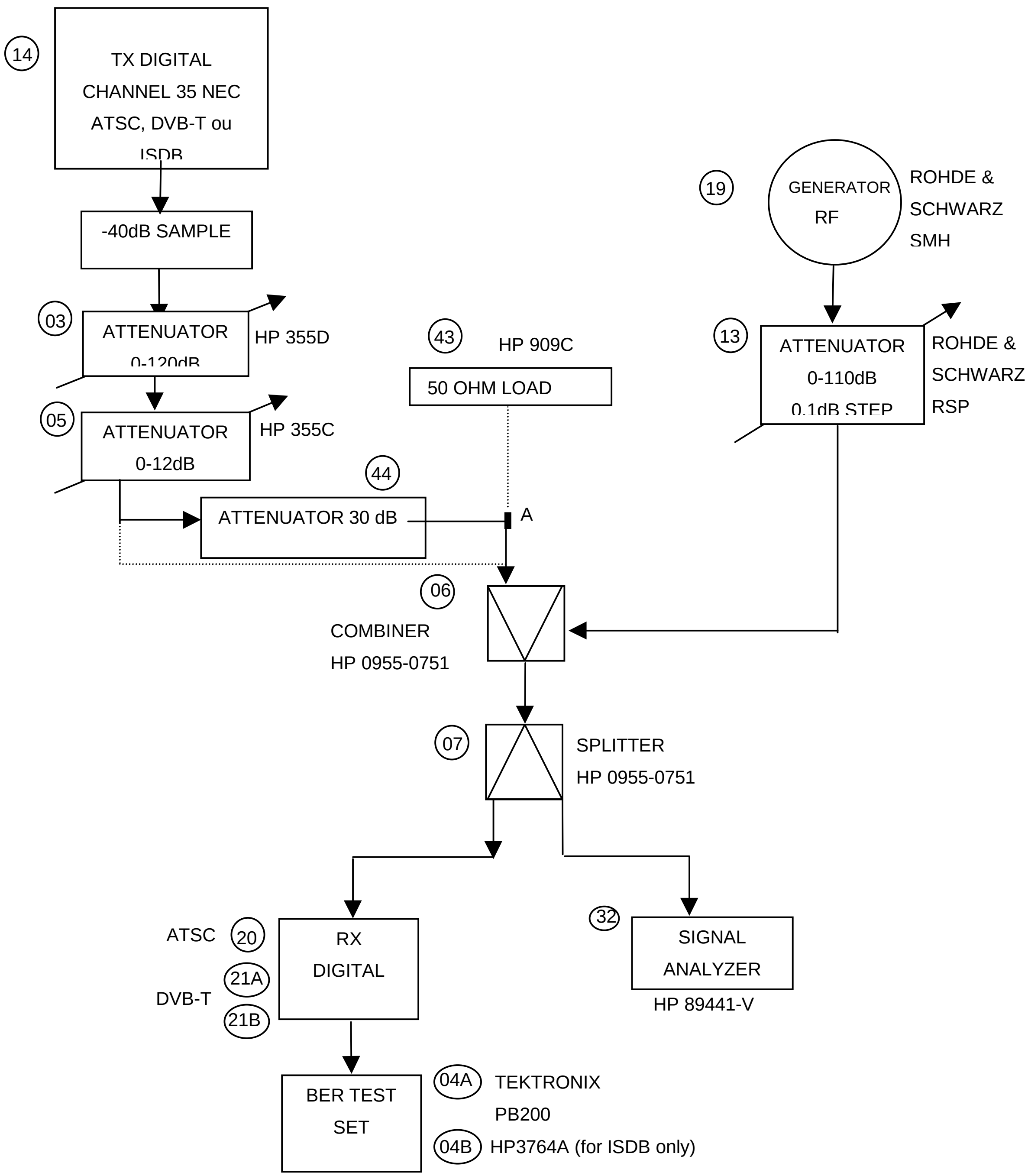
(21B) ISDB digital receiver

(32) HP 89441 V signal analyser

(44) Attenuator 30dB

(43) 50-ohm load - HP909C

2.4.6 Block diagrams



2.4.7 Test procedures

Observation: The procedures described below should be accomplishedwith "pure" CW first, and after with a 1kHz FM modulation, with 25 kHz deviation, for ATSC, DVB-T and ISDB.

2.4.7.1 - Adjust the digital signal level at the initial condition described at 2.4.3.4.

2.4.7.2 - Adjust the RF generator (19) frequency to the centered frequency of the 35 channel (599MHz).

2.4.7.3 - Act on the attenuator (13) until obtain the "BER threshold" in the BER test set.

2.4.7.4 - Calculate the interference signal power value U (dBm) by the position of the attenuator (13) in relation with the initial value of item 2.4.3.3.

2.4.7.5 - Calculate the protection ratio subtracting the U value (dBm) reached in 2.4.7.4 of the D value (dBm) adjusted in 2.4.7.1

2.4.7.6 - Repeat the procedures 2.4.7.3 until 2.4.7.5 to successive offset from 0,2MHz until ±3 MHz and after to 0,5MHz until ±6MHz offset. Specially for ATSC system, accomplish more measurements around the pilot frequency: Δf= (-2,6MHz; -2,65 MHz; -2,675 MHz; -2,7 MHz; -2,725 MHz; -2,75 MHz).

2.4.7.7 - Trace the curves 2.4.8.1 9D/U against "pure" CW offset) and 2.4.8.2 (D/U to CW Modulated in FM, by a 1kHz signal with 25kHz deviation).

2.4.7.8 - Specially for DVB-T system, beyond the measurements of 2.4.7.6 item, accomplish also the measurements for these frequency offsets:

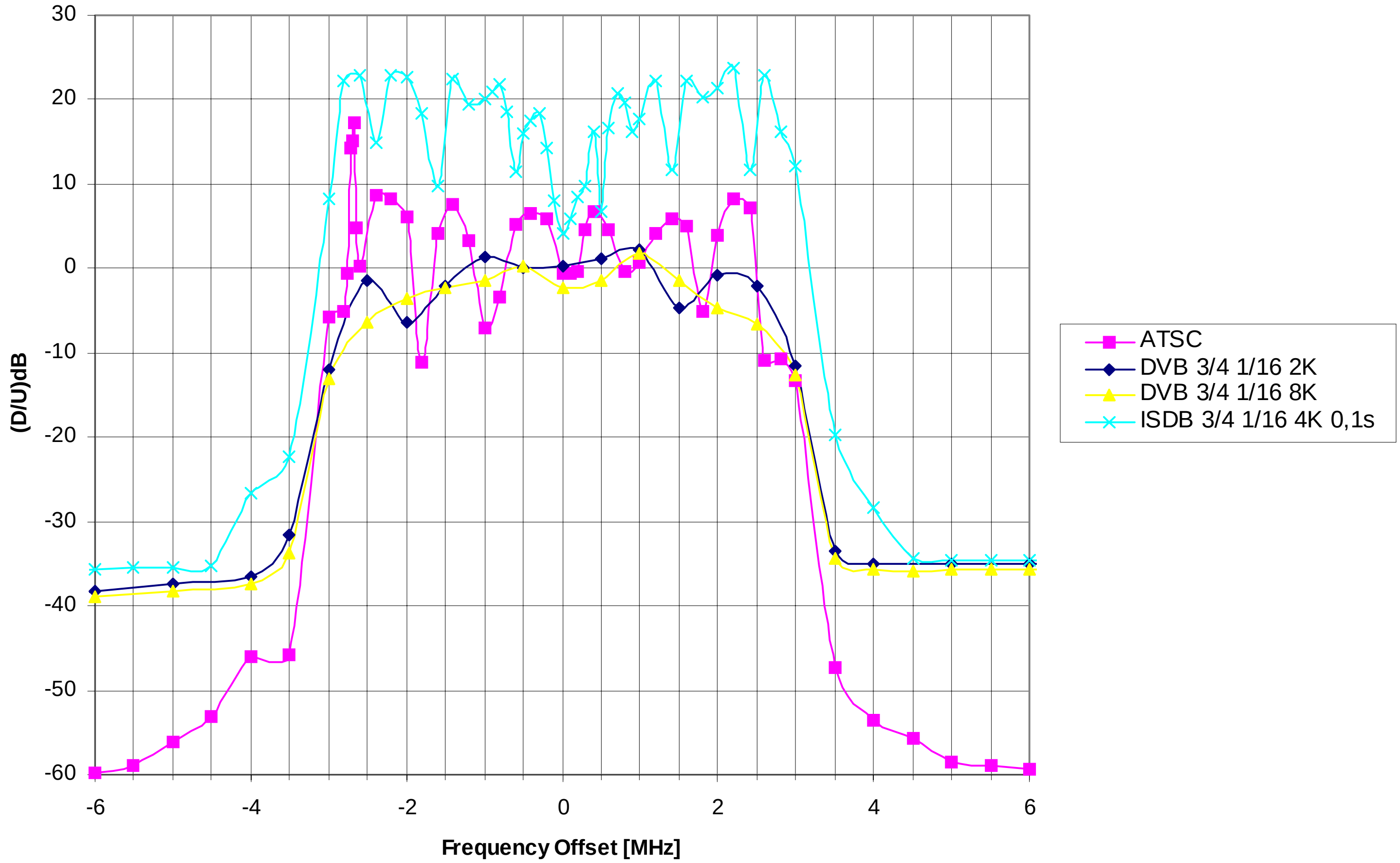
+1674,11Hz + n.3348,21 (integer N positive or negative).

These measurements should be carried out until ±40KHz.

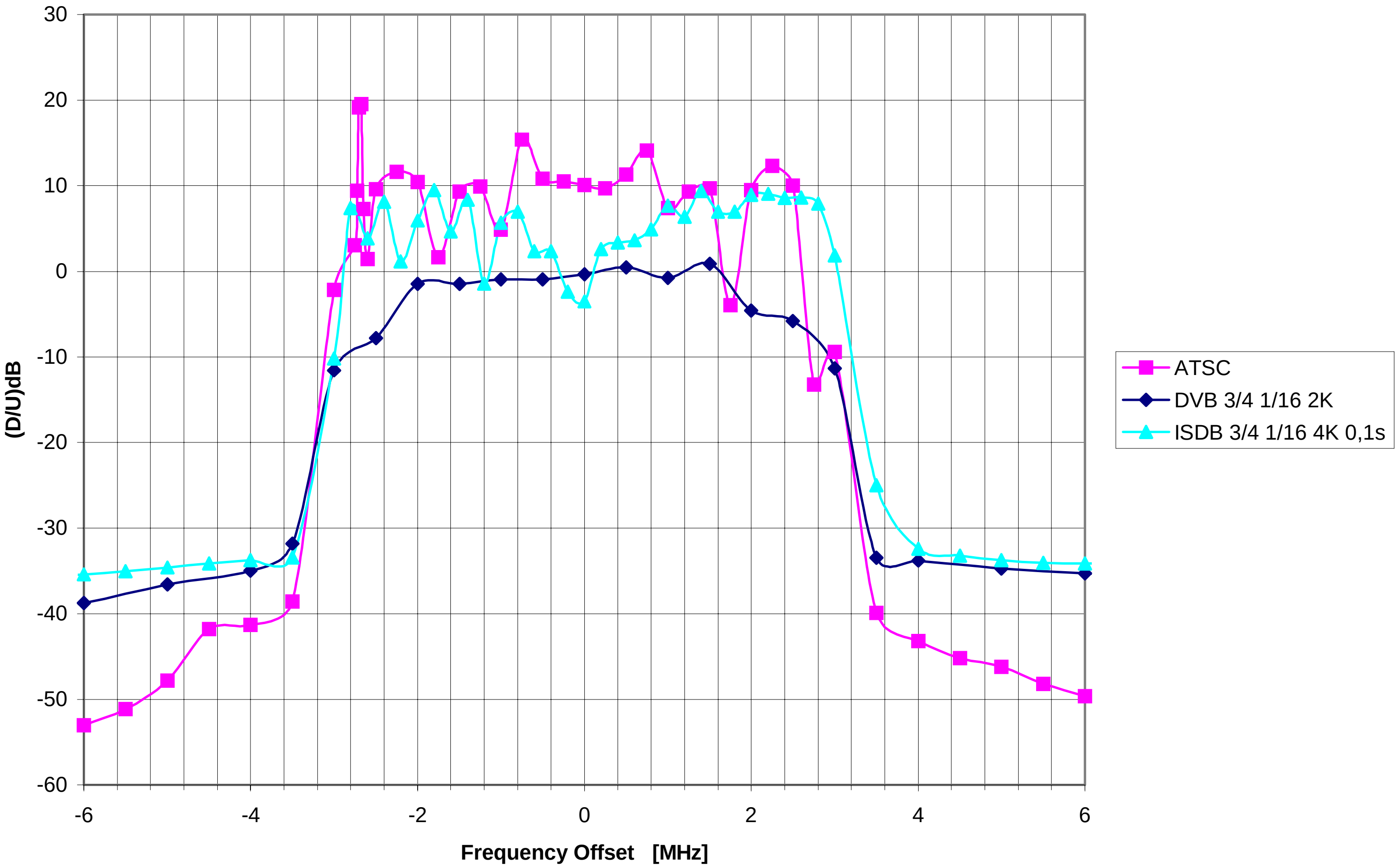
2.4.7.9 - Using the data from 2.4.7.8 item, trace curves 2.4.8.3 (protection ratio for small frequency offsets - DVB-T system).

2.4.8 Results

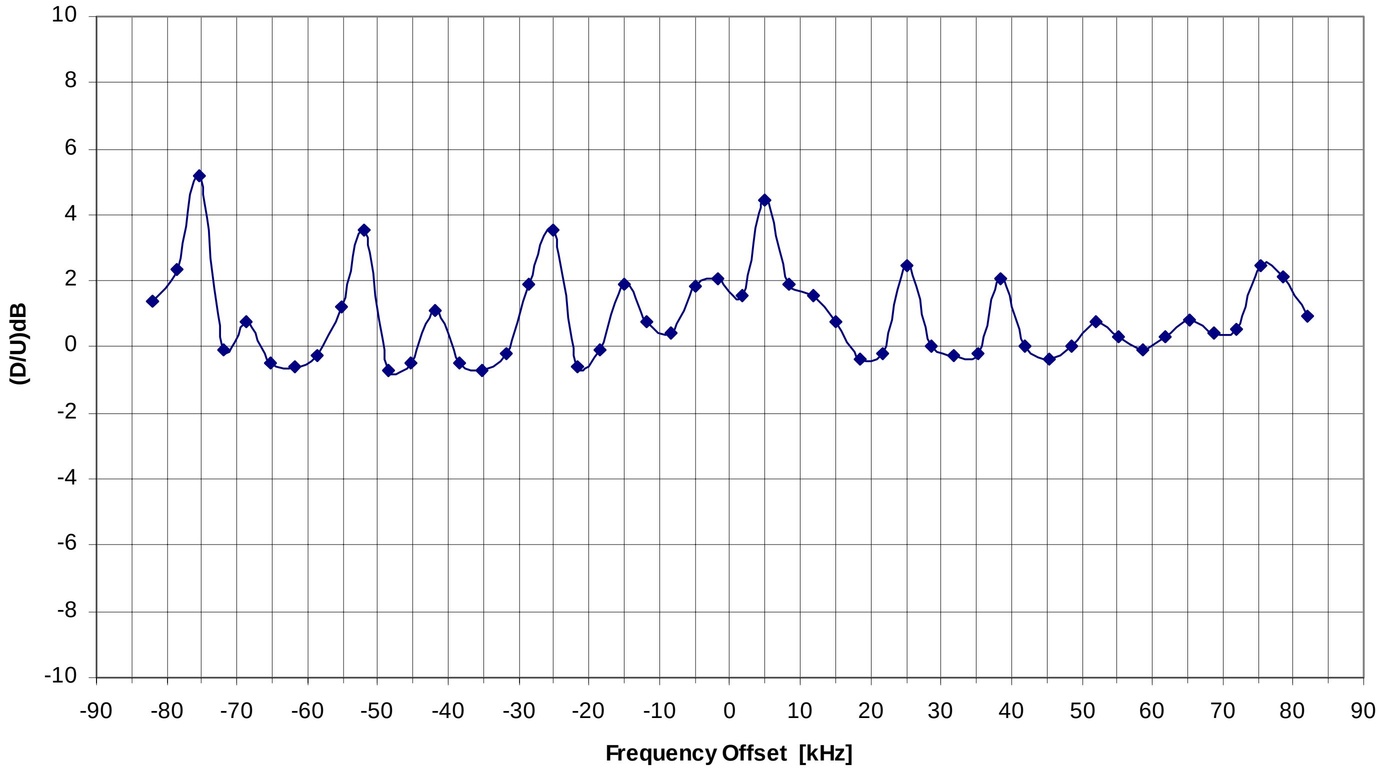
Graph 2.4.8.1: Protection Ratio for CW interference into Digital TV Channel



Graph 2.4.8.2: Protection ratio for FM interference into Digital TV channel



Graph 2.4.8.3: Protection Ratio for CW interference into Digital TV channel
Small offsets analisys
DVB 64 QAM FEC 3/4 GI 1/16 2K



2.5 ATSC, DVB-T and ISDB systems behaviour with impulse noise interference

2.5.1 Aim

This measurement method aims to evaluate the performance degradation produced by noise impulsive presence into Digital channel.
This degradation is measured by the evaluation of "Protection ratio threshold".

2.5.2 Basic parameters characteristics

2.5.2.1 C= wanted signal power level (in dBm) at the receiver input.

2.5.2.2 BER: Bit error rate

2.5.3 Initial figures and characteristics

2.5.3.1 C= wanted signal power level = -40dBm.

2.5.3.2 Protection ratio = C/N = greater than 50dB.

2.5.3.3 The impulsive noise will be generated by a prototype: Ignition Interference Simulator. Noise variable from 1us to 999us.

2.5.4 Measurement general description

There will be two measurements criterions:

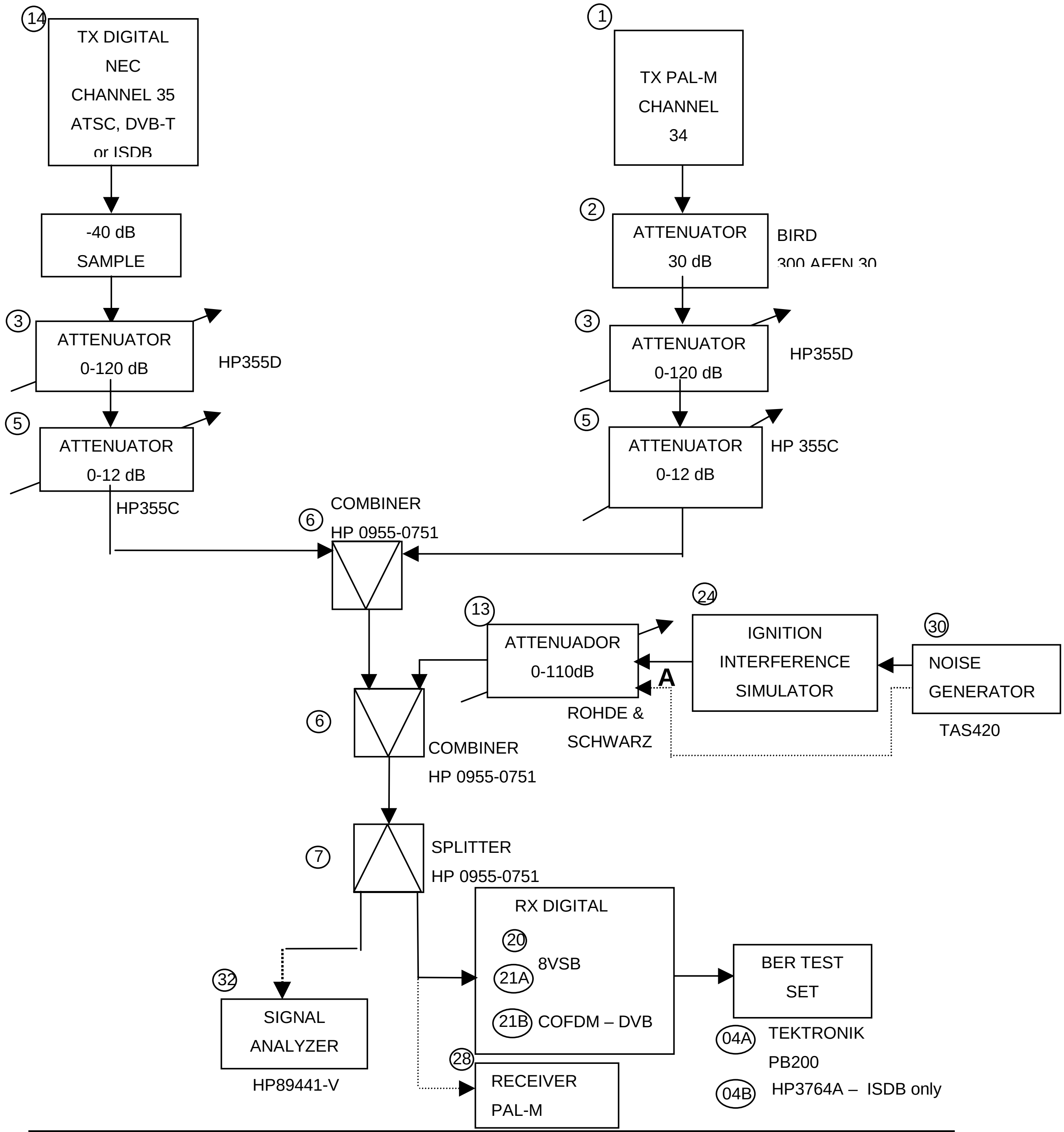
Criterion 1: Keeping the digital signal level constant, to many values of "Pulse Width", vary the noise level injected into "width" until we reach the BER threshold, read by BER test set.

Criterion 2: Keeping the digital level signal constant, and also keeping the noise injected into "Width", vary the time of the "width", taking notes of the Bit error rate reached.

2.5.5 Equipment used

(1) PAL-M Transmitter, channel 34
(2) BIRD 30dB attenuator, model 300AFFN30
(3) 2 HP 0-120dB attenuators, model 355D
(4A) Tektronix PB200 BER test set
(4B) HP 3764A BER Test set (for ISDB only)
(5) HP0-12dB attenuator, model HP355C
(6) HP combiner, model 0955-0751
(7) HP splitter, model 0955-0751
(13) R&S 0-110dB 0.1dB step attenuator, model RSP
(14) NEC channel 35 Digital transmitter
(20) ATSC digital receiver
(21A) DVB-T digital receiver
(21B) ISDB digital receiver
(28) PAL-m receiver
(30) TAS 420 Noise generator
(24) Ignition Interference Simulator
(32) HP 89441 V signal analyser

2.5.6 Block Diagrams



2.5.7 Test Procedures

A) Calibration procedure for Criterion 1 execution (see item 2.5.4)

This procedure creates a reference qualitative parameter to analyze the noise impulsive interference. The impulsive noise will be originated from an Ignition interference Simulator, with variable time "pulse width" from 1us to 999us. This reached noise will be combined with a signal obtained from a PAL-M transmitter.

Follow these procedures:

A1) Attenuate to the maximum the attenuators (3) and (5) from digital channel.

A2) Adjust the PAL-M attenuators (3) and (5) to reach the synchronism peak power from approximately -15dBm read by signal analyzer (32).

A3) Adjust the interference simulator (24) "pulse width" to 500us.

A4) turn the interference simulator (24) on. Turn the noise generator (30) on and act on attenuator (13) until occasionally white points turn visible in the PAL-M receiver screen.

A5) Take the interference simulator out of the circuit and turn the noise generator (30) on directly to attenuator's input (13) - point A.

A6) In the conditions of A5 item, measure the noise power in the 6MHz bandwidth, using the signal analyzer (32). Take notes of this value, it will be the reference for all noise measurements of the Criterion 1, explained in item 2.5.4. Register the attenuator's (13) position too.

B) Criterion 1 - To evaluate the digital channel interference.

Observation: Do this test for: 50us, 100us, 150us, 200us, 300us, 400us, 500us, 600us, 700us, 800us and 900us.

B1) Attenuate to the maximum the PAL-M attenuators (3) and (5), with the noise source turned off.

B2) Adjust the digital channel attenuators (3) and (5) to read in the signal analyzer (32) approximately the level -40dBm. Register this value C of the signal.

B3) Turn the noise source and act on attenuator (13) until the BER test set (4) reaches the BER threshold.

B4) Check the amount of decibels, which were attenuated, in relation to the attenuator's position, registered in item A6. Subtract this number of the of the noise power value measured in A6, calculate the noise in 6MHz in dBm. Call this noise as "Equivalent Noise Neq").

B5) Calculate the behavior (C/Neq)dB, subtracting the value reached in B4, of the digital signal read in B2.

B6) The procedures described above should be done for ATSC, DVB-T and ISDB. Take note in the table 2.5.8.1.

B7) With the results of item B6, trace curves 2.5.8.1: Relation (C/Neq)dB vs. Impulse noise bandwidth (us).

C) Criterion 2: Evaluating the digital channel interference.

C1) Leave the signal PAL-M attenuators (3) and (5) in the maximum.

C2) Leave the noise attenuator (13) in the maximum position.

C3) Adjust the digital signal attenuators (3) and (5) to read in the signal analyzer (32) the approximately level of -40dBm. Take note of this value and the position of the respective attenuators.

C4) Leave the digital signal attenuators (3) and (5) in the maximum.

C5) Take the interference simulator out of the circuit and turn the noise generator on directly to the attenuator's input (13) - point A.

C6) In the conditions of item C5, using the signal analyzer (32) adjust the attenuator (13) so that the noise power in the 6MHz bandwidth is 5dB upon the digital signal power level in item C3.

C7) Insert the interference simulator in the circuit again and turn the digital signal attenuators (3) e (5) back to the position obtained in item C3.

C8) In the conditions of item C7, vary the noise pulse width between 10us and 800us, always registering the correspondent reading in the BER test set.

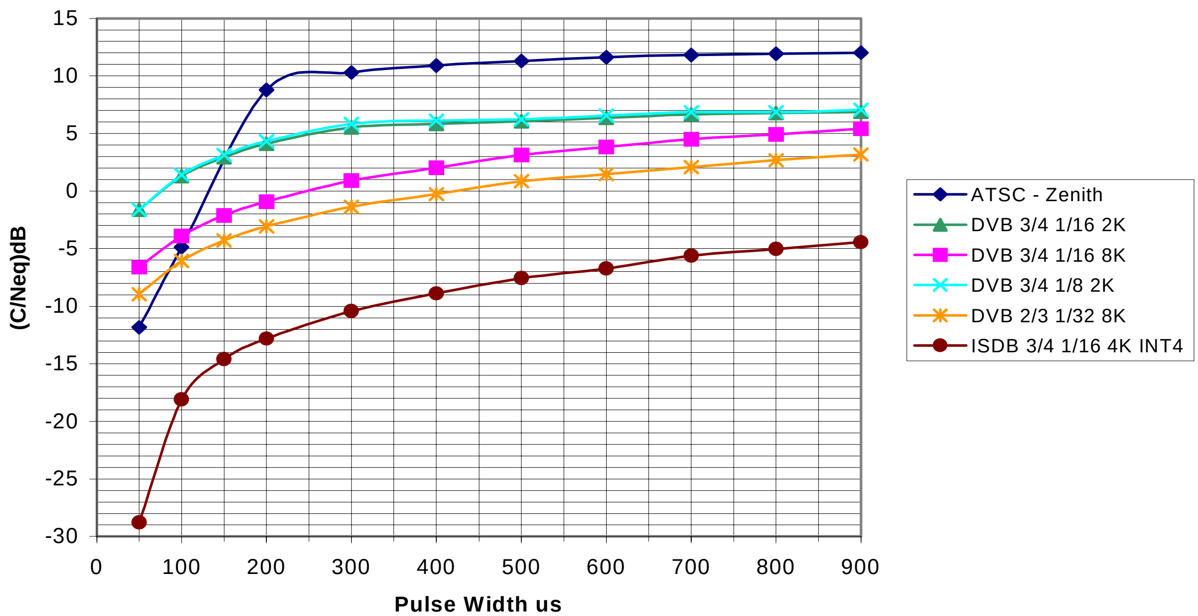
C9) With the results of item C8, trace curves 2.5.8.2: Bit error Rate *vs*. Noise Pulse Width (us).

2.5.8 Resultados

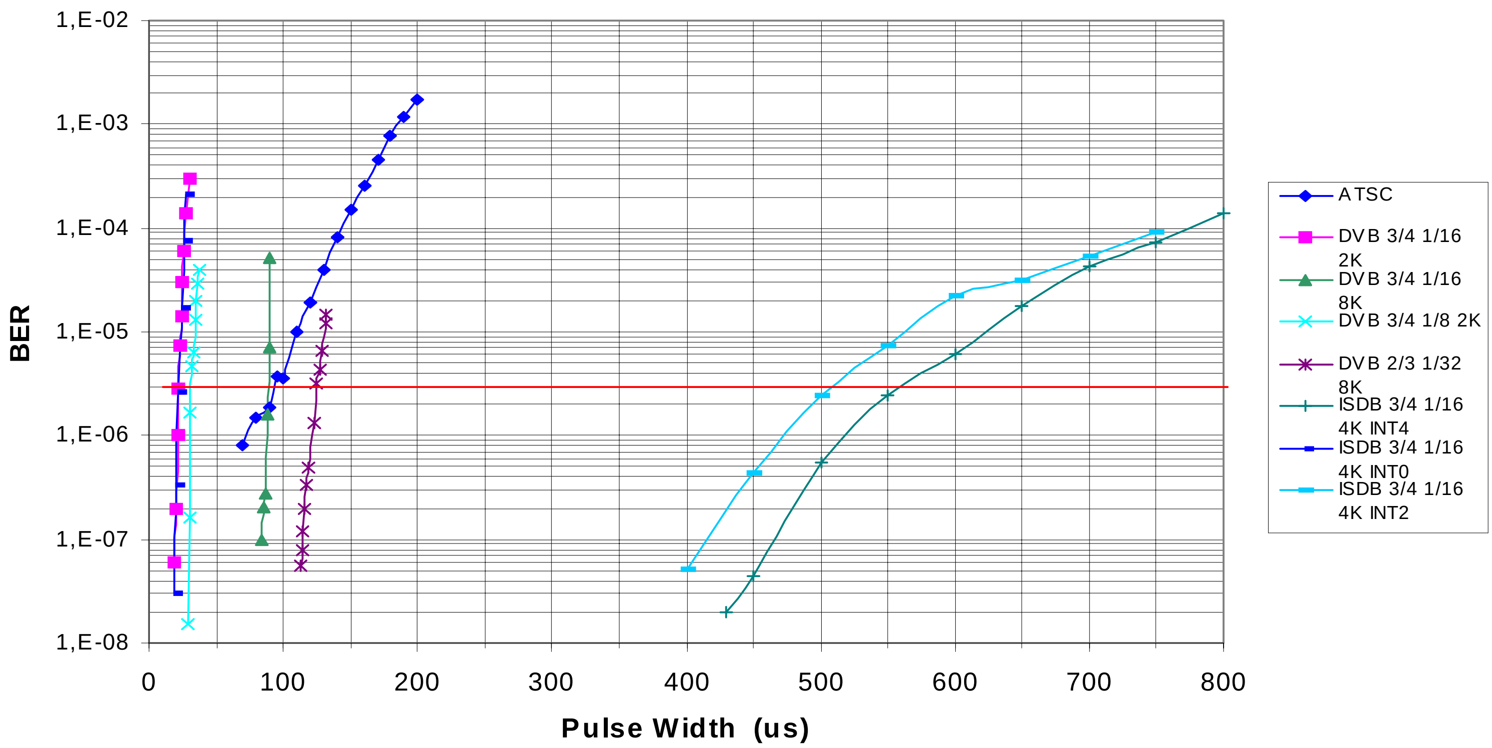
Table 2.5.8.1

Width (µs)	Behaviour (C/Neq)dB					
	8VSB	COFDM				ISDB
		3/4; 1/16; 2K	3/4; 1/16; 8K	3/4; 1/8; 2K	2/3; 1/32; 8K	64QAM 3/4; 1/16 Modo2=4K; INT4
50	-11,8	-1,6	-6,6	-1,6	-9,0	-28,8
100	-4,9	+1,3	-3,9	+1,4	-6,1	-18,1
150						-14,6
200	+8,8	+4,1	-0,9	+4,3	-3,1	-12,8
300	+10,3	+5,5	+0,9	+5,8	-1,4	-10,4
400	+10,9	+5,8	+2,0	+6,1	-0,3	-8,9
500	+11,3	+6,1	+3,1	+6,2	+0,9	-7,6
600	+11,6	+6,3	+3,8	+6,6	+1,5	-6,7
700	+11,8	+6,7	+4,5	+6,9	+2,1	-5,6
800	+11,9	+6,8	+4,9	+6,9	+2,7	-5,0
900	+12	+6,9	+5,4	+7,1	+3,2	-4,5

Graph 2.5.8.1: (C/Neq)dB *vs. Noise Impulsive Pulse Width*



Graph 2.5.8.2: Error rate *vs. Pulse Width* (us)



2.6 Simultaneous Interference of Digital & Noise over a PAL-M Analogic Channel

2.6.1 Aim

This measurement method aims the evaluation of the degradation produced over a PAL-M analogic signal, while under simultaneous interference from both a digital signal and Gaussian noise.

The interfering digital channel may be either one of the following types: adjacent below, adjacent above, co-channel and "Taboo" channels.

In this degradation evaluation, the independent variable is the ratio of interfered signal power (PAL-M) over the interfering noise power (C/N). The dependant variable is the ratio of interfered signal power over the interfering signal power (C/I) while the parameter variable is represented by the 3 image quality levels, i.e., Grade 3, Grade 4 and LOP. Thus, for each interfering channel condition (co-channel, upper adjacent, etc), 3 (three) curves must be then generated, each one corresponding to each one of those video quality Grades.

2.6.2 *The Basic Parameters Characteristics*

The basic parameters for the determination of the ratio C/N over C/I, with parameters based on the video quality Grade, are as follows:

- C/N (dB) = dB ratio between the power at the synchronism peak of the interfered signal (PAL-M) and the gaussian noise power at the receiver input measured in the range of the receiver noise (this range must be considered as 6 MHz).
- C/I (dB) = ratio between the power at the synchronism peak of the interfered signal (PAL-M) and the power of interfering signal (digital), at the receiver input in dB.
- Subjective Comparison Method - UIT-R level 3 (White Noise graded UIT-R level 3).
- Subjective Comparison Method UIT-R level 4 (White Noise graded UIT-R level 4).
- Limit of Perceptibility (LOP).

The values obtained as derived from methods UIT-R (3 & 4) nearly produce video equivalent to both quality grades 3 & 4.

2.6.3 *Initial Values and Characteristics*

2.6.3.1 Commercial Receivers PAL-M amount of 3, no one over 5 years of prior use and all provided with varactor tuners.

2.6.3.2 Initial Frequency Shift: 0 (zero) MHz (co-channel interference).

2.6.3.3 Number of trained observers: 3 – each one of them should analyse individually the receiver under test – the final outcome will be the average obtained from those three analysis.

2.6.3.4 PAL System Sound Signal: the PAL-M signal generator must have its audio channel adjusted for "stereo" transmission using 1 kHz tones and 50 kHz frequency deviation.

2.6.3.5 The interfering HDTV signals, either for DVB-T, ATSC or ISDB systems, must be provided from HDTV transmitters, through attenuators coupled to its output stages or to the IF.

2.6.3.6 The PAL-M input signal initial level at the receivers must be adjusted to -30 dBm (peak synchronism value).

2.6.3.7 The PAL-M signal should be generated by a transmitter.

2.6.3.8 The power of the digital television signal and the peak power of synchronism of the PAL-M signal must be both measured in dBm, matched to a 50 ohms load, by using the HP model 89441-V signal analyser.

2.6.3.9 The image to be used in PAL-M system as a reference for the subjective analysis of quality must be the one with “color bar”.

2.6.4 Measurement general description

To start off and for each video quality grade, (Grades 3 & 4 & LOP), the limit values of C/N (dB) for I$\rightarrow$zero (C/I$\rightarrow\infty$) and C/I (dB) for N$\rightarrow$zero (C/N$\rightarrow\infty$) must be determined.

After that, N must be fixed (so that a C/N within the determined limits above is then defined) and I must be varied until the image shows the desired quality grade.

For a certain quality grade determine the ratios C/I as a function of C/N and plot them in a graphic.

2.6.5 Equipment used

(1) PAL-M Transmitter, channel 34.

(2) Bird 30 dB Attenautor model: 300AFFN30.

(3a) and (3b) 2 HP 0-120 dB Attenuators model: 355D.

(5a) and (5b) 2 HP 0-12 dB Attenuators model: 355C.

(6a) and (6b) 2 HP combiners model: 0955-0751.

(7a) and (7b) 2 HP signal splitters model: 0955-0751.

(10) PAL-M 1 receiver.

(11) PAL-M 2 receiver.

(12) PAL-M 3 receiver.

(13) Rohde & Schwarz 0-110 dB step 0,1 dB Attenuator model: RSP.

(14) Digital Transmitter, channel 35.

(17a) and (17b) 2 Mini-Circuits Mixers model:ZLW186MH

(16a) and (16b) 2 Telonic Filters 12 MHz model: TTF600

(18) HP Amplifiers model 8347 A

(19a) and (19b) RF Rohde & Schwarz Generators model: SMH.

(30) TAS Noise generator model 420.

(32) HP Signal Analyser 89441V.

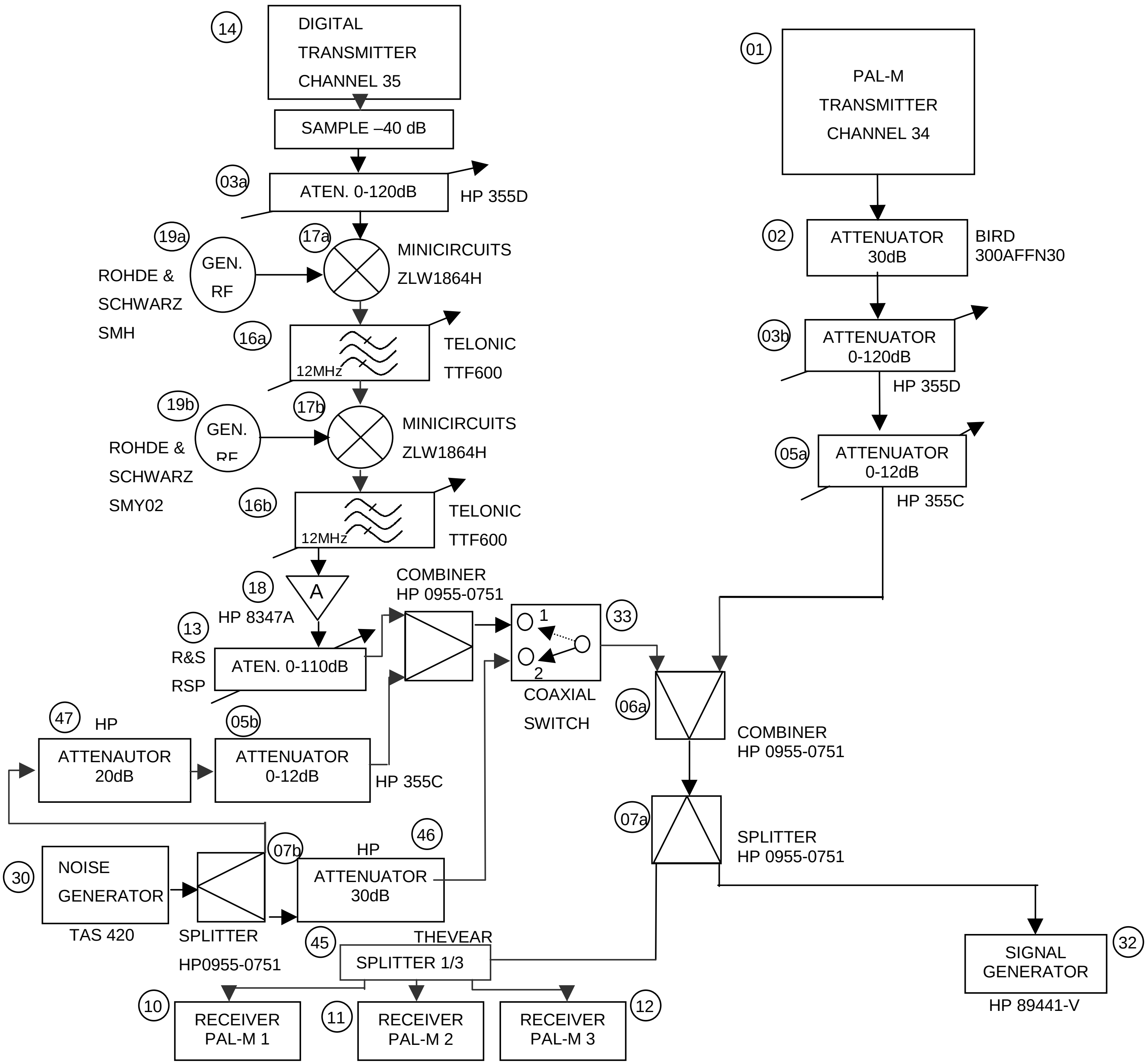
(33) Coaxial Switch RF 1 pole 2 positions.

(45) Splitter1:3 75ohms – Thevear

(46) HP fixed attenuator of 30dB.

(47) HP fixed attenuator of 20dB.

2.6.6 Measurements basic lay out



2.6.7 Test Procedures

A) Co-channel Interference

A-1) Keep the coaxial switch (33) at position 1, the digital system attenuators positioned for maximum attenuation and the noise generator (34) OFF. Next, adjust the PAL-M system attenuators until a level of -30 dBm (C/N) appears at the input of receiver 1 (10) and read by (32). This level must be taken as a reference.

A-2) Keep the coaxial switch (33) at position 2 and the PAL-M system attenuators positioned for maximum attenuation. Next, adjust the noise generator (30) level at the receiver input to produce a level of 33,0 dB below the reference level obtained in A-1 and read by (32). Return the PAL system attenuators to the position previously determined in A-1. This will produce at the PAL-M (10) receiver (1) an video quality corresponding to level 3.

A-3) Return the coaxial switch (33) to position 1, and adjust the digital system attenuators to a position of maximum attenuation. Turn ON the noise generator (34) and adjust the noise power to produce at receiver 1 (10) a video quality as near alike as possible to that one obtained at the item A-2. Commute switch (33) between positions 1 e 2 until obtaining the greater grade of similitude as possible. Write down, as read in (09), the noise power (N).

A-4) Determine the ratio C/N (dB) for the condition I = 0, i.e., C/I = ∞.

A-5) Turn off the noise generator (34) and with the coaxial switch (33) at position 1 adjust the digital system attenuators until obtaining at the receiver 1 (10) a video quality as near as possible to the one obtained at item A-2. Commute switch (33) between positions 1 e 2 until the obtaining the greater grade of similitude as possible. Write down now, as read in (32), the interfering signal power (I).

A-6) Determine the ratio C/I (dB) for the condition N=zero , i.e., C/N=∞. The items A-4 and A-6 set the limits for C/N and C/I to be applied.

A-7) Repeat items A-3, A-4 and A-5 for intermediary conditions among those described in A-4 e A-6 establishing C as a fixed and non-mutable value, and then for a certain N, vary the interfering signal power until the video quality so obtained in (10) be a Grade 3 image.

A-8) Determine the ratios C/N (dB) and C/I (dB), both as outcomes from A-7.

A-9) Repeat the procedures as described in A-2 until A-8 for the receivers 2 (11) and 3 (12).

A-10) Determine the average of the obtained values with respect to the 3 receivers and trace curves to the 3 systems.

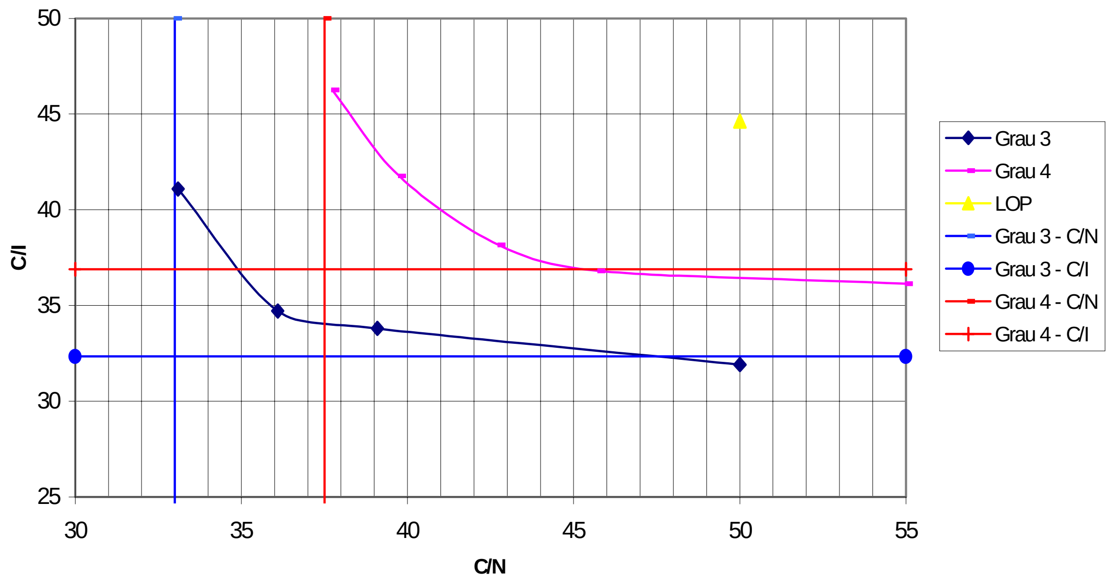
A-11) Repeat the procedures as described in A-2 until A-10 for Grade 4 images, i.e., for a signal-to-noise ratio of 37,5 dB at the input of the PAL-M receivers (see item A-2).

A-12) Repeat the procedures described from A-2 to A-10 for LOP images, i.e., at the limit of perceptivity of PAL-M receivers.

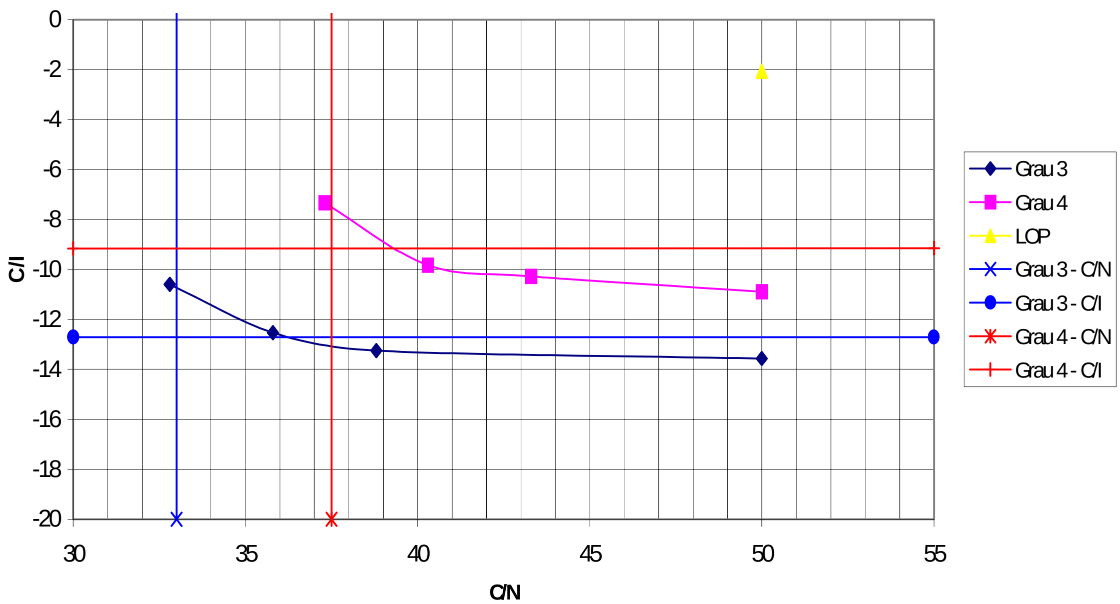
B) Repeat items A-2 to A-12 for measurements of upper and lower adjacent channels as well as channels "taboo".

2.6.8 Results

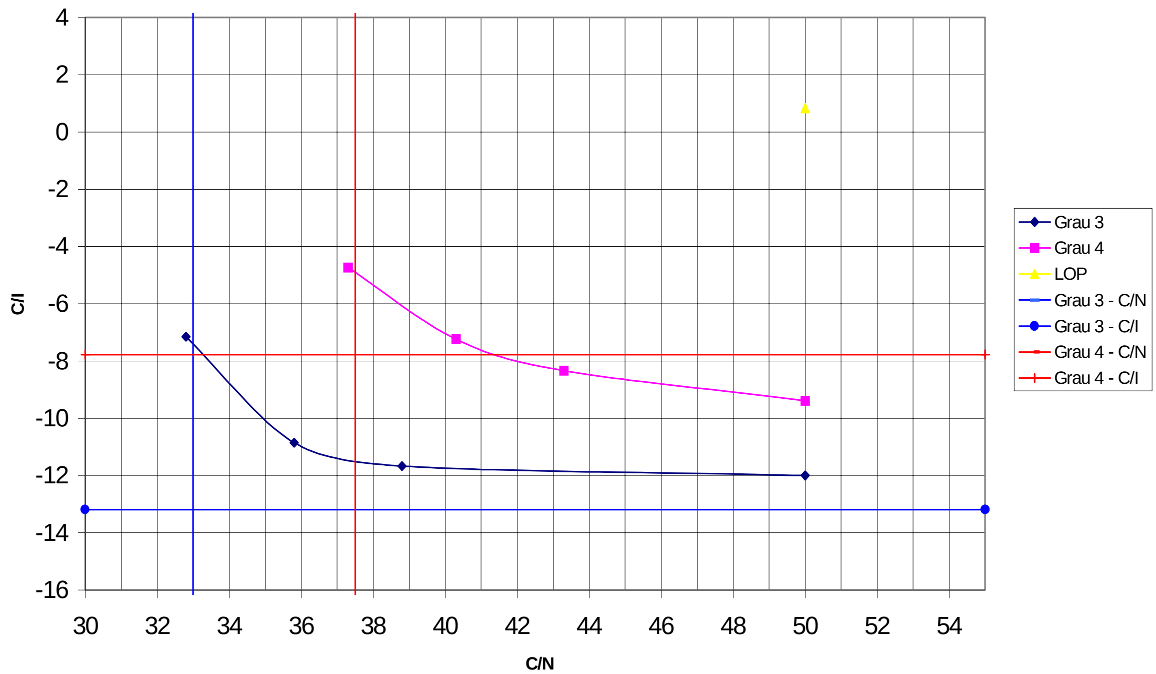
Graph 2.6.8.1: C/I Relation against C/N Relation
Interferent: Co-channel (ATSC)



Graph 2.6.8.2: C/I Relation against C/N Relation
Interferent: Lower adjacent (ATSC)



Graph 2.6.8.3: C/I Relation against C/N Relation
Interferent: Upper adjacent (ATSC)



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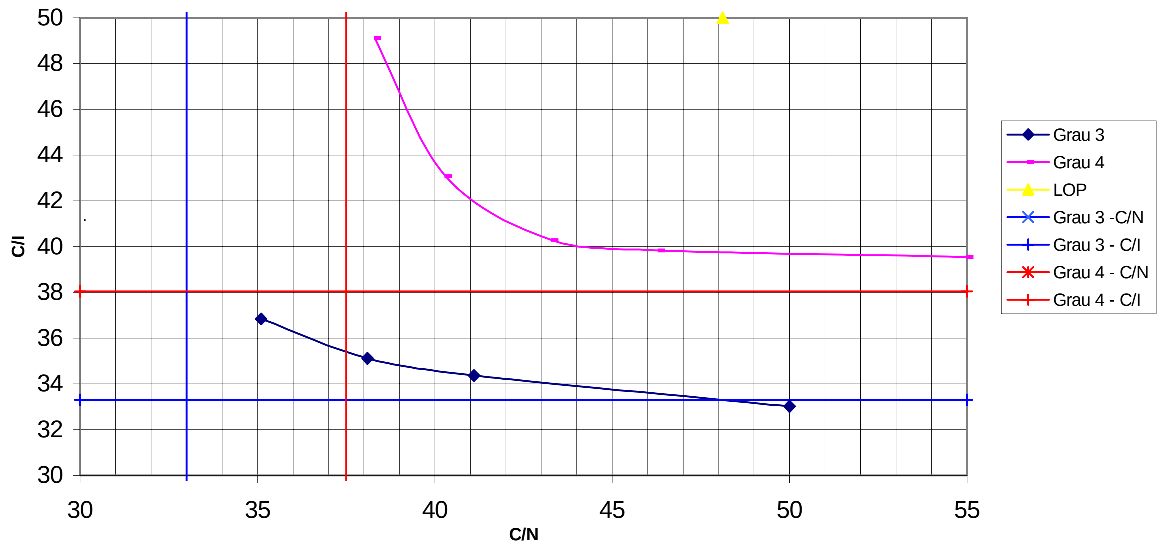
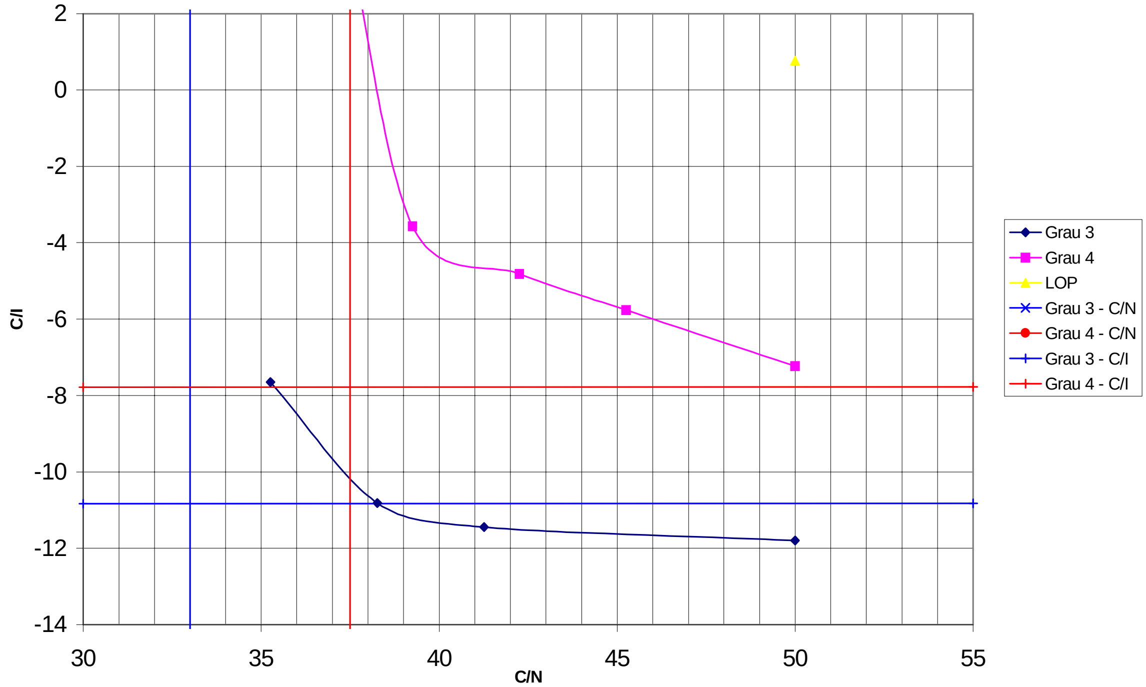
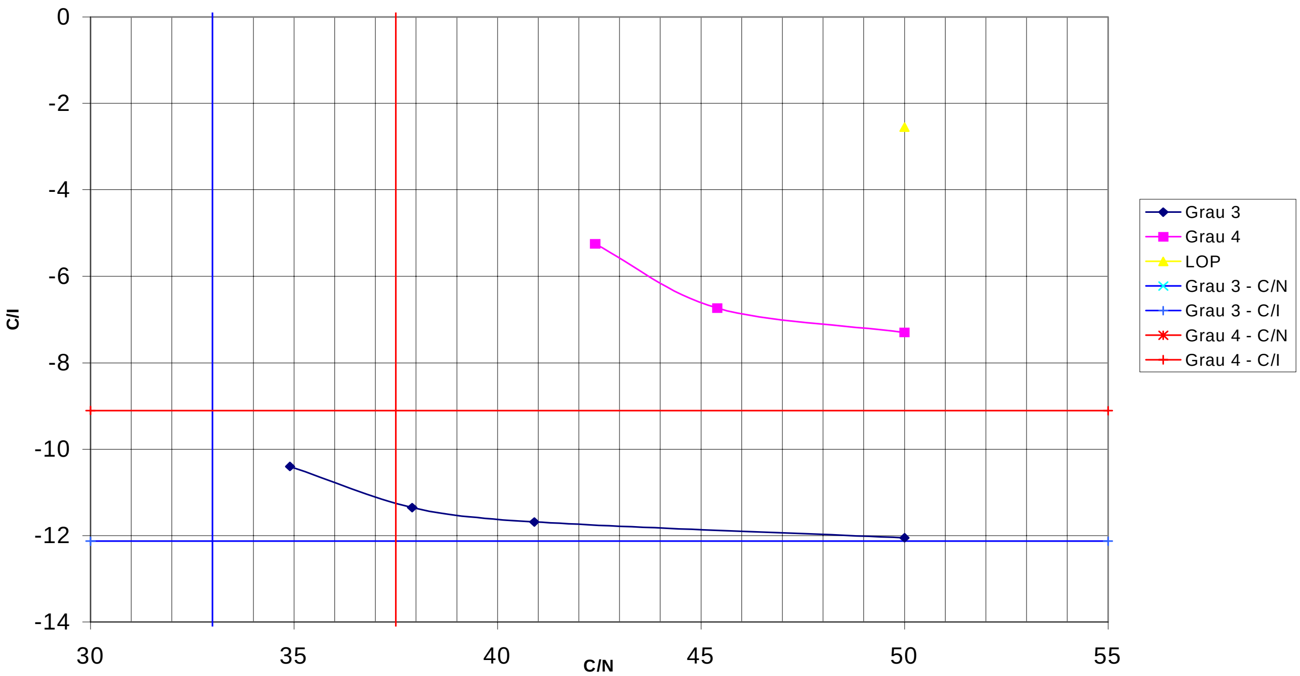
Graph 2.6.8.4: C/I Relation against C/N
Interferent: Co-channel (DVB - 64 QAM FE3/4 GI1/16 2K)

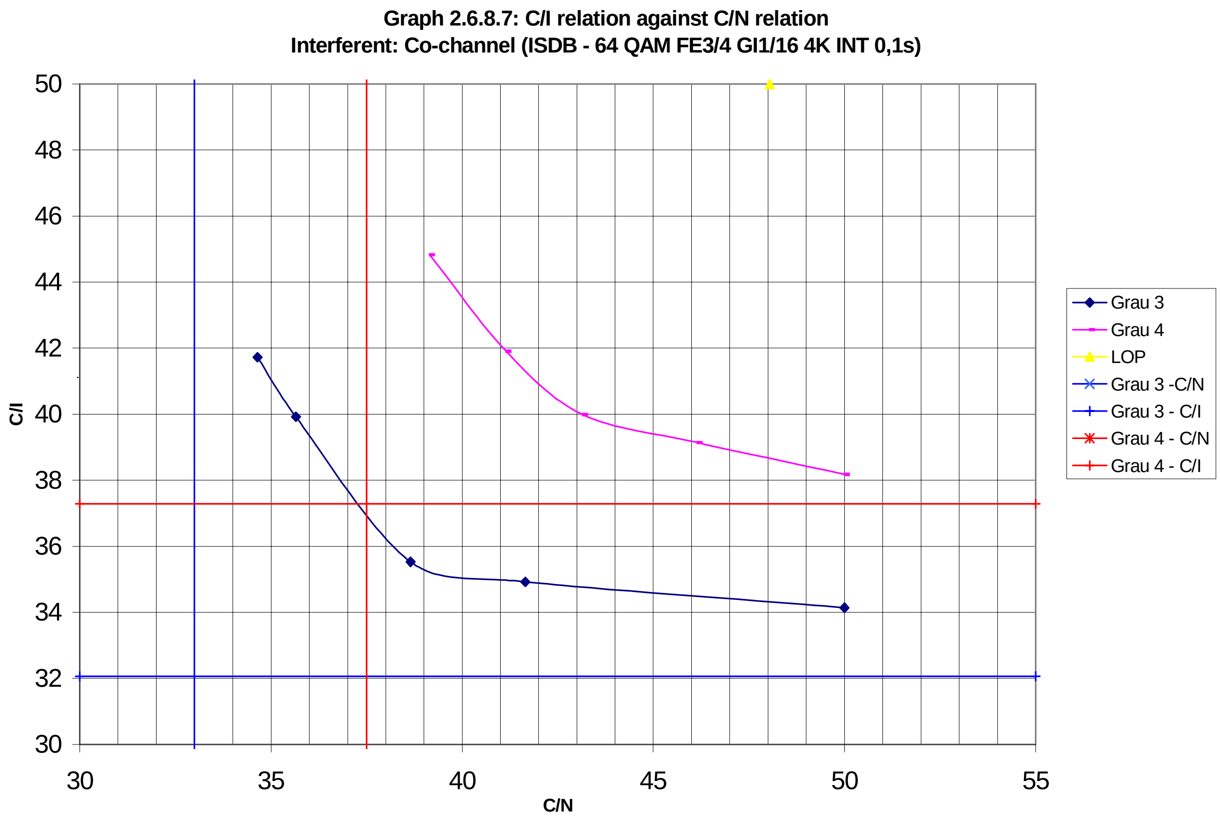


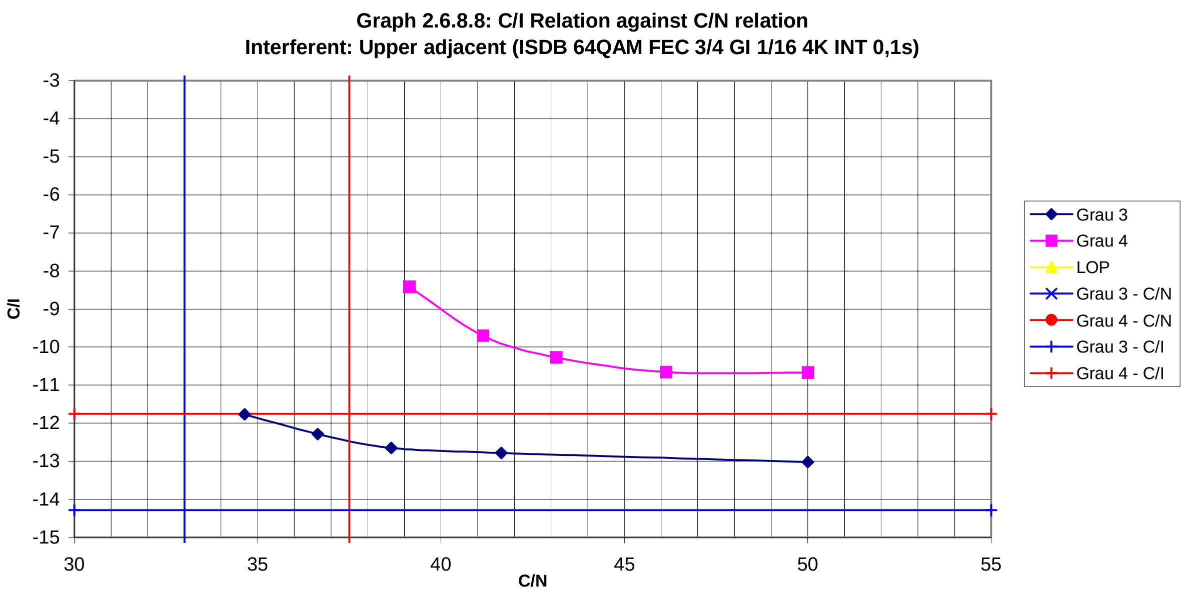
Graph 2.6.8.5: C/I Relation against C/N Relation
Interferent: Upper adjacent (DVB 64QAM FEC 3/4 GI 1/16)



Graph 2.6.8.6: C/I Relation against C/N Relation
Interferent: Lower adjacent (DVB 64 QAM FEC 3/4 GI 1/16 2K)

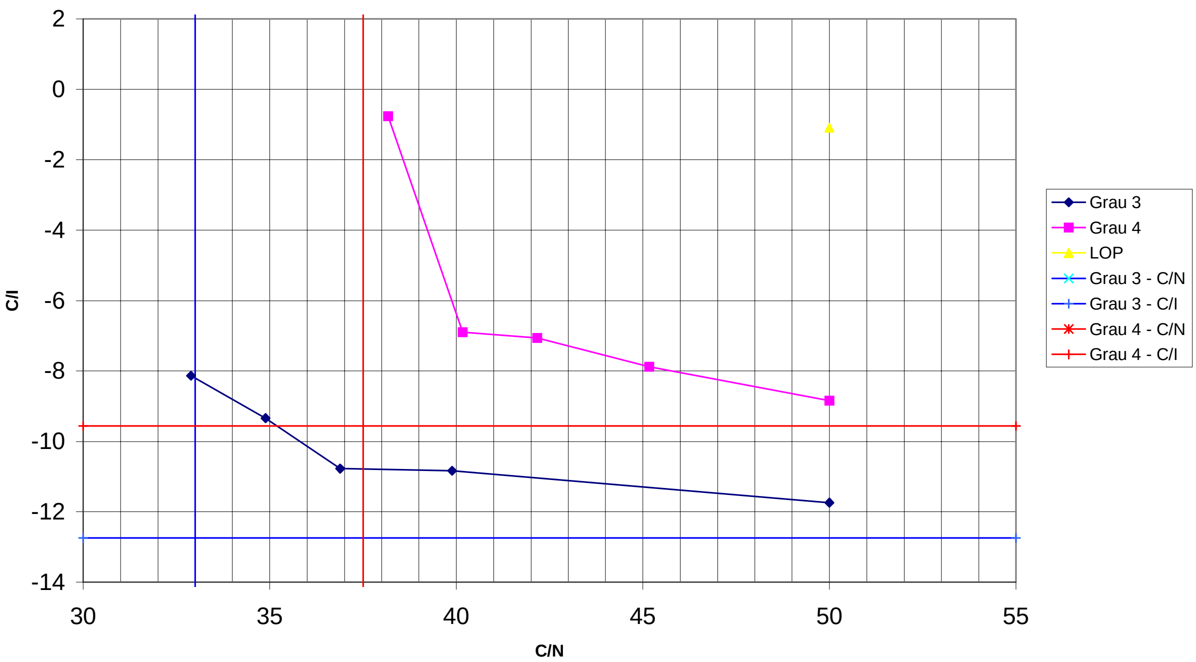



Graph 2.6.8.7: C/I relation against C/N relation
Interferent: Co-channel (ISDB - 64 QAM FE3/4 GI1/16 4K INT 0,1s)
50
48
46
44
42
40
38
36
34
32
30
C/I
30
35
40
45
50
55
C/N
Grau 3
Grau 4
LOP
Grau 3 -C/N
Grau 3 - C/I
Grau 4 - C/N
Grau 4 - C/I



Graph 2.6.8.8: C/I Relation against C/N relation
Interferent: Upper adjacent (ISDB 64QAM FEC 3/4 GI 1/16 4K INT 0,1s)
C/I
C/N
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
30
35
40
45
50
55
Grau 3
Grau 4
LOP
Grau 3 - C/N
Grau 4 - C/N
Grau 3 - C/I
Grau 4 - C/I

Graph 2.6.8.9: C/I Relation against C/N Relation
Interferent: Lower adjacent (ISDB 64 QAM FEC 3/4 GI 1/16 4K INT 0,1 s)



2.7 Simultaneous Interference of Analogue PAL-M channel and Noise in Digital Channel

2.7.1 Aim

This measurement method aim the assessment of degradation produced in a digital signal simultaneously interfered by an analogue signal PAL-M and by Gaussian noise.

The interfering digital channel may be of the following types: lower adjacent channel upper adjacent channel, co-channel and "taboo" channels.

In this degradation assessment, the independent variable is the ratio of the interfered signal (digital) and the interfering noise power, i.e., C/N (dB). The dependent variable is the digital system bit error rate (BER). The variable parameter is represented by the ratio of interfered signal power and the interfering signal power (C/I (dB)). Thus, for each chosen value of C/I (dB), a curve of BER as a function of C/N (dB) will be derived.

2.7.2 Basic Parameters Characteristics

The basic parameters in the determination of the rate C/N to BER, with parameters in the ratio C/I, are as follows:

- C/N (dB) = rate of interfered signal power (digital) and gaussian noise power, in dB, at the receiver input, measure in the noise range of the receiver (consider the range as 6 MHz).
- BER= Bit error rate of the digital system measured at the demodulator output, at the interface with decoder/decompressor MPEG-2.

- C/I (dB) = ratio of interfered signal power (digital) and interfering signal power (PAL-M) in dB.

2.7.3 Initial Values and Characteristics.

2.7.3.1 The interfered signal is obtained at the IF output of the PAL-M transmitter as shown in figure 2.7.6.

2.7.3.2 The interfered digital channel, either in DVB-T, ATSC and ISDB systems, is provided by a transmitter allocated at channel 35.

2.7.3.3 The signal level coming from the digital transmitter must be adjusted for -30 dBm at the input of the digital receiver.

2.7.3.4 The generator RF frequency (19) must be adjusted for the condition of co-channel interference, i.e., for a initial frequency displacement of 0 (zero) MHz.

2.7.3.5 The PAL-M transmitter must have the audio carrier modulated in stereo by tones of 1 kHz and frequency deviation of 50 kHz.

The PAL-M system video carrier must be modulated at 100% by a signal "Zone Plate" with movement.

2.7.4 Measurement General Description

For a certain parametered value of C/I (dB), vary the noise power N (keeping C constant) and read the correspondent BER.

Trace the BER curve as a function of C/N (dB) for the respective value of C/I (dB) parametered. This way, a curve for each parametered value of C/I (dB) will result .

2.7.5 Equipment used

(1) PAL-M Transmitter, channel 34.

(4A) BER Test set - Tektornix PB200

(4B) BER Test set HP3764A (for ISDB only).

(3a) and (3b) 2 HP 0-120 dB Attenuators model: 355D.

(5a) and (5b) 2 HP 0-12 dB Attenuators model: 355C.

(6) and (35) HP combiners model: 0955-0751.

(7) HP signal splitter model: 0955-0751.

(13) Rohde & Schwarz 0-110 dB step 0,1 dB Attenuator model: RSP.

(14) Digital Transmitter, channel 35.

(17a) and (17b) 2 Mini-Circuits Mixers model:ZLW186MH

(16a) and (16b) 2 Telonic Filters 12 MHz model: TTF600

(18) HP Amplifiers model 8347 A

(19) RF Rohde & Schwarz Generator model: SMH.

(20) ATSC digital receiver

(21A) DVB-T digital receiver

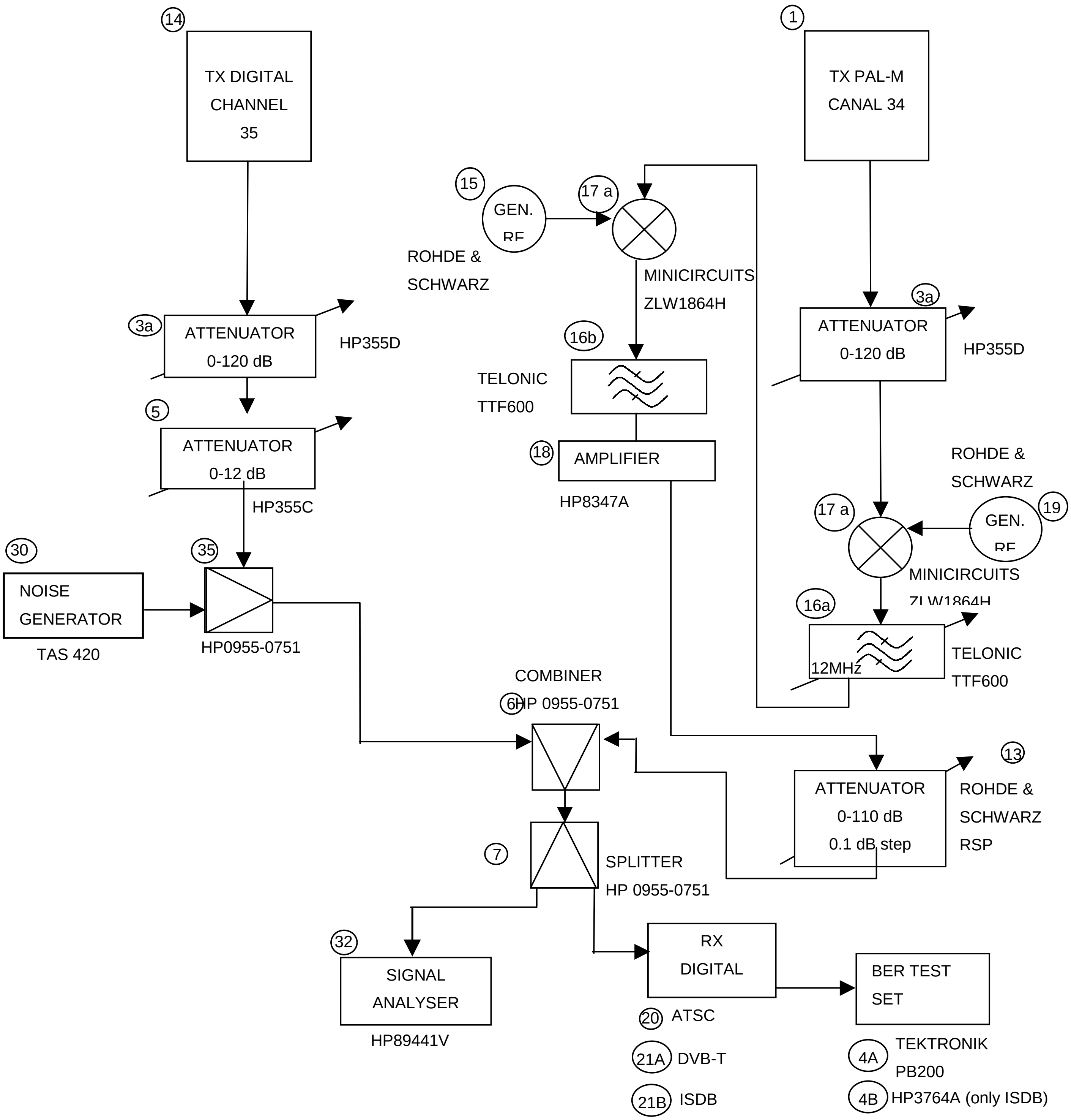
(21B) ISDB digital receiver

(30) TAS Noise generator model 420.

(32) HP Signal Analyser 89441V.

(15) R&S RF generator, model SMY02

2.7.6 Measurement Basic lay out



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2.7 7 Test procedures

A) Co-channel Interference

A1) With the PAL-M system attenuators at a position of maximum attenuation and the noise generator (30) OFF, adjust the digital system attenuators in such a way that the digital signal power reading at the signal analyser (32) be -30 dBm. Write down these attenuators positions.

A2) Turn on the noise generator (30) and adjust its level until the BER indicated is equal to the lower BER limit (BER mín.) Determine the C/N value (dB) for each minimum BER.

Repeat the described above for the upper BER limit and determine the C/N value (dB) for this maximum BER. In this case we will have limit points of the curve BER X C/N (dB) for C/I (dB) = ∞.

A3) Repeat item A2 for intermediary values of C/N(dB). Locate the values into the graphics.

We will have now a complete curve of BER X C/N for C/I (dB) = ∞.

A4) Turn OFF the noise generator (30) and, with the digital system attenuators at position of maximum attenuation, act upon the PAL-M attenuators until the interfering signal power corresponds to the value of the parametric curve of C/I indicated by the ratio R1.

A5) Return the digital system attenuators to the position adjusted in A1.

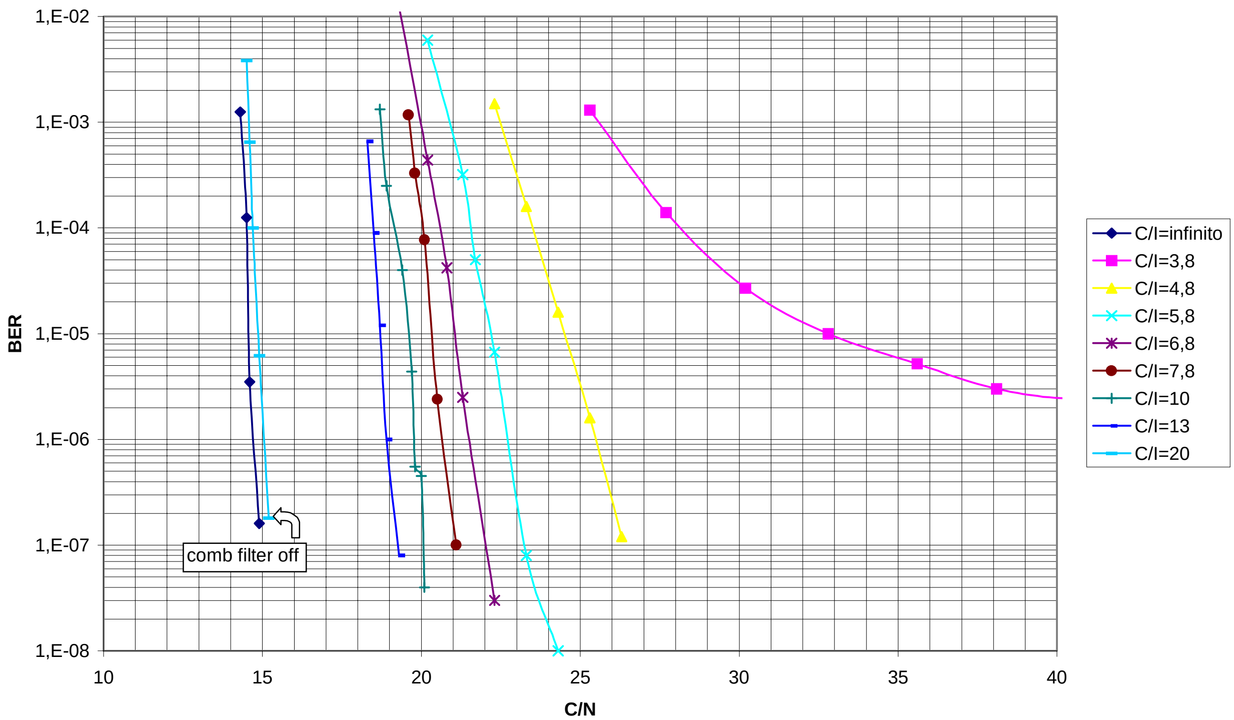
A6) Turn ON the noise generator (30) and repeat items A2 and A3 until obtaining all values of BER X C/N (dB) for the parametric curve of C/I as R1.

A7) Repeat items A2 until A6 for all other parametric values for C/I, i.e., from R2 to Rx. Build up the graphics.

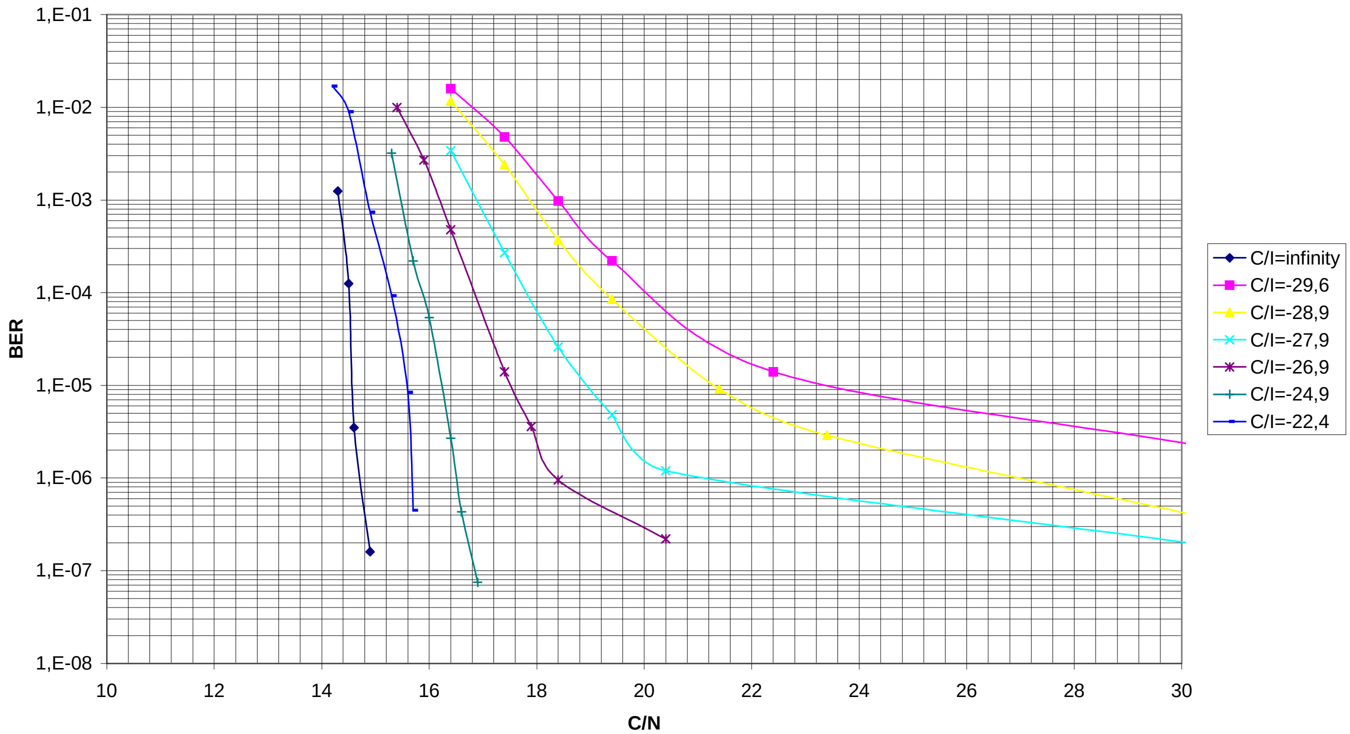
B) Repeat items A1 to A7 adjusting the RF generator (15) and the TELONIC filter (16b) for the conditions of upper and lower adjacent channels and "taboo" channels.

2.7.8 Results

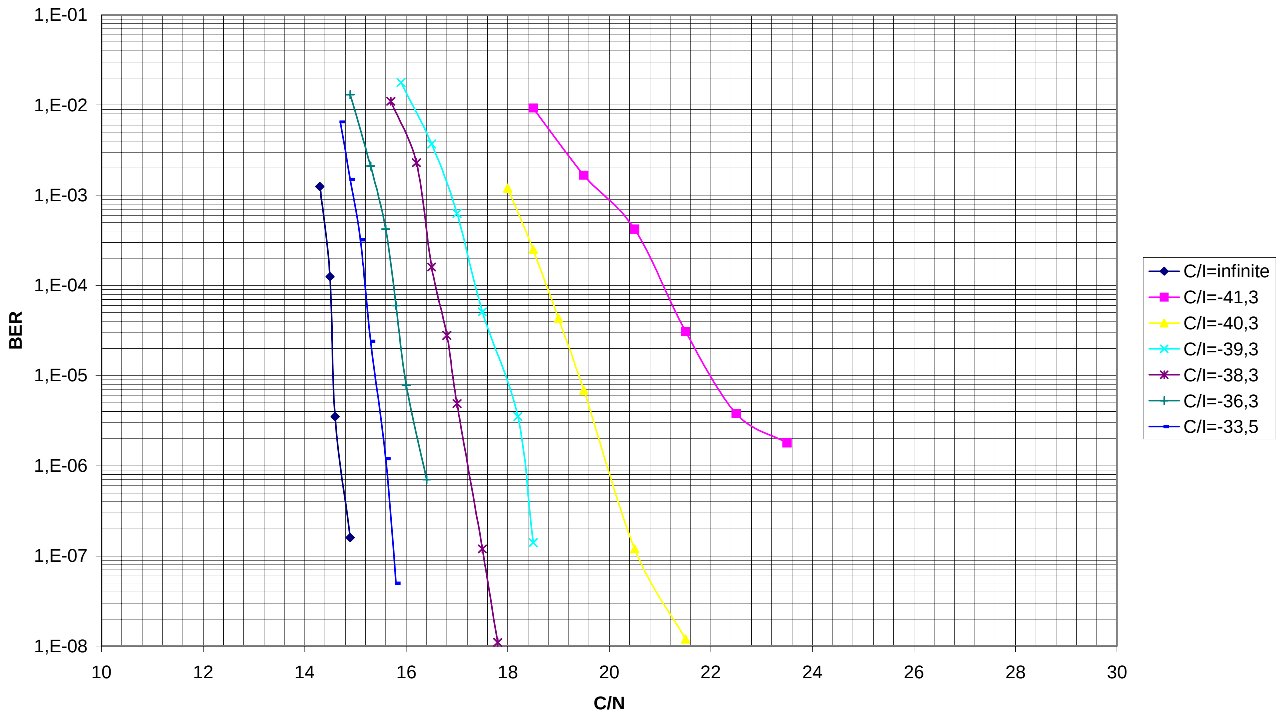
Graph 2.7.8.1: BER against C/N
Interferent Signal= Co-chanel - ATSC



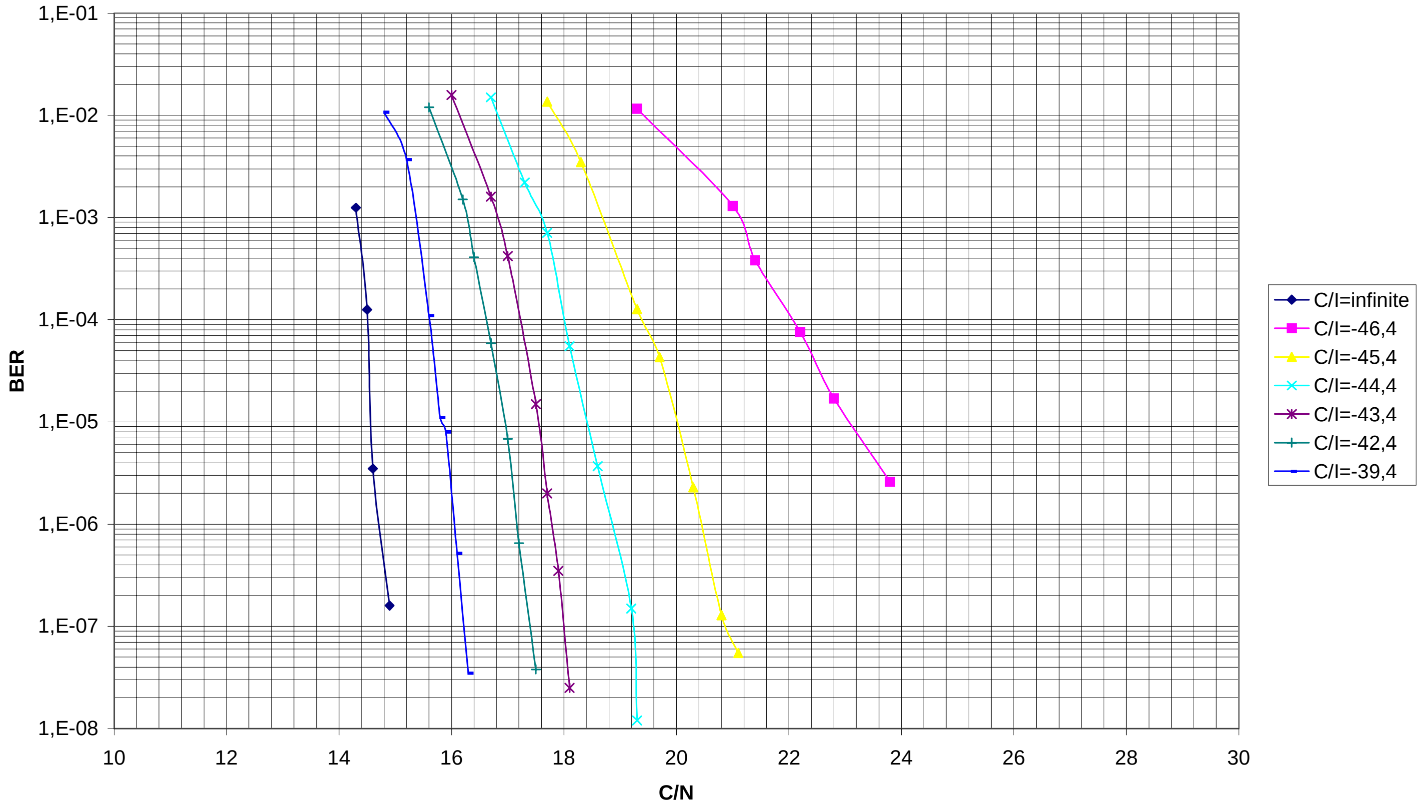
Graph 2.7.8.2: BER against C/N
Interferent signal = Lower adjacent - ATSC



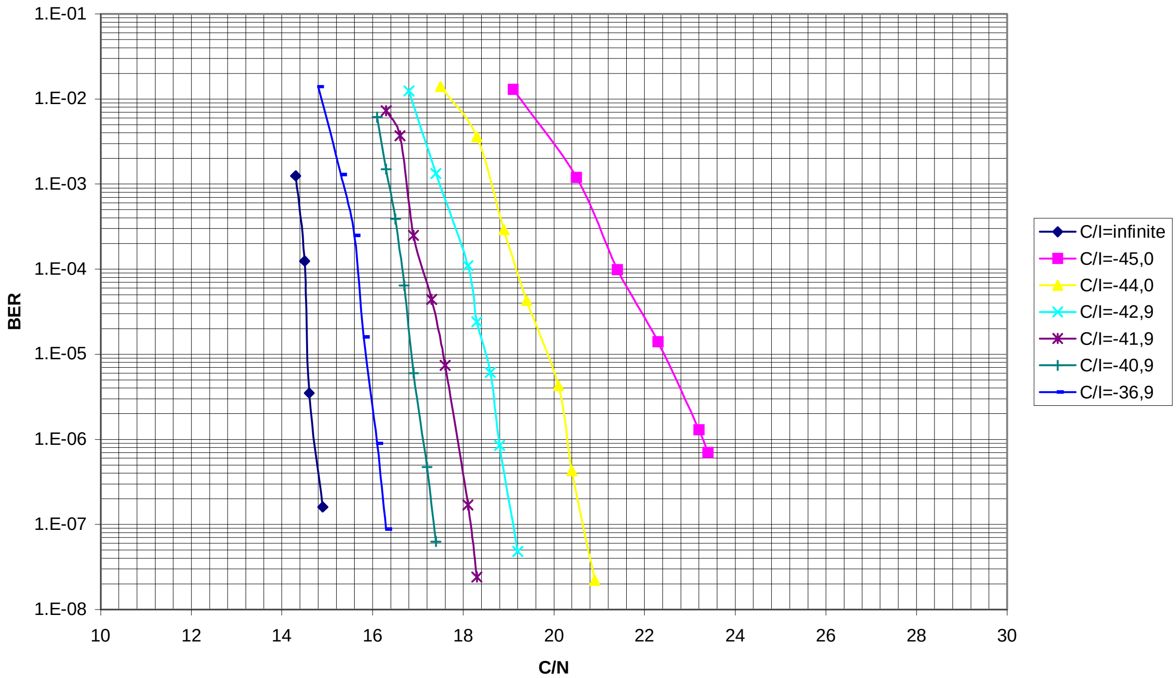
Graph 2.7.8.3: BER against C/N
Interferent signal=Upper Adjacent - ATSC



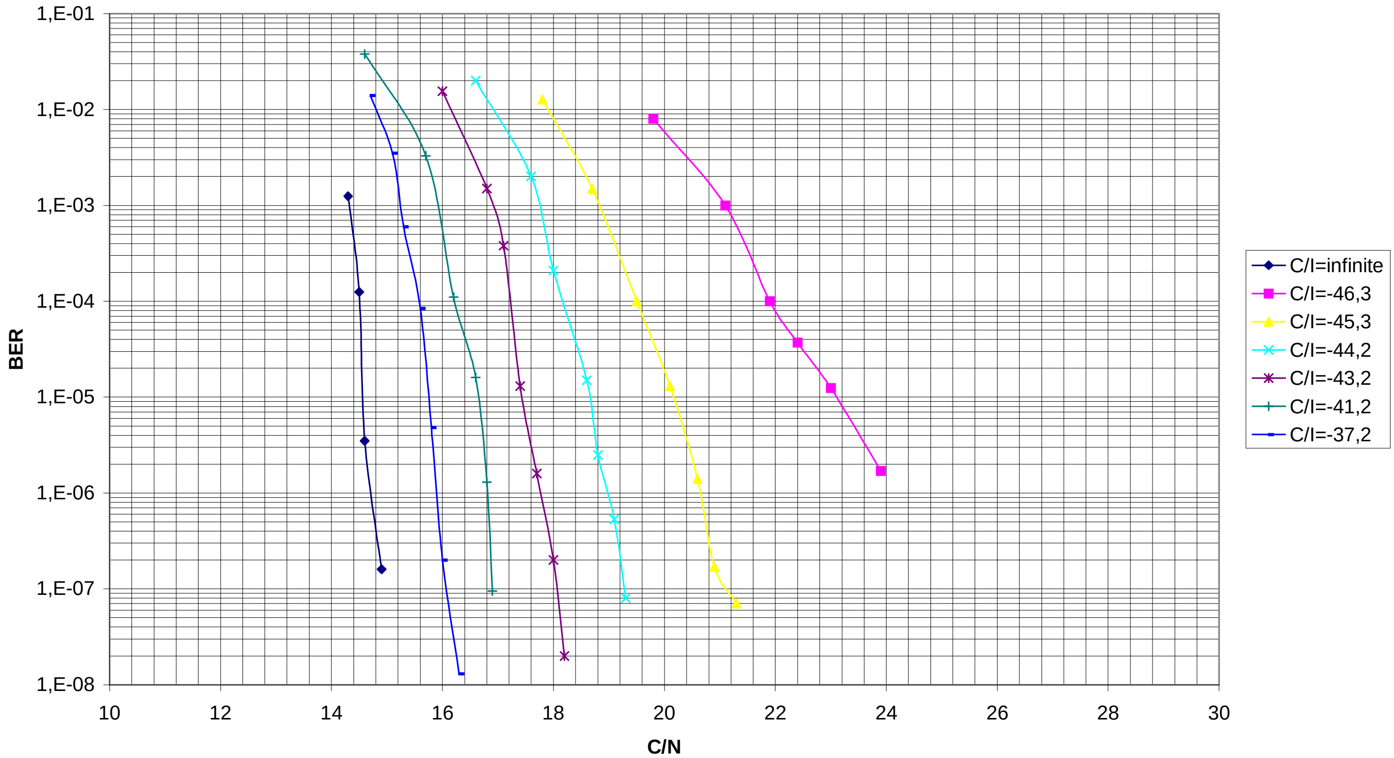
Graph 2.7.8.4: BER against C/N
Interferent signal =Taboo -7BW - ATSC



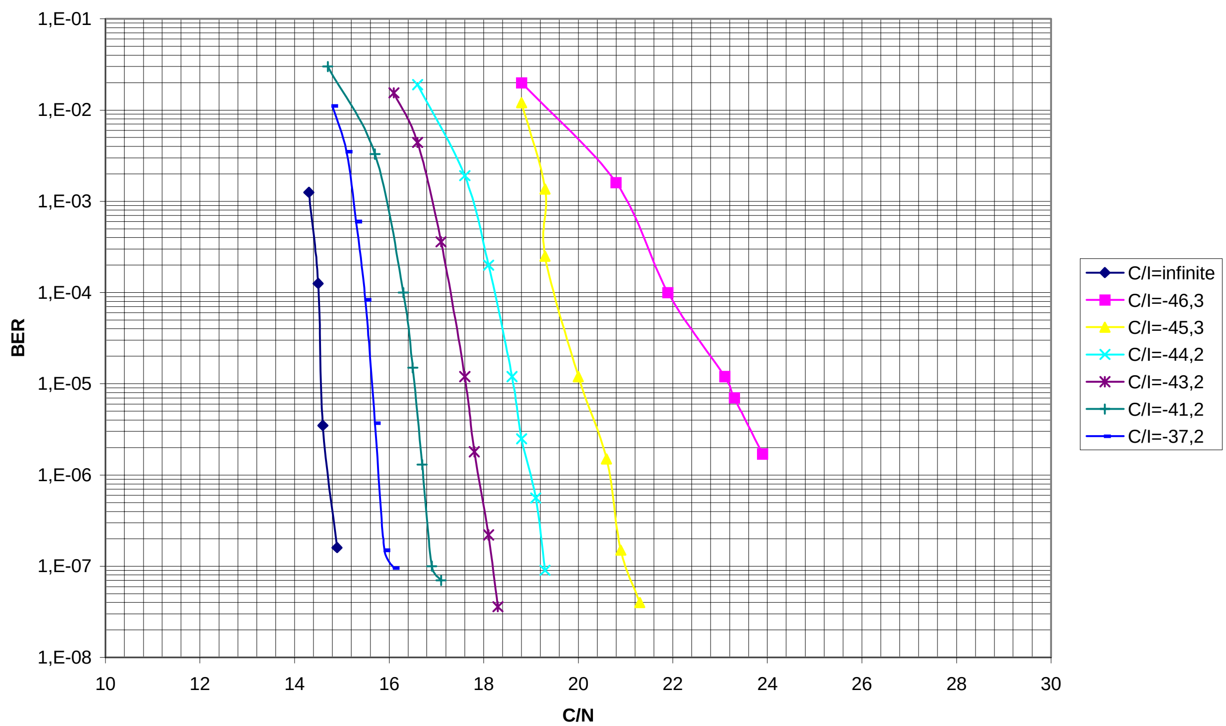
Graph 2.7.8.5: BER against C/N
Interferent signal noise =Taboo -8BW - ATSC



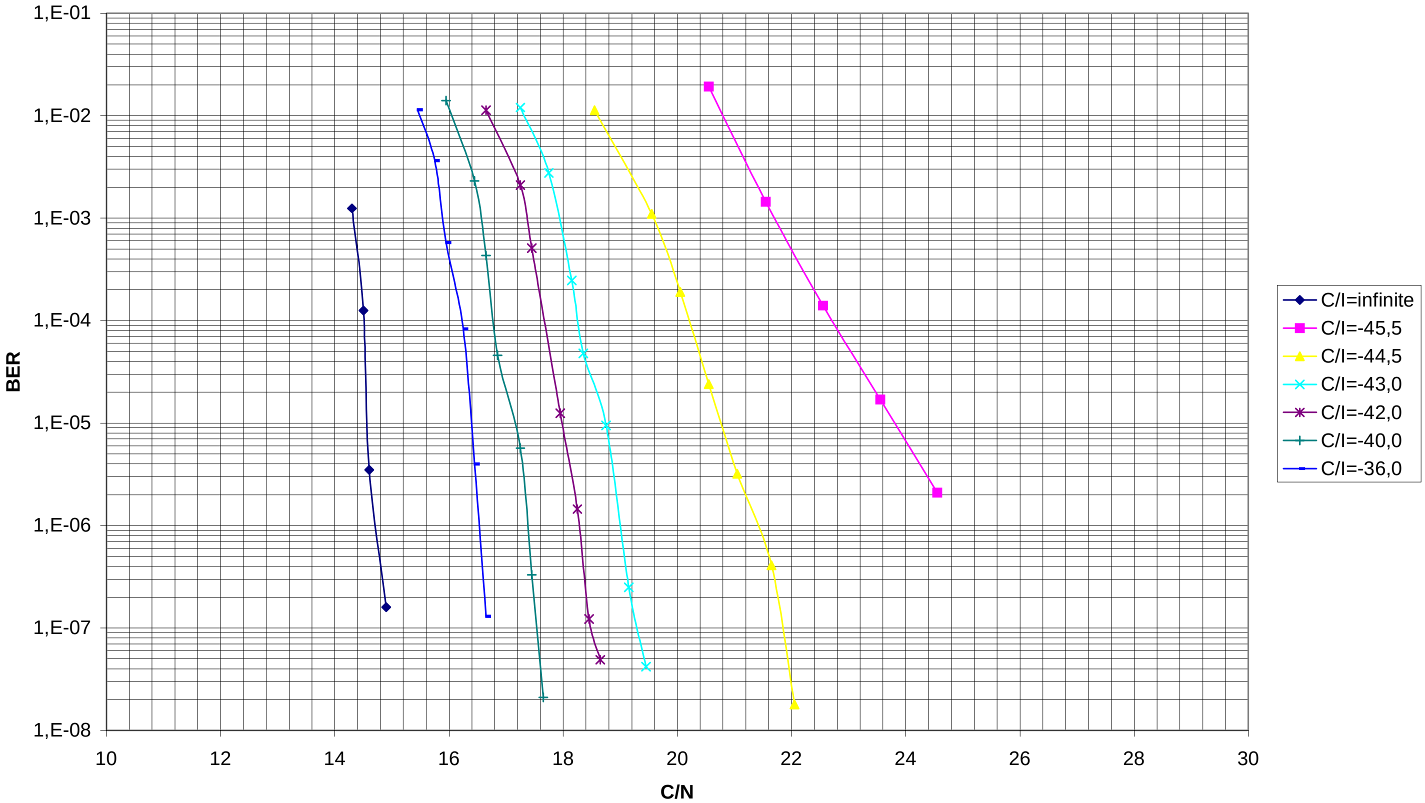
Graph 2.7.8.6: BER against C/N
Interferent signal=Taboo +7BW - ATSC



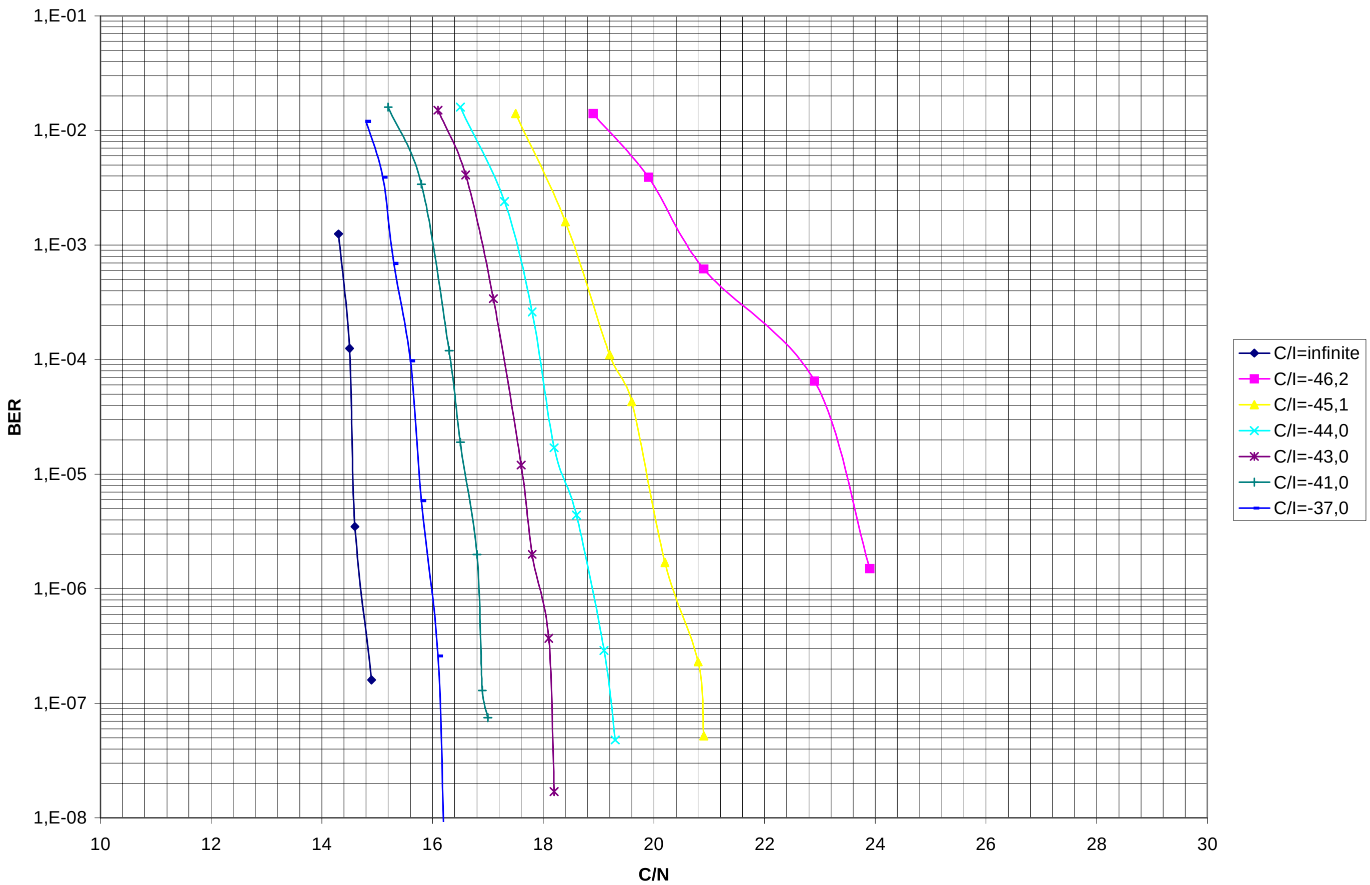
Graph 2.7.8.7: BER against C/N
Interferent signal =Taboo +8BW - ATSC



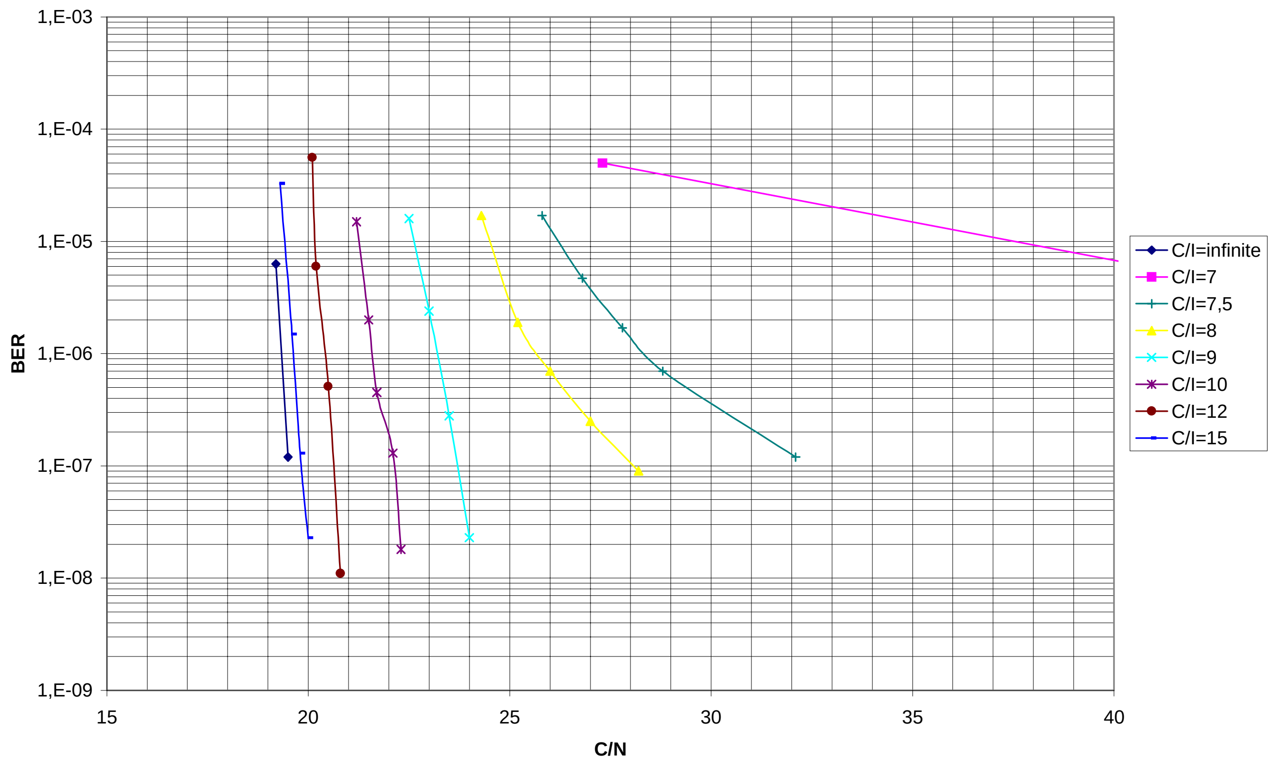
Graph 2.7.8.8: BER against C/N
Interferent signal =Taboo +14BW - ATSC

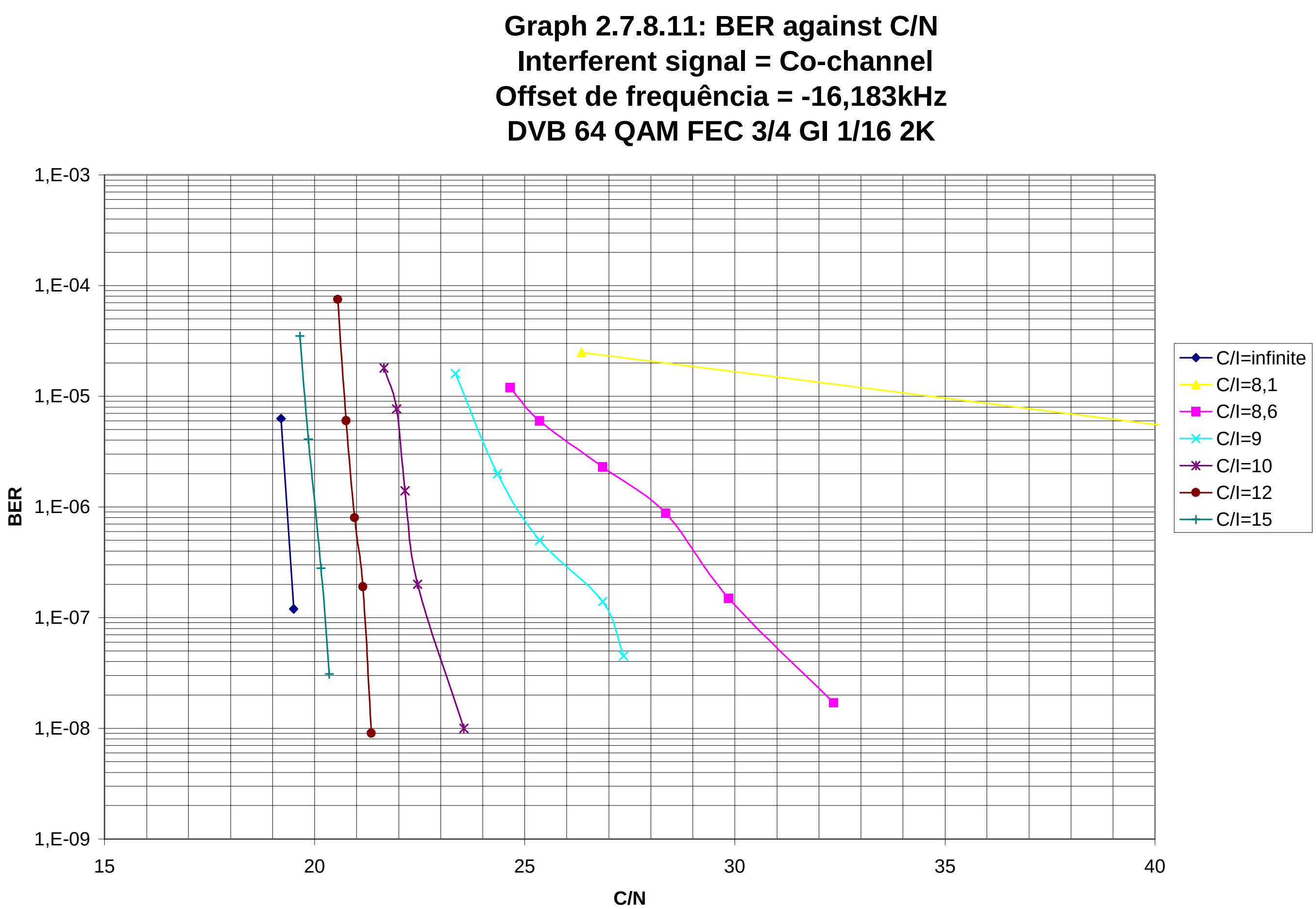


Graph 2.7.8.9: BER against C/N
Interferent signal =Taboo +15BW - ATSC



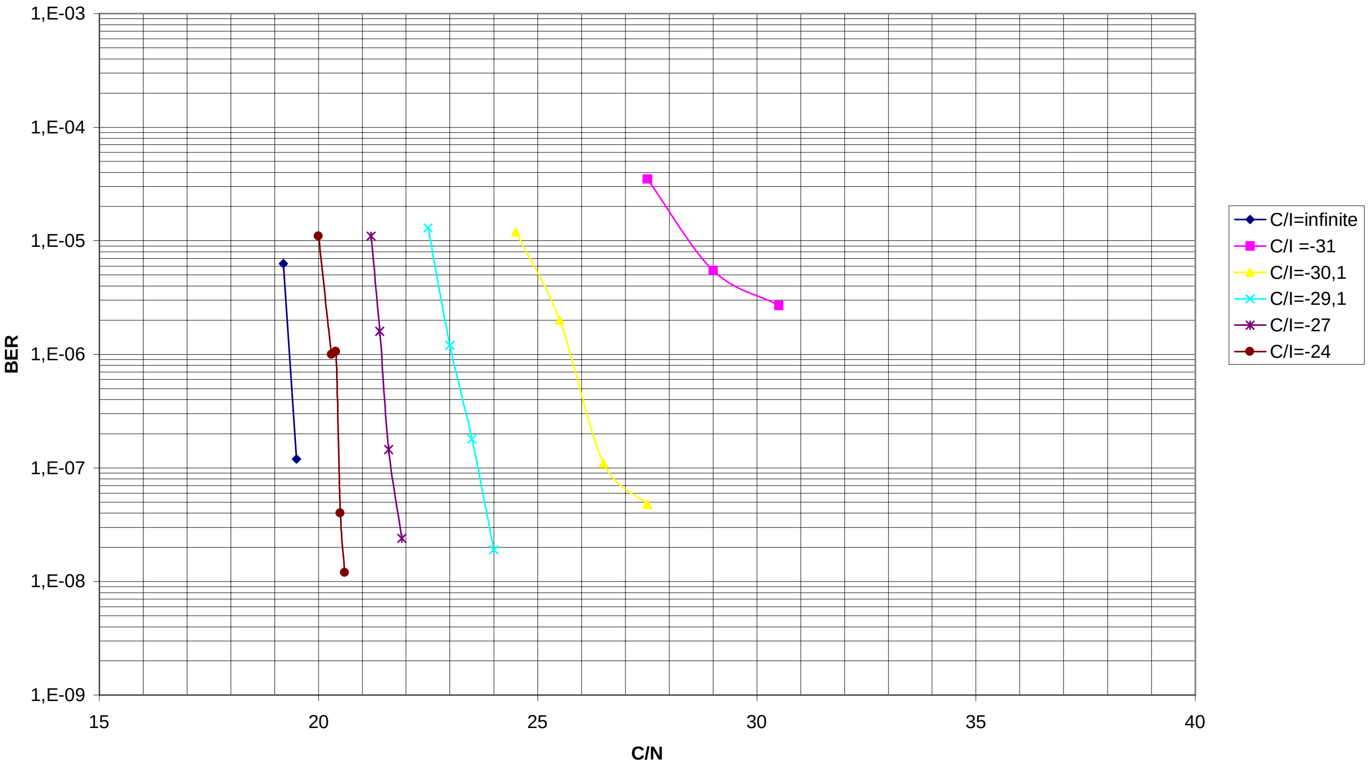
Graph 2.7.8.10: BER against C/N
Interferent signal= Co-channel
DVB 64 QAM FEC 3/4 GI 1/16 2K



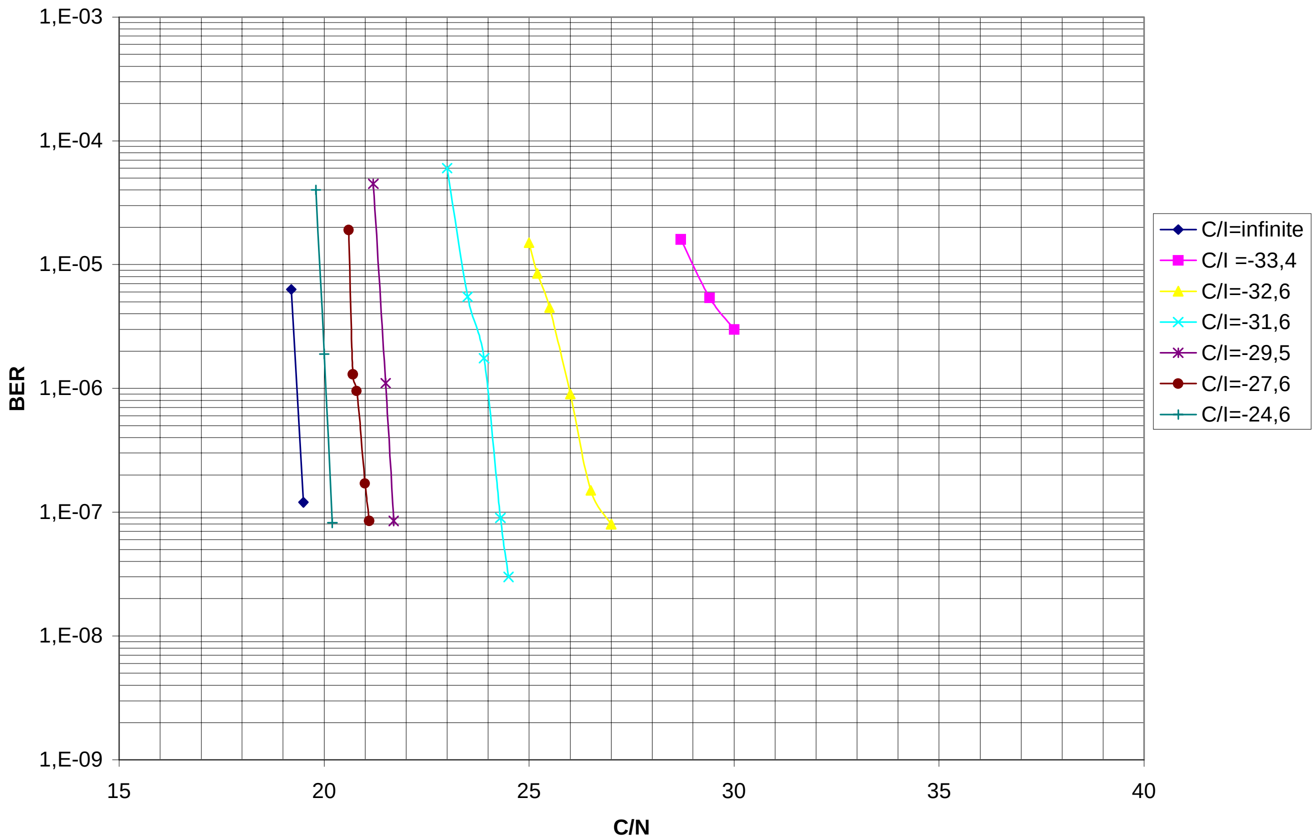


Graph 2.7.8.11: BER against C/N
Interferent signal = Co-channel
Offset de frequência = -16,183kHz
DVB 64 QAM FEC 3/4 GI 1/16 2K
1,E-03
1,E-04
1,E-05
1,E-06
1,E-07
1,E-08
1,E-09
BER
15
20
25
30
35
40
C/N
C/I=infinite
C/I=8,1
C/I=8,6
C/I=9
C/I=10
C/I=12
C/I=15

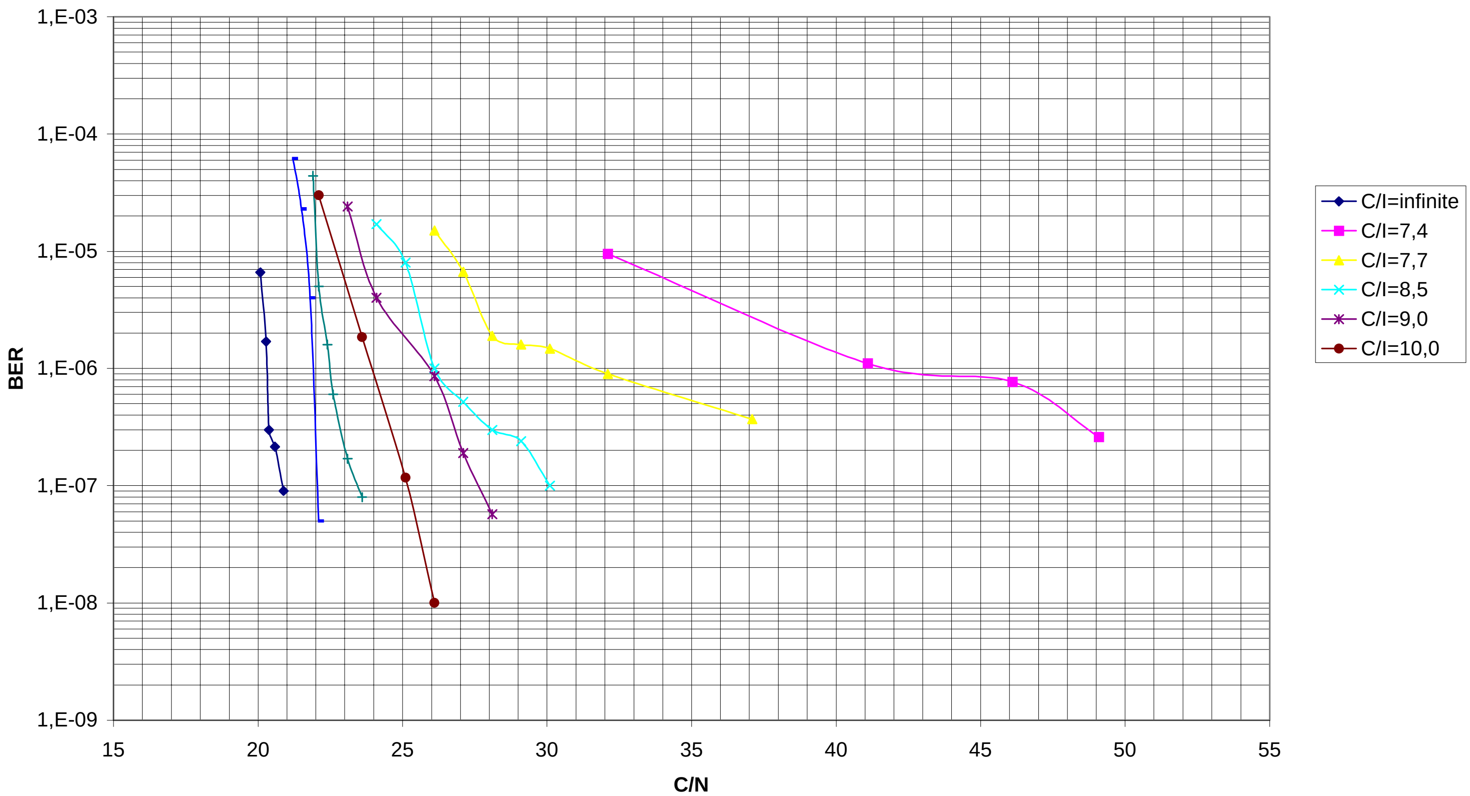
Graph 2.7.8.12: BER against C/N
Interferent signal = lower adjacent analogic
DVB 64 QAM FEC 3/4 GI 1/16 2k



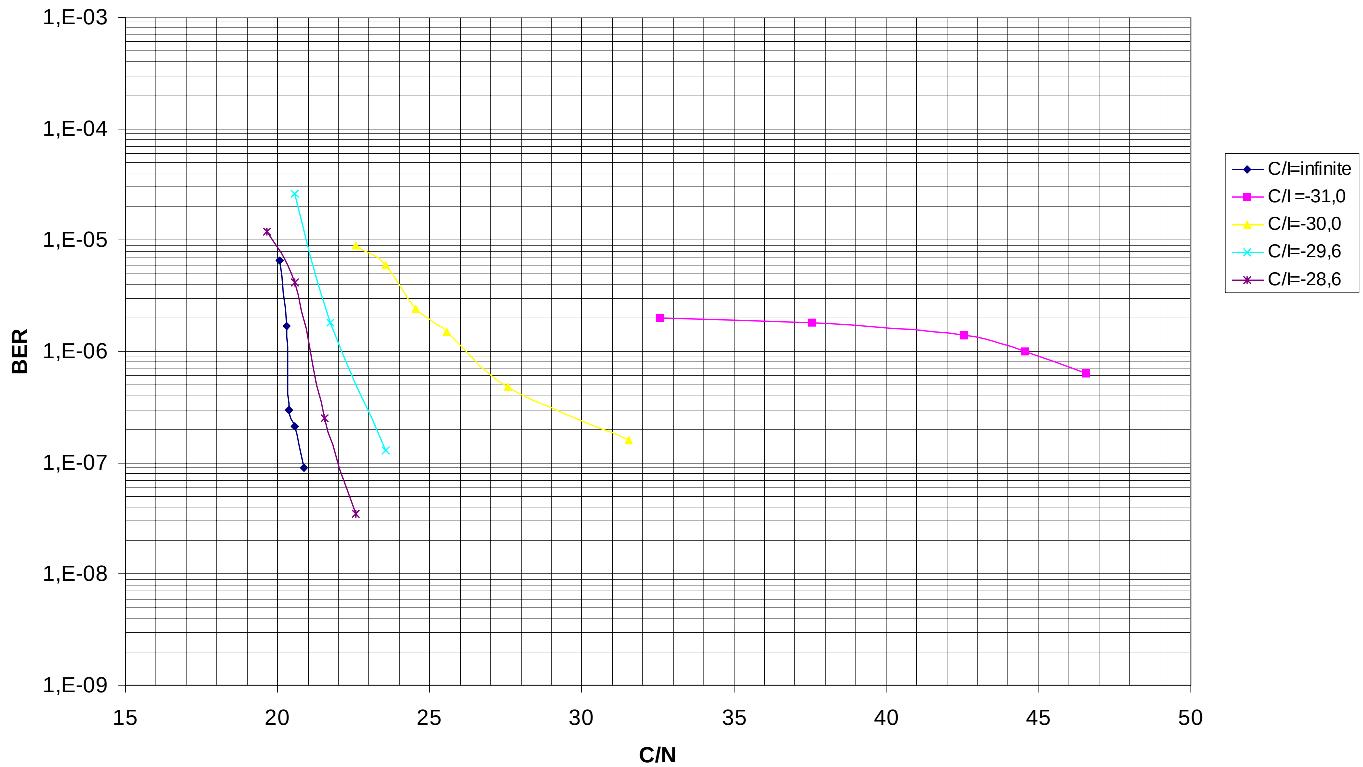
Graph 2.7.8.13: BER against C/N
Interferent signal= Upper adjacent analogic
DVB 64 QAM FEC 3/4 GI 1/16 2K



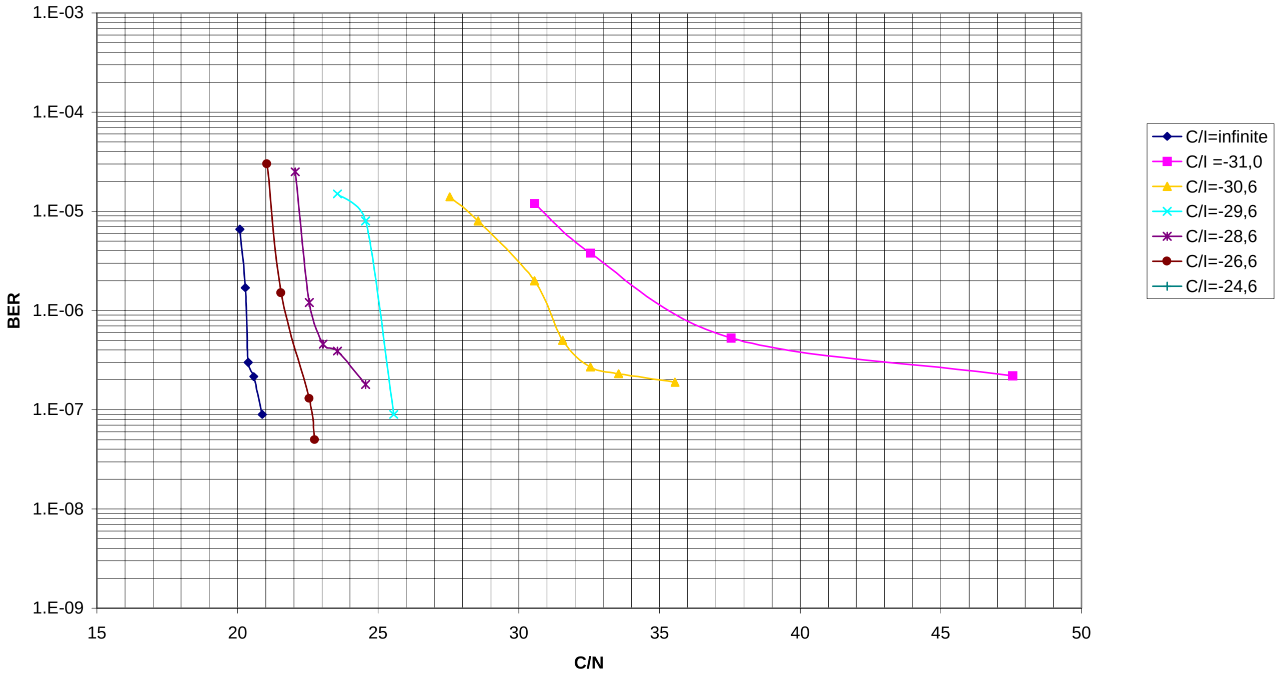
Graph 2.7.8.14: BER against C/N
Interferent signal = Co-channel
DVB 64 QAM FEC 3/4 GI 1/16 8K



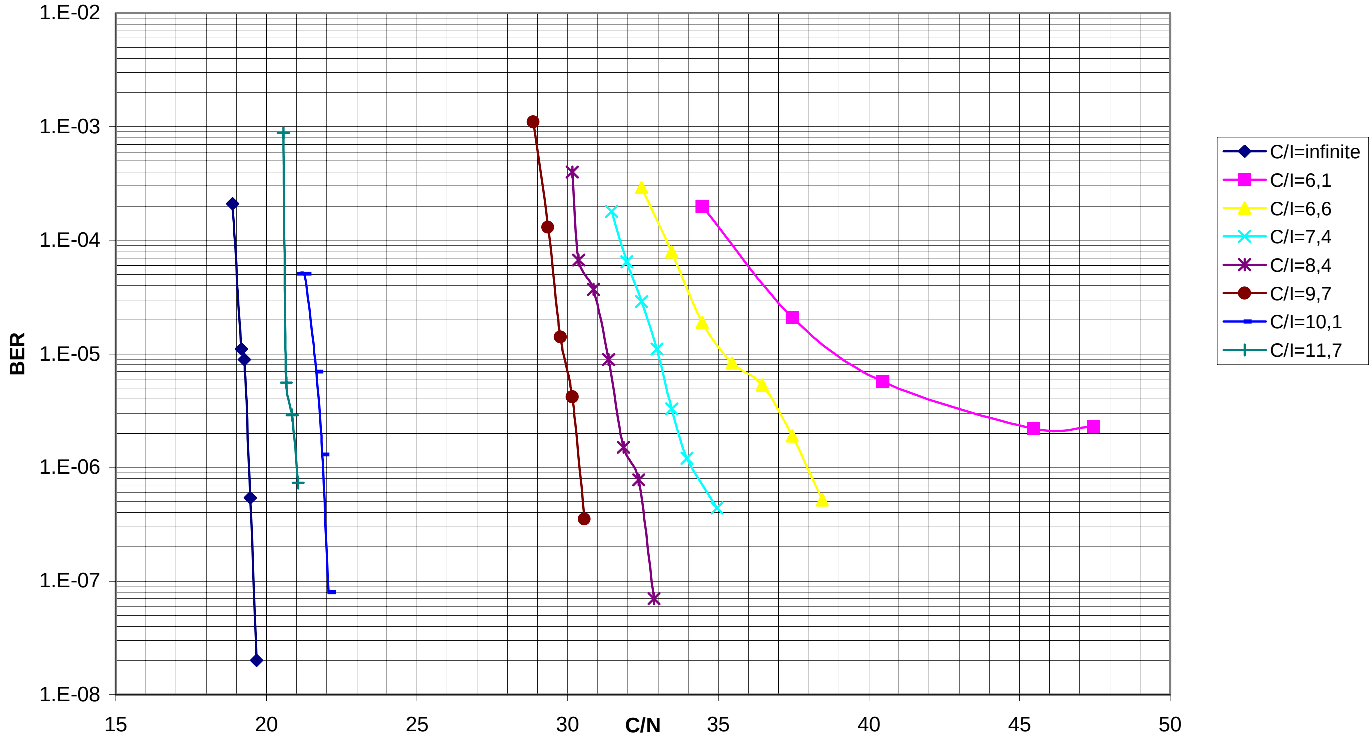
Graph 2.7.8.15: BER against C/N
Interferent signal = Lower adjacent analogic
DVB 64 QAM FEC 3/4 GI 1/16 8k



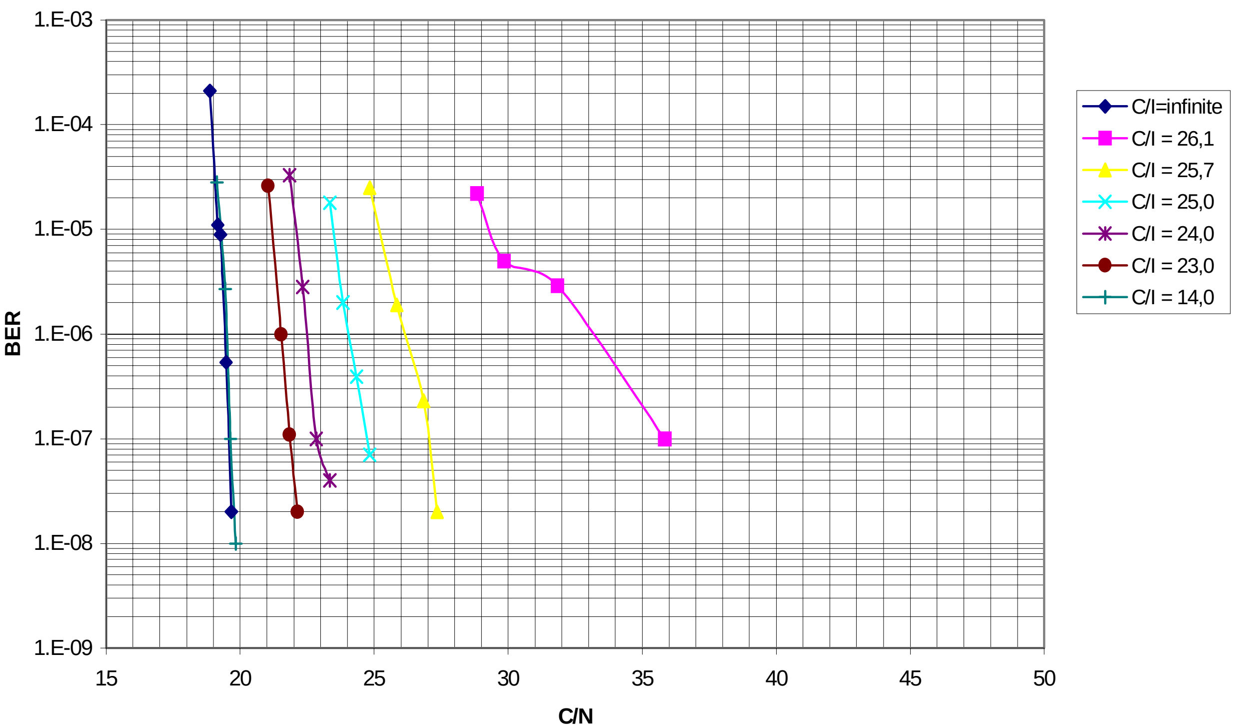
Graph 2.7.8.16: BER against C/N
Interferent signal= Upper adjacent analogic
DVB 64 QAM FEC 3/4 GI 1/16 8K



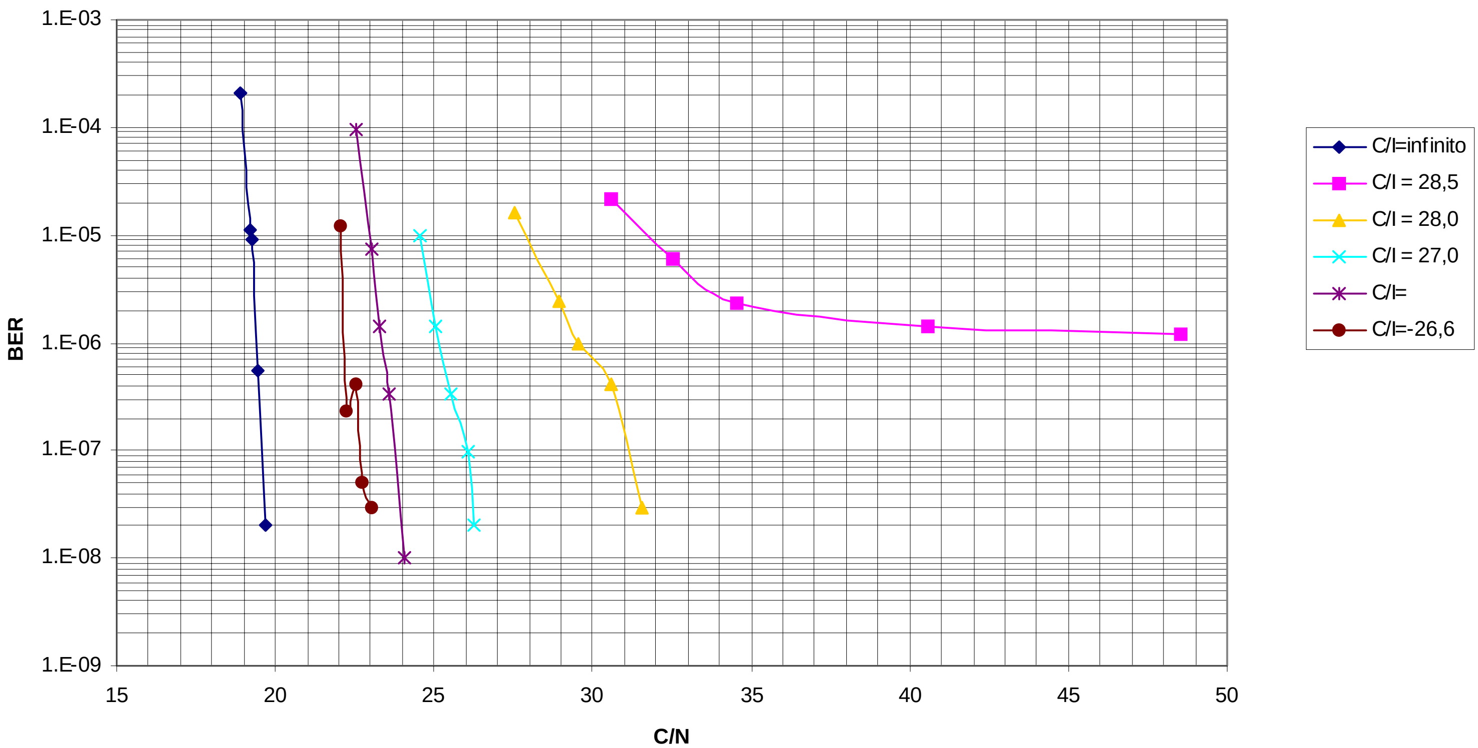
Graph 2.7.8.17: BER against C/N
Interferent signal = Co-channel
ISDB 64 QAM FEC 3/4 GI 1/16 MODE 2 (4K) INT 2 (0,1s)



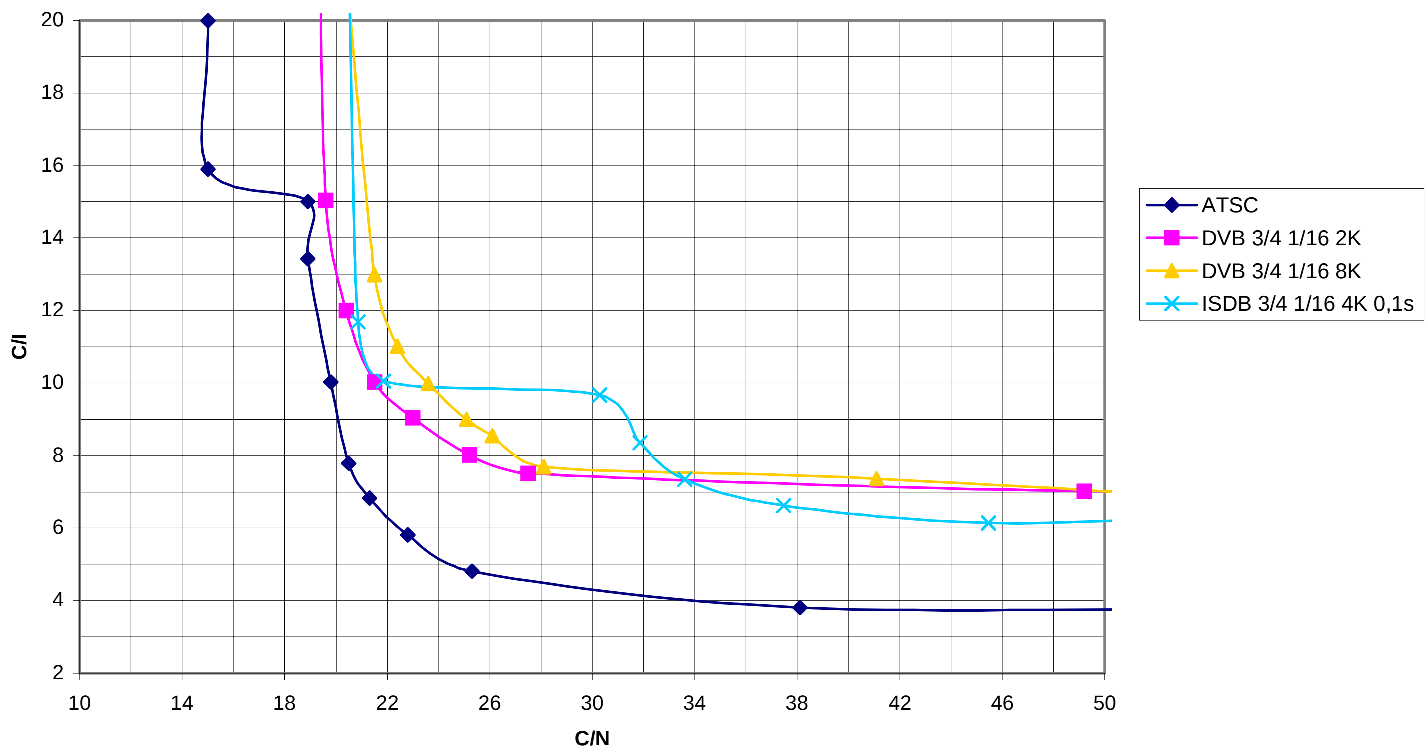
Graph 2.7.8.18: BER against C/N
Interferent signal = Lower adjacent analogic
ISDB 64 QAM FEC 3/4 GI 1/16 MODE 2(4K) INT2 (0,1s)



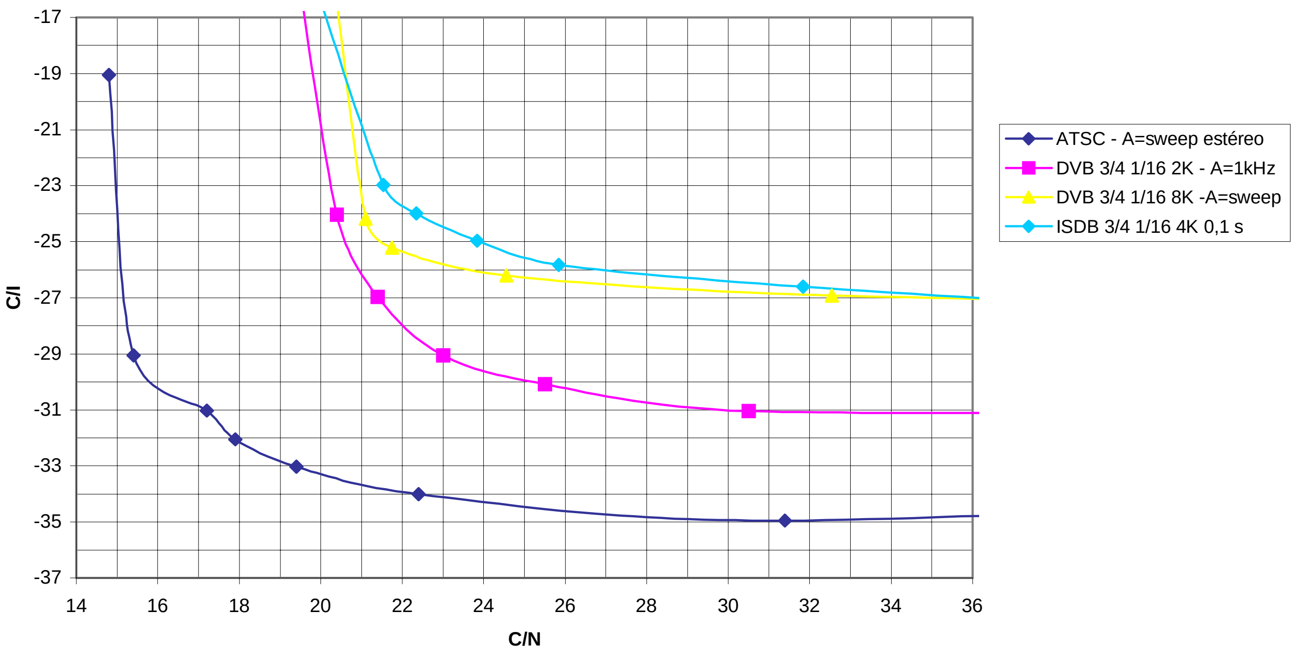
Graph 2.7.8.19: BER against C/N
Sinal Interferente= Analógico Adjacente Superior
ISDB 64 QAM FEC 3/4 GI 1/16 MODE 2 (4K) INT 2 (0,1s)



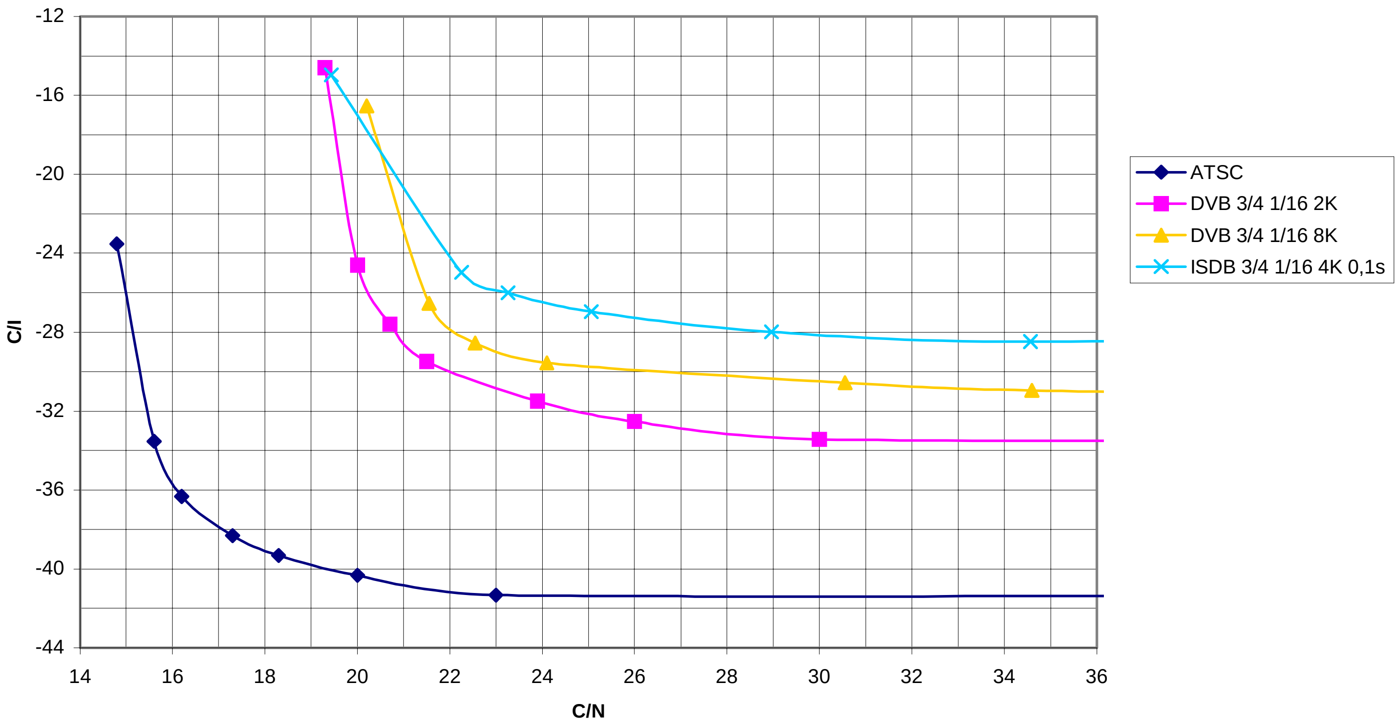
Graph 2.7.8.20: C/I against C/N
Interferent signal = Co-channel



Graph 2.7.8.21: C/I against C/N
Interferent signal = Lower adjacent



Graph 2.7.8.22: C/I against C/N
Interferent signal = lower adjacent



2.8. SIMULTANEOUS INTERFERENCE OF DIGITAL CHANNEL AND NOISE IN DIGITAL CHANNEL

2.8.1 Aim

This measurement method aims to evaluate the degradation assessment as produced upon a digital signal, interfered simultaneously by another digital signal and by gaussian noise.

The interfering digital channel may be of the following types: lower adjacent channel, upper adjacent channel, co-channel and "taboo" channel.

In this degradation assessment, the independent variable is the ratio of the interfered signal (digital) and the interfering noise power, i.e., C/N (dB). The dependent variable is the digital system bit error rate (BER). The parameter variable is represented by the ratio of interfered signal power and the interfering signal power (C/I (dB)). Thus, for each chosen value of C/I (dB), a curve of BER as a function of C/N (dB) will be derived.

2.8.2 The Basic Parameters Characteristics

The basic parameters in the determination of the rate C/N to BER, with parameters in the ratio C/I, are as follows:

- C/N (dB)= ratio of interfered signal power (Digital) to gaussian noise power at the receiver input, in dB.
- BER= Interfered Digital System Bit Error Rate measured at the demodulator output, in the interface with the decoder/decompressor MPEG-2.

- C/I (dB)= rate, of interfered signal power (Digital) to interfering signal power (Digital), in dB.

2.8.3 Initial Values and Characteristics

2.8.3.1 The interfering signal is obtained at the output of FI of the digital interfering transmitter as indicated in Figure 2.8.6.

2.8.3.2 The interfered digital channel, either in DVB or ATSC systems, is provided by a digital transmitter allocated to channel 35.

2.8.3.3 The signal level coming from the digital interfered transmitter (canal 35) must be adjusted in -30dBm at the digital receiver input.

2.8.3.4 The RF generator frequency (19) must be adjusted for the co-channel interference condition , i.e., for an initial frequency shift of 0 (zero) MHz.

2.8.3.5 The two digital transmitters should be modulated by their own pseudo-random sequences (PRBS).

2.8.4 Measurement general description

For a certain parametric value of C/I (dB), vary the noise power N (keeping C/I constant) and read the corresponding BER. Trace the BER curve as a function of C/N (dB) for the respective value of parametric C/I (dB). Thus, a curve for each parametric value of C/I (dB) will be derived.

2.8.5 Equipment used

(14) PAL-M Transmitter, channel 35.

(3a) and (3b) 2 HP 0-120 dB Attenuators model: 355D.

(4A) Ber Test Set Tektronix PB200

(4B) BER Test set HP3764A (for ISDB only)

(6a) and (6b) 2 HP combiners model: 0955-0751.

(13) Rohde & Schwarz 0-110 dB step 0,1 dB Attenuator model: RSP.

(17a) and (17b) 2 Mini-Circuits Mixers model:ZLW186MH

(16a) and (16b) 2 Telonic Filters 12 MHz model: TTF600

(18) HP Amplifiers model 8347 A

(19a) and (19b) RF Rohde & Schwarz Generators model: SMH.

(20) ATSC digital receiver

(21A) DVB digital receiver

(21B) ISDB digital receiver

(30) TAS Noise generator model 420.

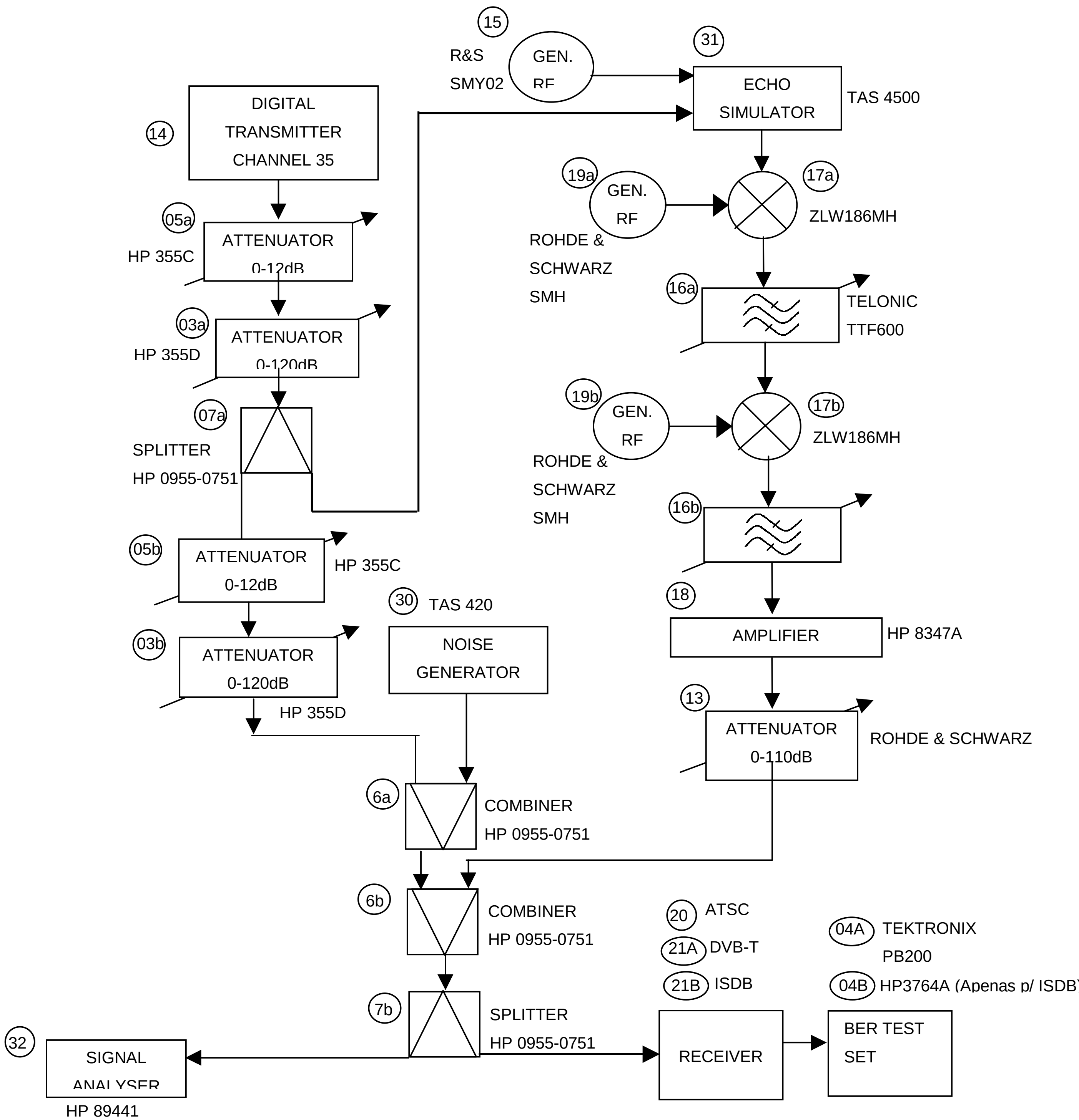
(31) Echo Simulator: TAS4500

(32) HP Signal Analyser 89441V.

(15) RF Generator R&S model: SMY02

(7a) and (7b) 2 HP signal splitters model: 0955-0751.

2.8.6 *Measurements basic lay out*



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2.6.7 Test Procedures

A) Co-channel Interference

A1) With the Interfering digital system attenuators at the position of maximum attenuation and the noise generator (30) OFF, adjust the Interfered digital system attenuators such as the digital signal power read by the signal analyser (32) be -30 dBm. Write down the position of these attenuators.

A2) Turn ON the noise generator (30) and adjust its level until the indicated BER is equal to the lower limit BER (minimum BER). Determine the value of C/N (dB) correspondent to the minimum BER.
Repeat the described above for the upper limit of BER and determine the value of C/N (dB) for such maximum BER. In this case we will have the limit points of the curve BER X C/N (dB) for C/I (dB) = ∞.

A3) Repeat item A2 for intermediary values of C/N (dB). Fulfill tables and locate the values on the graphics.
The complete curve of BER X C/N for C/I (dB) = ∞ will result.

A4) Turn OFF the noise generator (30) and, with the interfered digital system attenuators at the position of maximum attenuation, act upon the interfering digital system attenuators until the interfering signal power corresponds to the value in the parametric curve of C/I indicated by the ratio R1.

A5) Return the attenuators of the interfered digital system to the position adjusted in A1.

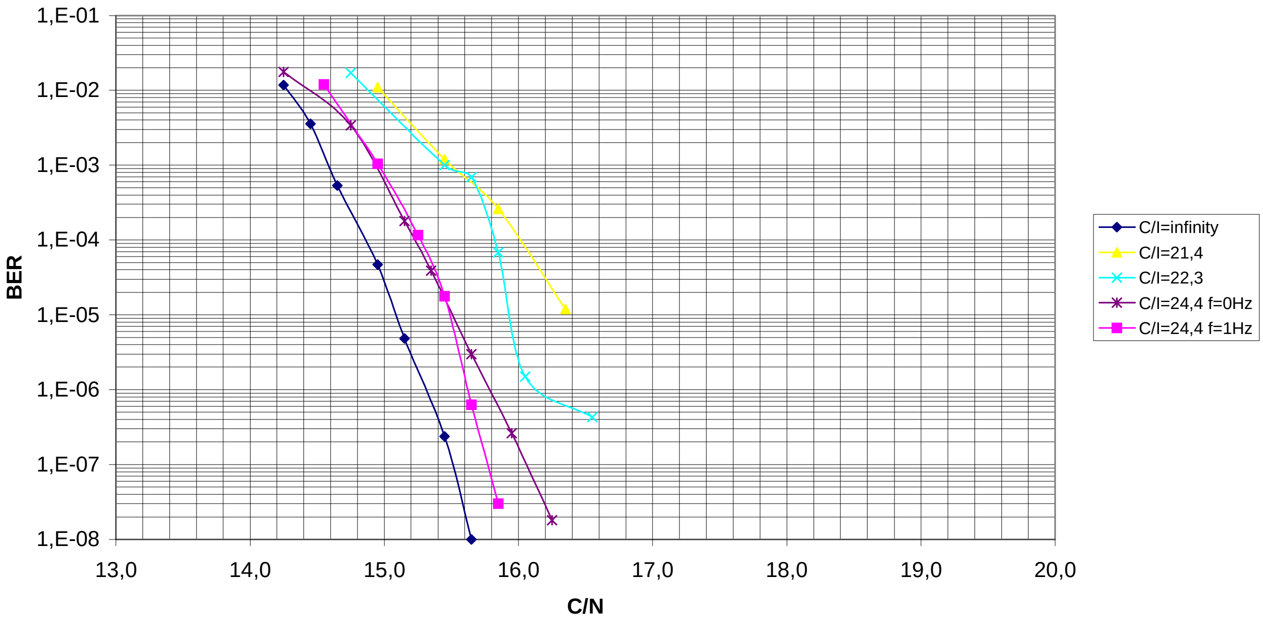
A6) Turn ON the noise generator (30) and repeat items A2 and A3 until obtaining all values of BER X C/N (dB) for the curve C/I with parameter R1.

A7) Repeat items A2 to A6 for all other parametric values of C/I, i.e., of R2 to Rn.
Transport those values to the tables and build up the graphics.

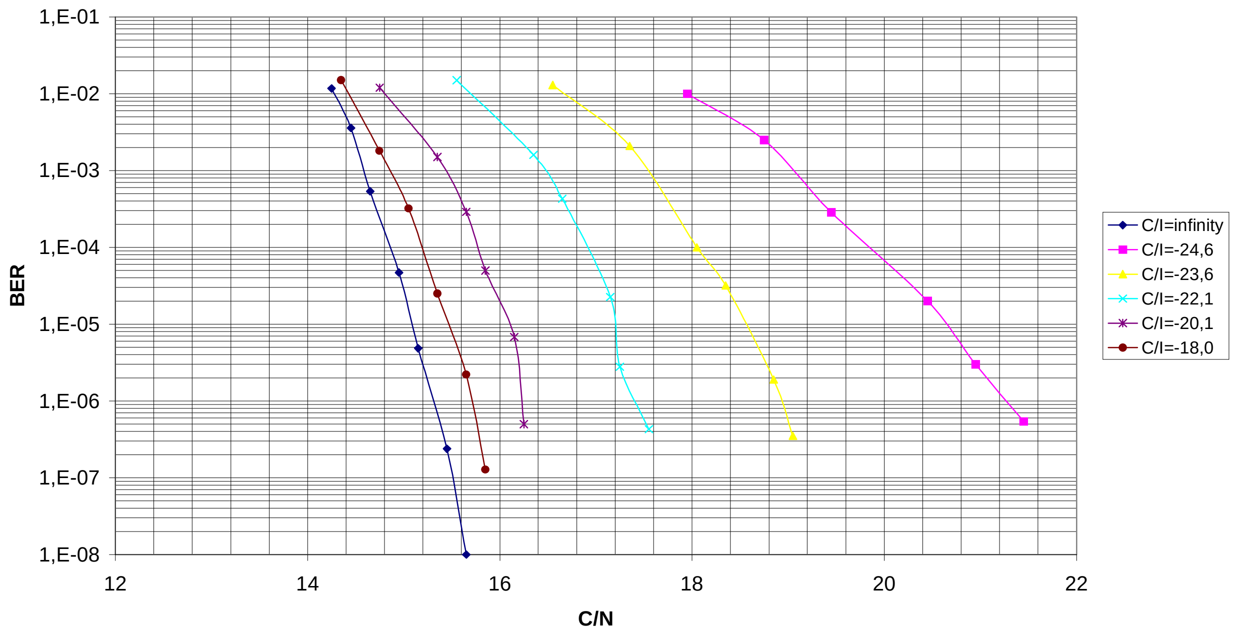
B) Repeat items A1 to A7 adjusting the RF generator (19) and the Telonic filter (16) for conditions of upper and lower adjacent channels and "taboo" channels.
For the "taboo" channel frequencies see test 2.3 (Interference between Two Digital TV Channels).

2.8.8 Results

Graph 2.8.8.1: Bit error rate against C/N Relation
Interferent signal = Co-channel
ATSC



Graph 2.8.8.2: bit error rate against C/N Relation
Interferent signal =Lower adjacent
ATSC



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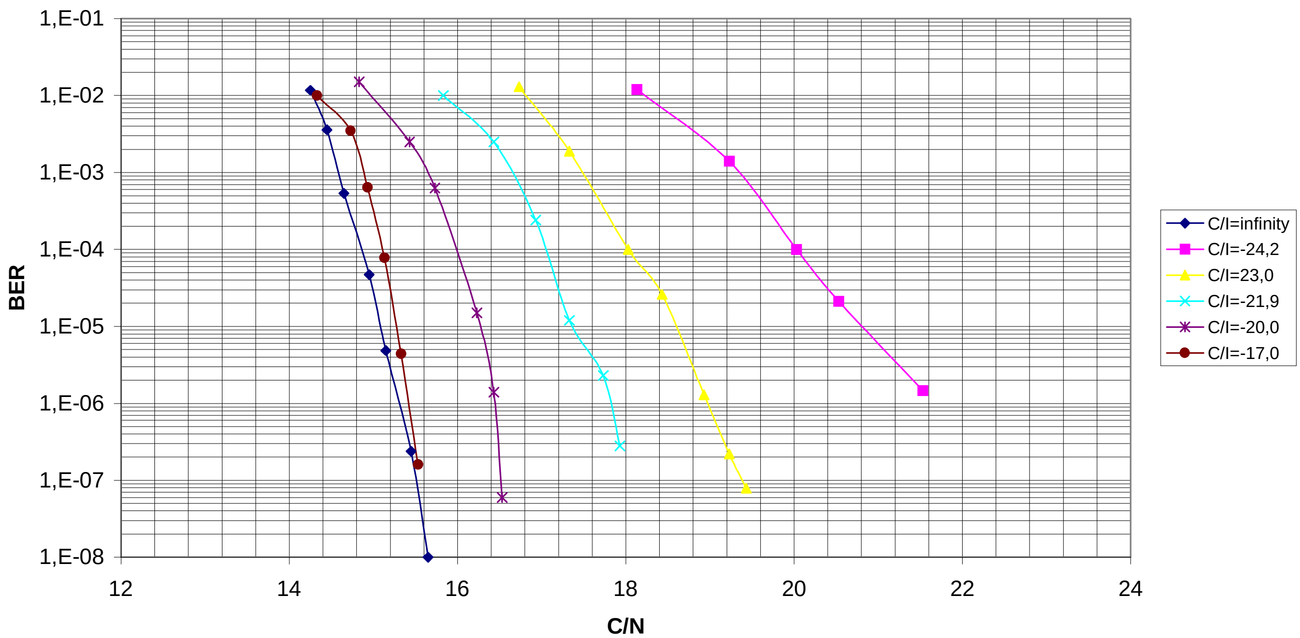
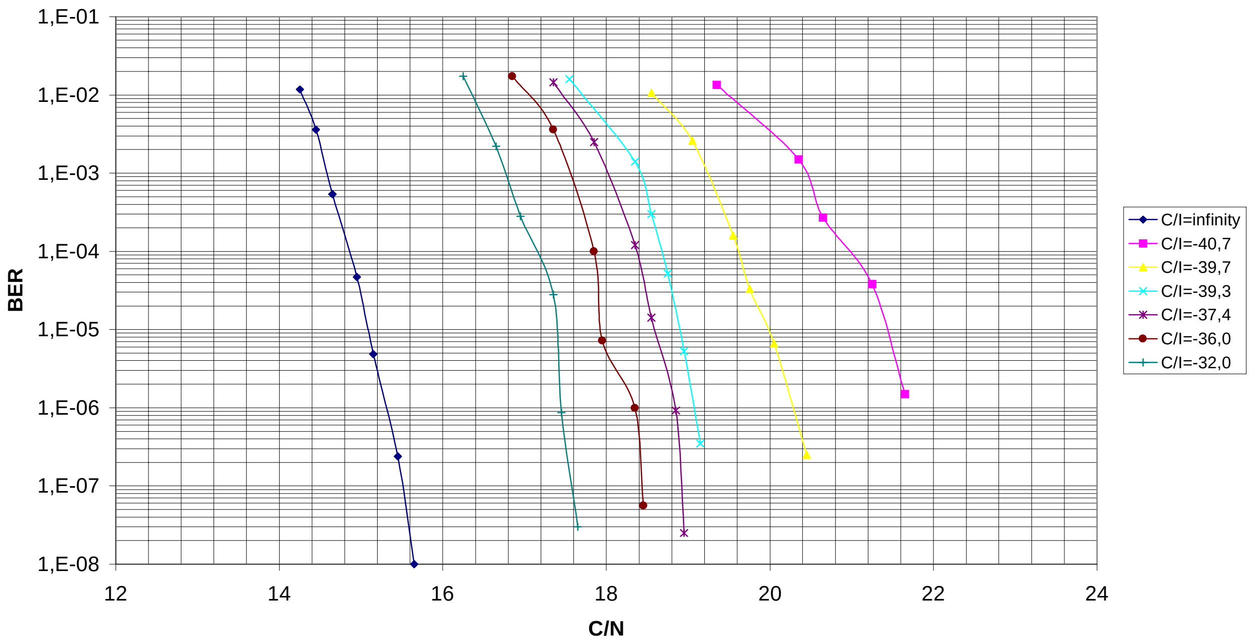
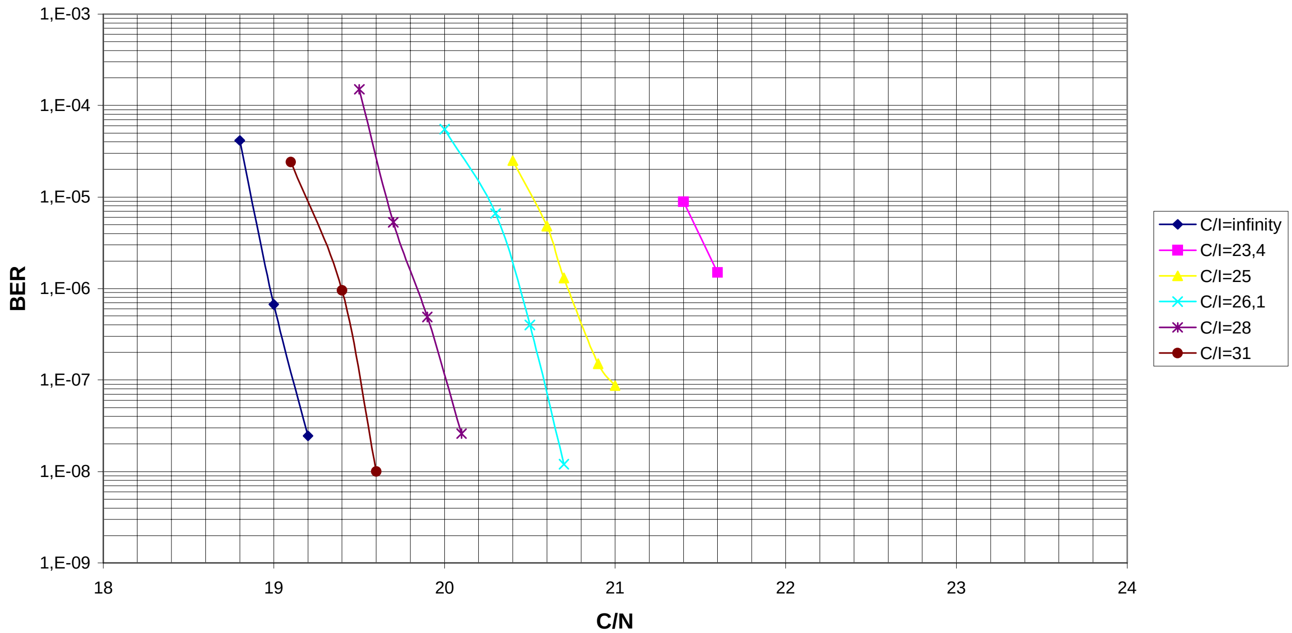
Grapf 2.8.8.3: Bit error rate against C/N Relation
Interferent Signal =Upper adjacent
ATSC



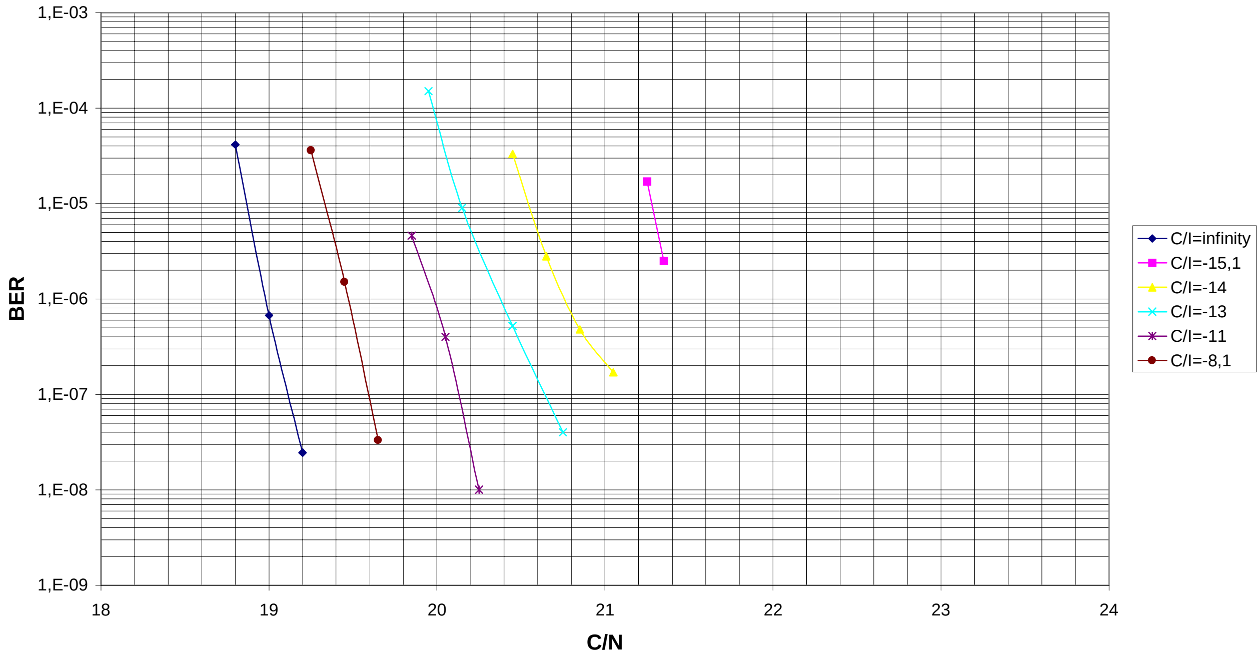
Graph 2.8.8.4: Bit error rate against C/N Relation
Interferent signal = - 7BW
ATSC



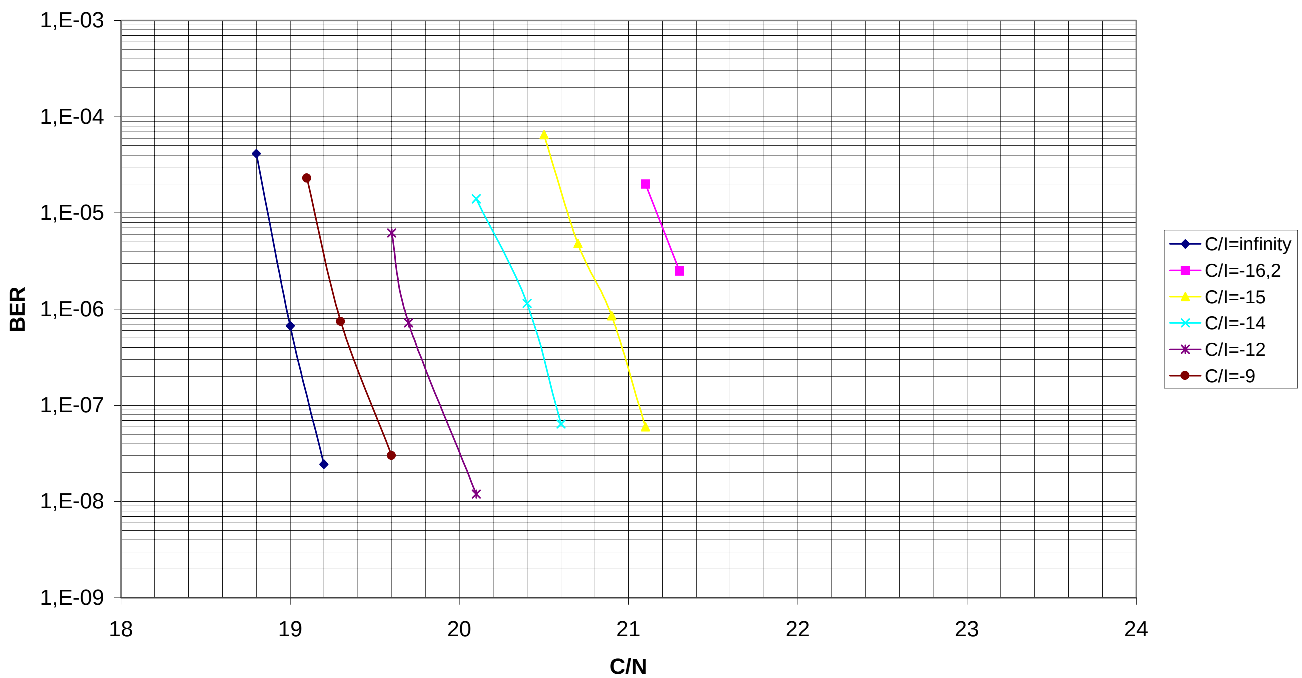
Graph 2.8.8.5: Bit error rate against C/N Relation
Interferent Signal =Co-channel
DVB 64 QAM FEC 3/4 GI 1/16 2K



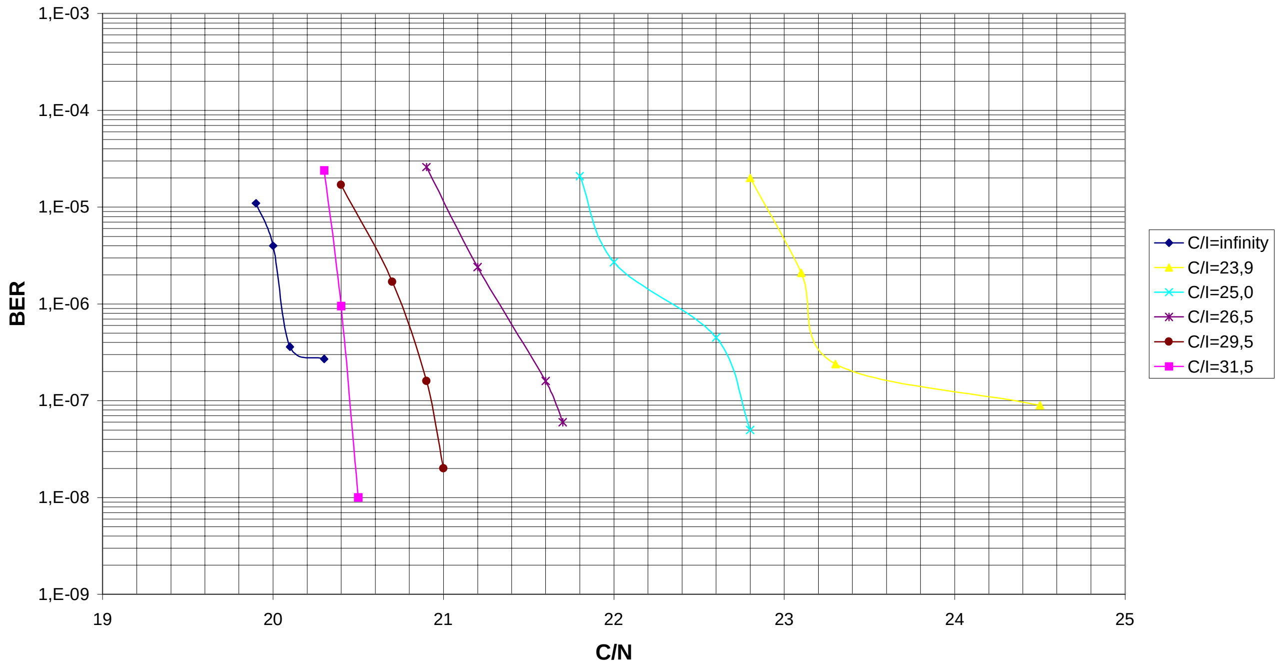
Graph 2.8.8.6: Bit error rate against C/N relation
Interferent Signal =Lower adjacent
DVB 64 QAM FEC 3/4 GI 1/16 2K



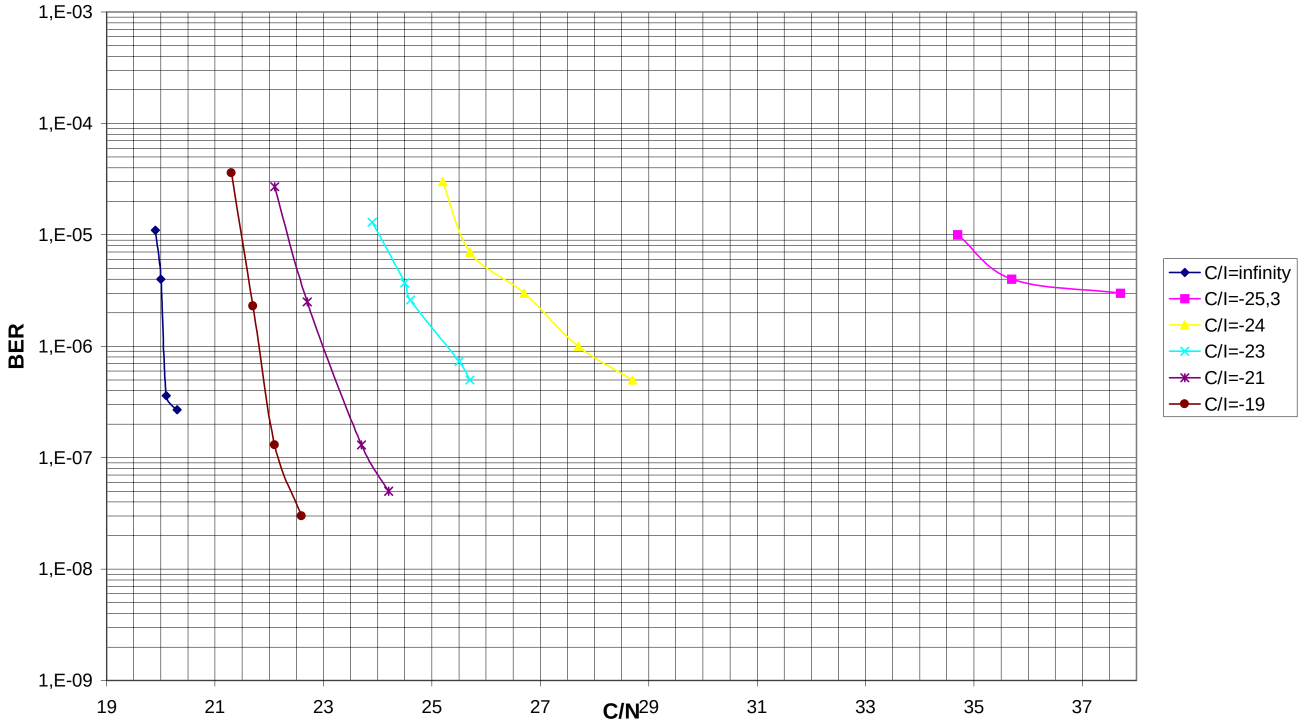
Graph 2.8.8.7: Bit error rate against C/N relation
Interferent Signal = Upper adjacent
DVB 64 QAM FEC 3/4 GI 1/16 2K



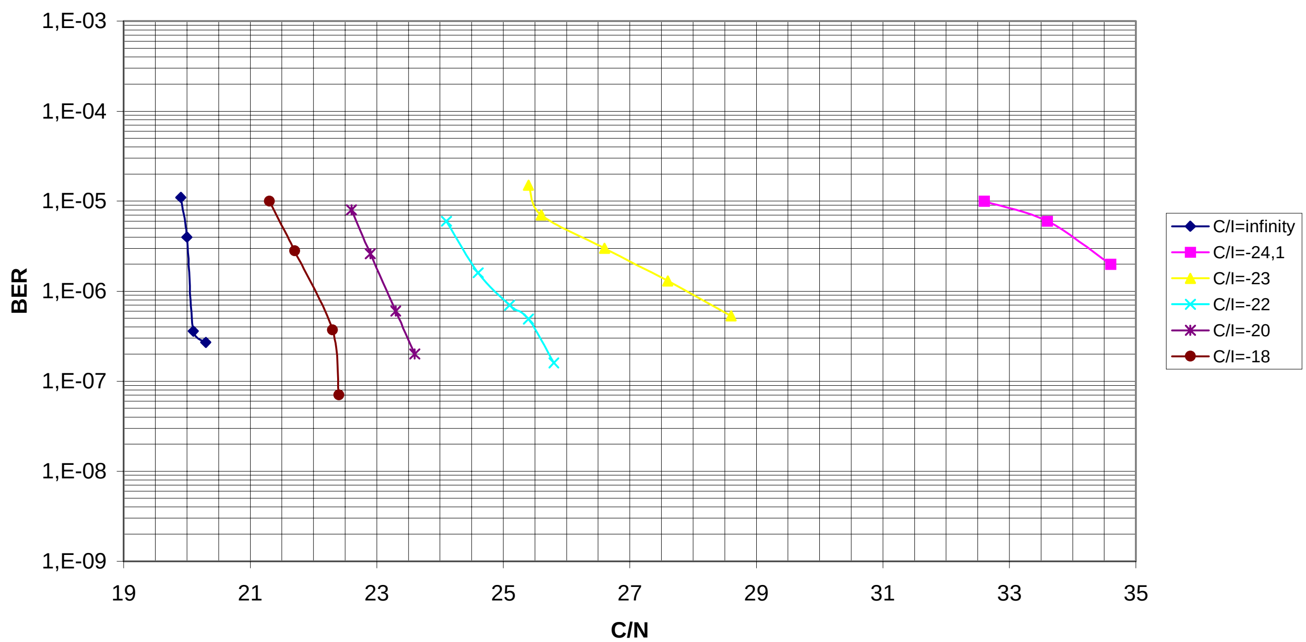
Graph 2.8.8.8: Bit error rate against C/N Relation
Interferent Signal =Co-channel
DVB 64 QAM FEC 3/4 GI 1/16 8K



Graph 2.8.8.9: Bit error rate against C/N Relation
Interferent Signal = Lower Adjacent
DVB 64 QAM FEC 3/4 GI 1/16 8K



Graph 2.8.8.10: Bit error rate against C/N Relation
Interferent Signal =Upper Adjacent
DVB 64 QAM FEC 3/4 GI 1/16 8K



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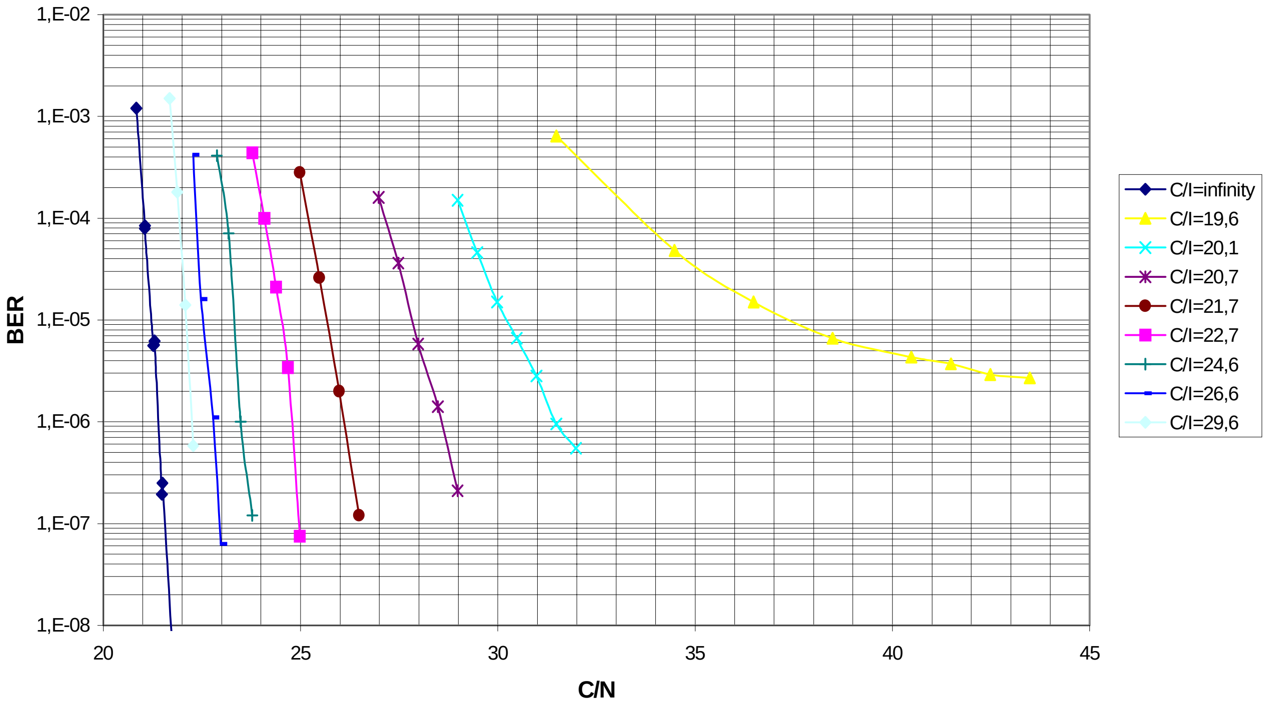
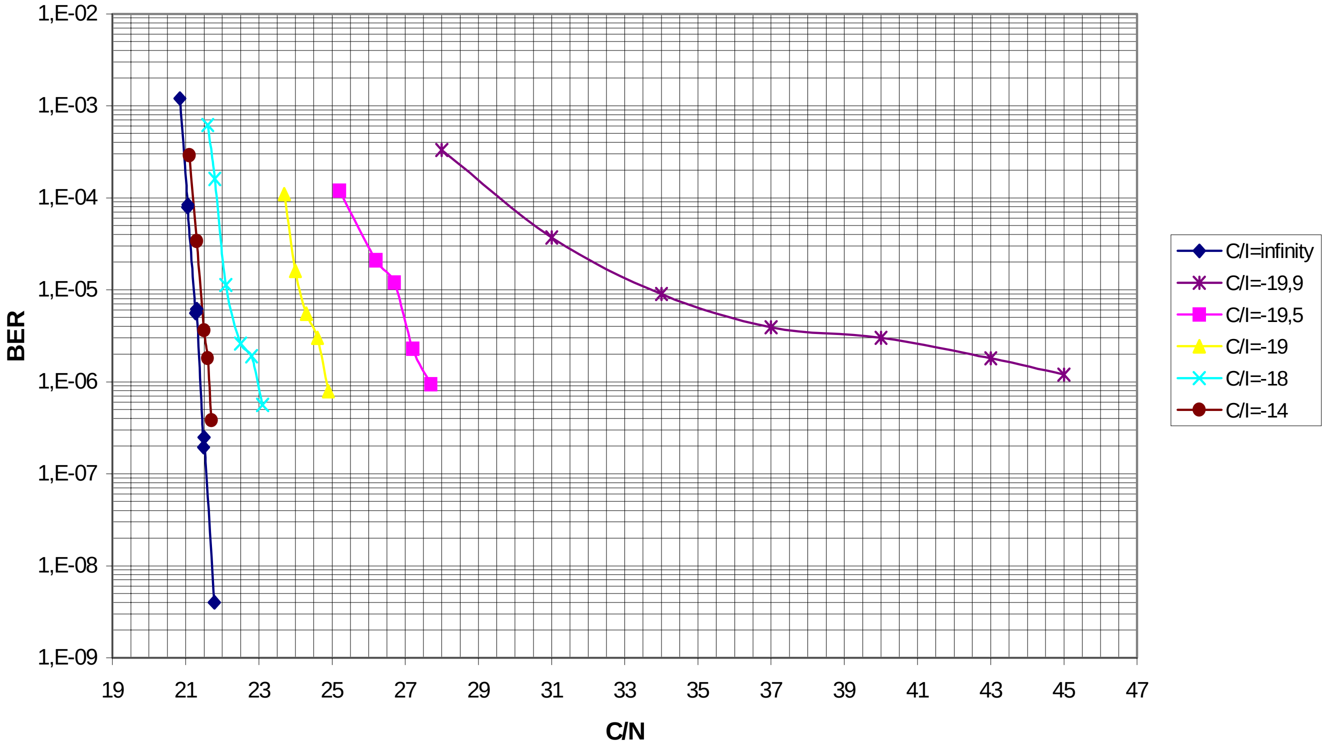
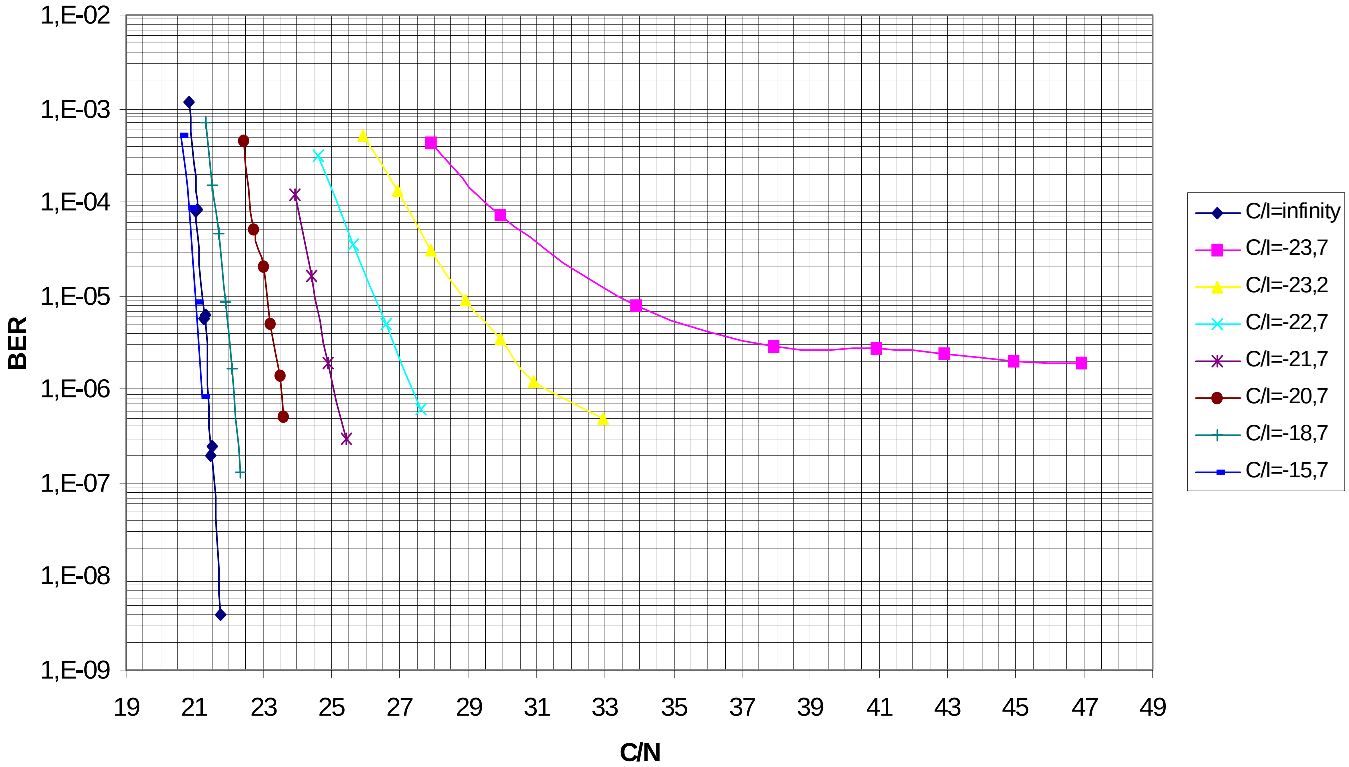
Graph 2.8.8.11: Bit error rate against C/N relation
Interferent Signal =Co-channel
ISDB 64 QAM FEC 3/4 GI 1/16 4K 0,1s



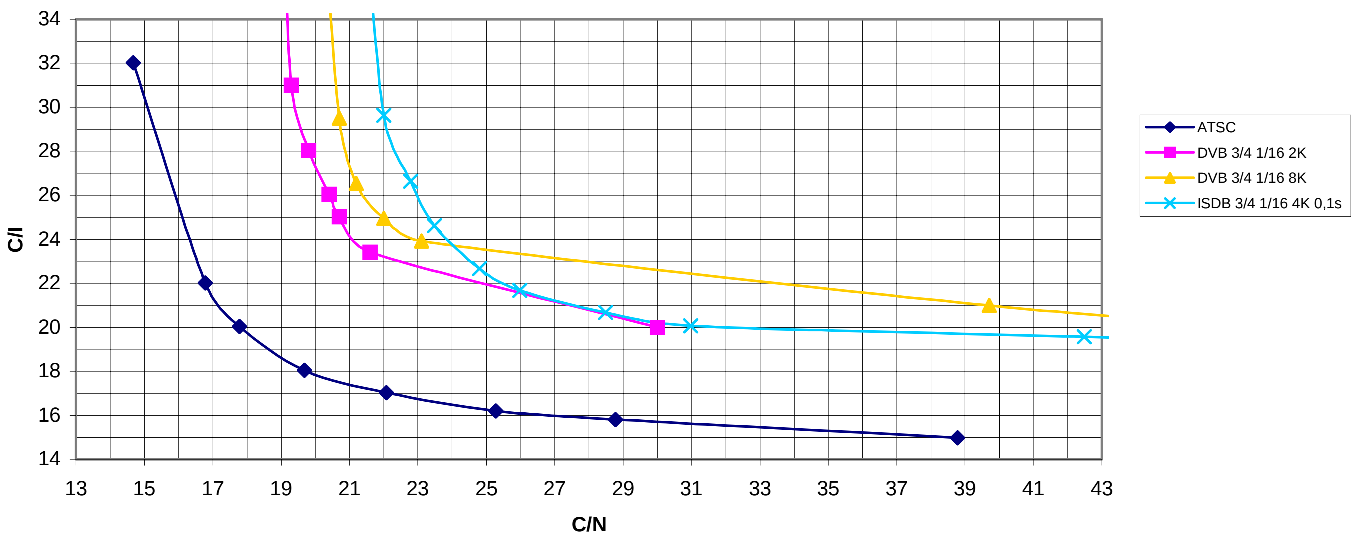
Graph 2.8.8.12: Bit error rate against C/N Relation
Interferent Signal =Lower adjacent
ISDB 64 QAM FEC 3/4 GI 1/16 4K 0,1s



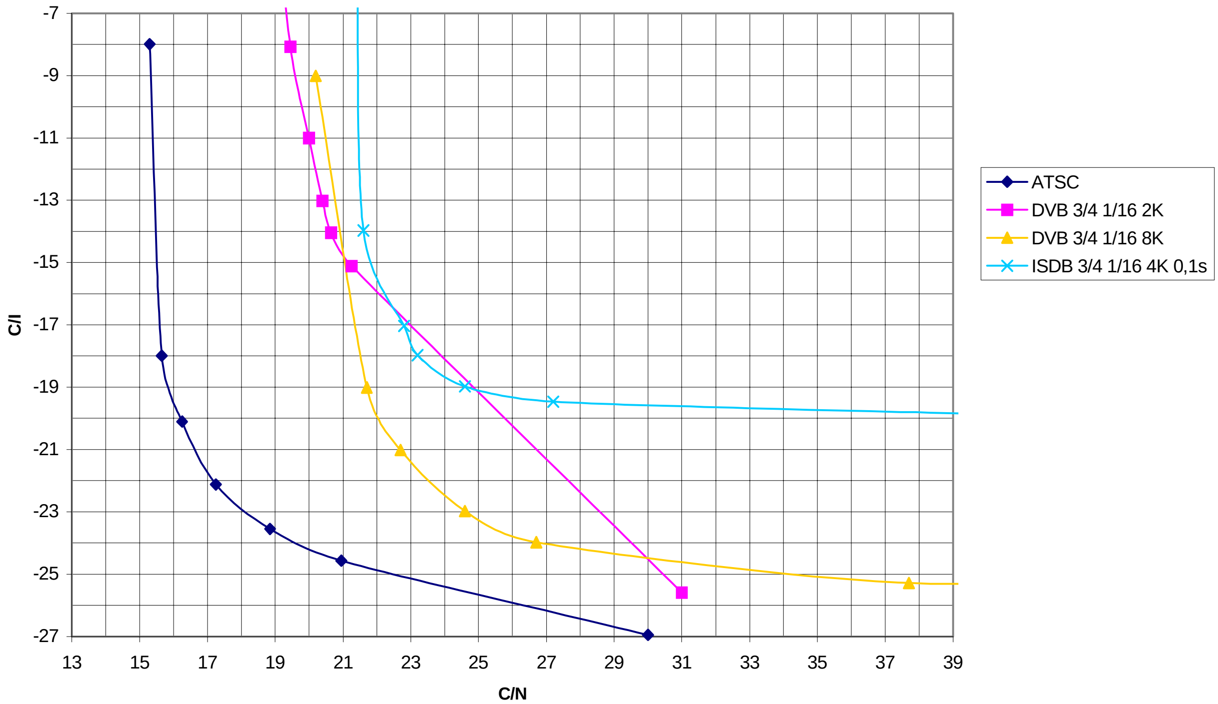
Graph 2.8.8.13: Bit error rate against C/N Relation
Interferent Signal =Upper adjacent
ISDB 64 QAM FEC 3/4 GI 1/16 4K 0,1s



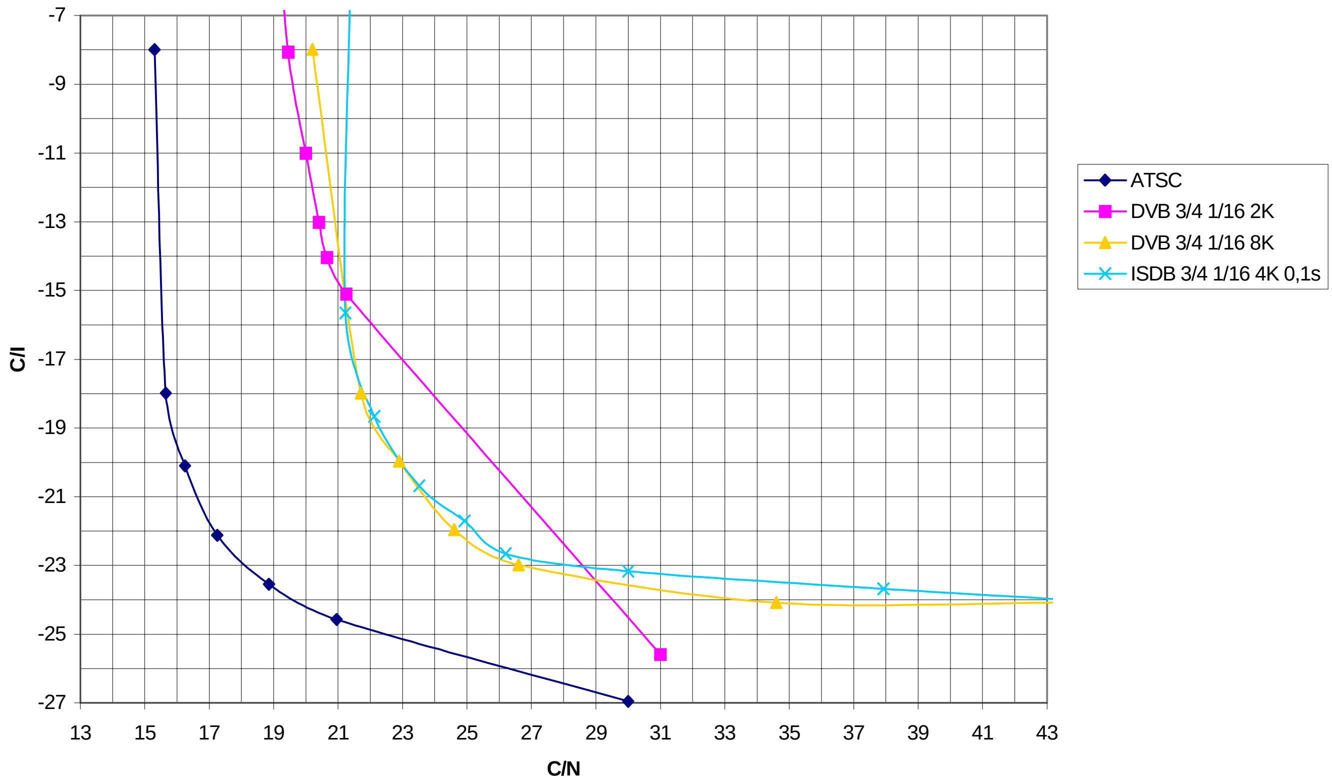
Graph 2.8.8.14: C/I against C/N
Interferent Signal = Co-channel



Graph 2.8.8.15: C/I against C/N
Interferent signal = Lower adjacent



Graph 2.8.8.16: C/I against C/N
Interferent Signal = Upper adjacent



3.1 Multipath Interference (echo or ghosting) without interfering noise

3.1.1 Aim

Echo or ghosting is the signal that arrives at the receiver having suffered reflections caused by buildings, vehicles, hills etc and overlaps the main signal.

There can happen two sorts of echoes: pre-echo and post-echo.

In case of post-echo, the signal arriving late is the weakest. For post-echo, the signal arriving earlier is the weakest.

In our measurements, we will define “Echo Level” as being the ratio between echo signal power level and main (wanted) signal power level and when error rate (BER = Bit Error Rate) equals “ threshold error rate”.

The object of this analysis is to evaluate the degree of the digital systems(ATSC, DVB-T or ISDB-T) tolerance to echo interferences.

3.1.2 Basic Parameters Characteristics

3.1.2.1 D = main signal power.

3.1.2.2 E = echo signal power.

3.1.2.3 E/D = Echo level = ratio between the echo signal and the main signal.

E/D (dB) = E (dBm) – D (dBm)

3.1.2.4 BER = bit error rate.

3.1.3 Initial figures and characteristics

3.1.3.1 Main signal power = -30dBm.

3.1.3.2 Signal-to-noise ratio C/N, where C is the digital signal power measured at the receiver’s input (main signal + echo signal): greater than 50dB.

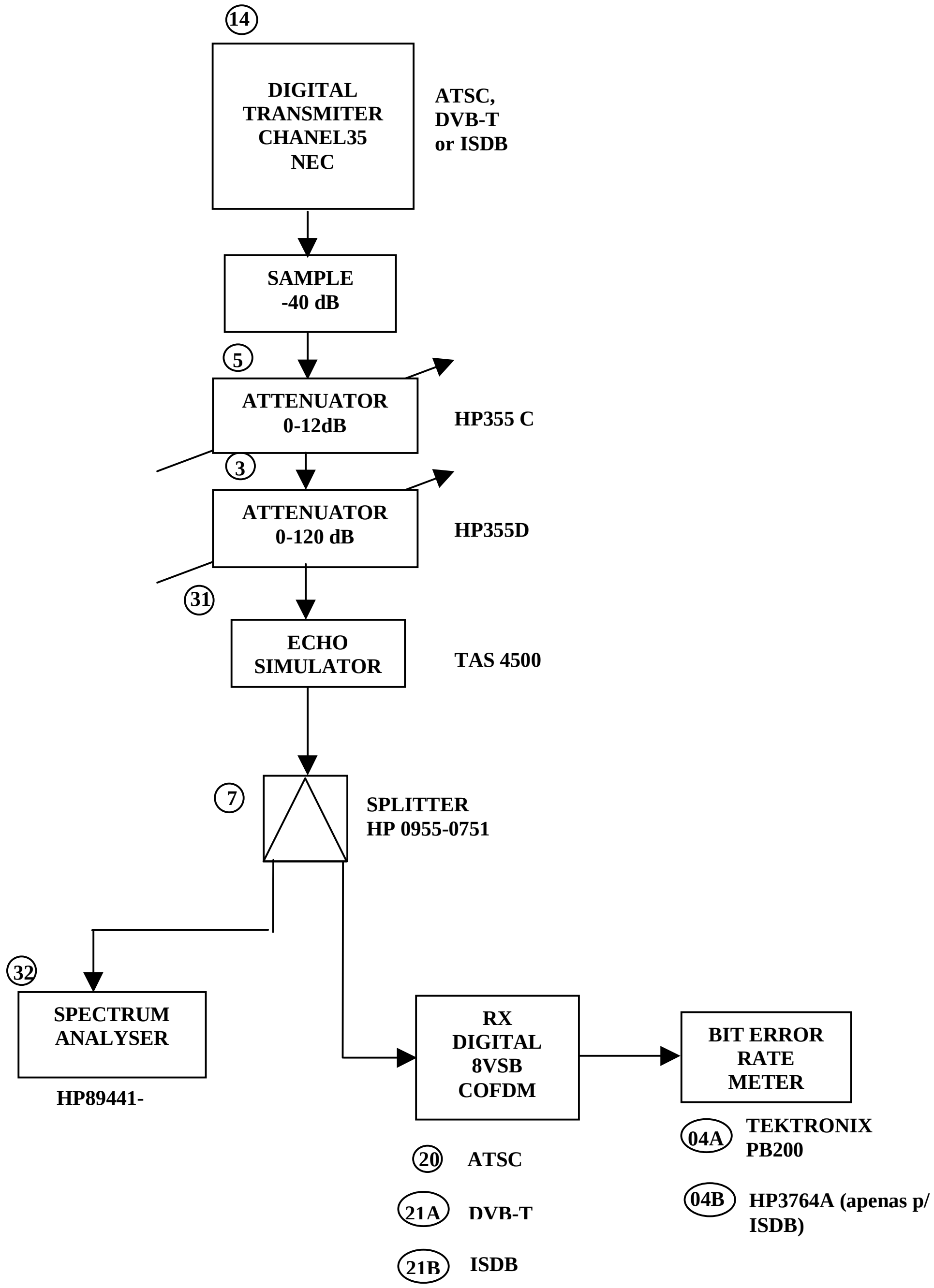
3.1.4 General description of the measurement procedure

For the different delays selected, the interfering signal amplitude (echo) is varied until the BER threshold is reached .

3.1.5 Equipment used

(14) NEC Digital transmitter tuned to channel 35
(3) HP 0-120dB attenuator, model 355D
(31) TAS echo simulator, model TAS4500
(7) HP signal splitter, model 0955-0751
(20) ATSC digital receiver - Zenith
(21A) DVB digital receiver - NDS
(21B) ISDB digital receiver
(4 A) TEKTRONIX bit error rate meter, model PB200
(4 B) HP3764A bit error rate meter (only for ISDB)
(32) HP89441-V spectrum analyser
(5) HP 0-12dB attenuator, model 355C

3.1.6 Measurement block diagram



3.1.7 Tests procedures

3.1.7.1 Adjust Attenuators (5) and (3) in order that the signal level at the input of the Echo Simulator TAS4500 (31) be approximately – 20 dB.
3.1.7.2 Turn off the echo signals at the Echo Simulator (31). Observe that in such conditions, the signal level at the output of the Echo Simulator will be approximately – 27 dBm. Consequently, the signal level at the input of the Digital Receiver will be – 33 dBm.
3.1.7.3 Adjust the Echo Simulator for a 1us delay (post-echo).
3.1.7.4 Turn the echo signal on and adjust its level until BER threshold is reached. Read the E/D ratio at the echo simulator (31).
3.1.7.5 Repeat the procedures described in items 3.1.7.3 and 3.1.7.4 for the following delay values: 2µs, 4µs, 8µs, 16µs, 32µs, 64µs, 128µs and 170µs.
3.1.7.6 Repeat the procedures described in items 3.1.7.3 and 3.1.7.4 for delay values under 1µs, looking for peaks in the E/D ratio.
3.1.7.7 Repeat the procedures described in items 3.1.7.3 to 3.1.7.6 using advance instead of delay at the echo simulator

3.1.8 Results

Table A: Post echo test (ATSC).

Delay time(µs)	E/D ratio (dB)
0,01 µs	0,0
0,05 µs	0,0
0,06 µs	0,0
0,066 µs	0,0
0,068 µs	-0,5
0,069 µs	-0,8
0,07 µs	-1,0
0,08 µs	-1,8
0,09 µs	-0,4
0,1 µs	-1,5
0,2 µs	-3,1
0,3 µs	-3,0
0,4 µs	-1,4
0,5 µs	-2,3
0,6 µs	-2,1
0,7 µs	-1,2
0,8 µs	-1,5
0,9 µs	-1,1
1,0 µs	-1,1

Delay time(µs)	E/D ratio (dB)
2,0 µs	-1,9
3,0 µs	-2,0
4,0 µs	-2,0
6,0 µs	-1,9
7,0 µs	-2,4
8,0 µs	-2,1
10,0 µs	-1,8
12,0 µs	-2,6
14,0 µs	-2,3
16,0 µs	-1,7
18,0 µs	-2,8
19,0 µs	-7,3
19,5 µs	-14,6
20,0 µs	-14,7
24,0 µs	-14,7
28,0 µs	-14,7
32,0 µs	-14,7
64,0 µs	-14,7
128,0 µs	-14,7

Table B: Pre echo test (ATSC).

Delay time (µs)	E/D ratio (dB)
-0,01 µs	0,0
-0,05 µs	0,0
-0,066 µs	0,0
-0,068 µs	-0,6
-0,069 µs	-1,1
-0,07 µs	-1,8
-0,08 µs	-2,2
-0,09 µs	-0,9
-0,1 µs	-0,3
-0,15 µs	-4,1
-0,2 µs	-6,4
-0,25 µs	-1,6
-0,3 µs	-1,3
-0,4 µs	-0,6

Delay time (µs)	E/D ratio (dB)
-0,5 µs	-0,9
-0,6 µs	-2,0
-0,7 µs	-1,8
-0,8 µs	-1,5
-0,9 µs	-0,7
-1,0 µs	-2,3
-2,0 µs	-4,4
-3,0 µs	-6,9
-4,0 µs	-7,6
-5,0 µs	-14,4
-6,0 µs	-14,6
-7,0 µs	-14,6
-8,0 µs	-14,5
-10,0 µs	-14,6

Table C: Post echo test (DVB-T).

Delay time (μs)	E/D ratio (dB)			
	3/4; 1/16; 2K	3/4; 1/16; 8K	3/4; 1/8; 2K	2/3; 1/32; 8K
0,1	0	0		
0,2	0	-1,9		
0,5	0	-0,8		
1	0	0		
2	0	-1,1		
4	0	0		
8	0	0		
12	0	-0,6		
15	0	-		
15,2	0	-		
15,4	0	-		
15,5	-0,1	-		
15,7	-6,4	-		
16	-6,5	-0,7		
18,7	-8,1	-		
24	-9,9	-0,8		
28	-10,8	-		
32	-11,7	-0,9		
36	-13,9	-		
40	-17,3	-		
48	-21,1	-		
56	-	-1,0		
60	-22,1	-		
64	-	-5,8		
68	-	-7,5		
72	-21,8	-8,0		
80	-	-8,9		
88	-	-9,9		
96	-21,3	-10,4		
112	-	-11,2		
128	-20,8	-11,9		
170	-	-19		
250	-19,4	-		

Table D: Pre echo test (DVB-T).

Delay time (μs)	E/D ratio (dB)			
	3/4; 1/16; 2K	3/4; 1/16; 8K	3/4; 1/8; 2K	2/3; 1/32; 8K
-0,1	0	-0,6		
-0,2	0	-2,1		
-0,5	0	-1,0		
-1	0	-0,2		
-2	0	-1,2		
-4	0	0		
-8	0	-0,4		
-12	0	-0,2		
-15	0	-		
-15,2	0	-		
-15,4	0	-		
-15,5	0	-		
-15,7	-6,2	-		
-16	-6,6	-0,6		
-18,7	-8,1	-		
-24	-10	-0,8		
-28	-10,7	-		
-32	-11,5	-1,0		
-36	-12,2	-		
-40	-12,8	-		
-48	-13,7	-		
-56	-	-0,9		
-60	-18	-		
-64	-	-6,2		
-68	-	-6,9		
-72	-21,7	-7,5		
-80	-	-8,6		
-88	-	-9,2		
-96	-21,3	-9,9		
-112	-	-10,8		
-128	-20,8	-12,2		
-170	-20,2	-18,2		
-250	-19,6	-		

Table E: Post echo test (ISDB).

Delay time (us)	E/D ratio (dB)		
	3/4; 1/16; 2K (0,1s)	3/4; 1/16; 4K (0,1s)	3/4; 1/16; 8K (0,1s)
0,01	0	0	0
0,068	0	0	0
0,069	-0,5	-0,5	-0,3
0,1	-0,9	-0,8	-0,9
0,5	-0,8	-0,7	-0,7
1	-0,8	-0,7	-0,7
2	-1,1	-1,0	-1,0
3	-1,1	-0,8	-1,0
4	-0,8	-1,0	-0,9
6	-1,0	-1,0	-1,0
8	-0,8	-1,0	-0,9
12	-1,1	-0,9	-0,9
14	-1,1	-	-
15	-1,3	-	-
15,5	-1,9	-	-
16	-3,0	-0,9	-
18	-5,3	-	-
20	-6,7	-0,9	-
24	-8,6	-0,9	-
28	-10,0	-1,0	-
32	-10,8	-3,6	-0,9
34	-	-4,7	-
36	-	-5,6	-
38	-	-6,3	-
40	-14,2	-6,9	-
45	-	-8,2	-
50	-19,4	-9,1	-1,2
60	-	-	-1,7
61	-	-	-2,4
62	-	-	-2,8
64	-19,9	-10,9	-3,8
80	-19,8	-14,3	-7,1
96	-19,6	-19,0	-8,8
112	-19,5	-20,0	-10,1
128	-19,2	-19,9	-11,0
170	-19,2	-19,7	-16,1

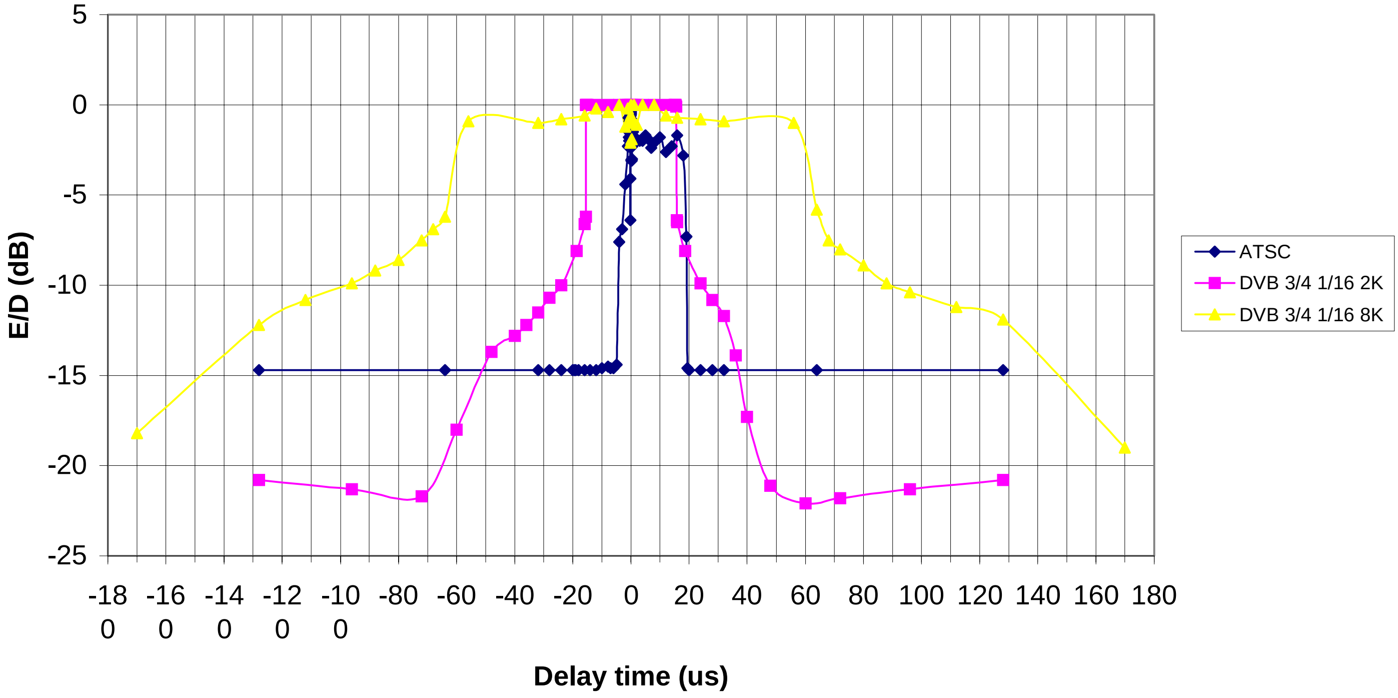
Table F: Pre echo test (ISDB).

Delay time (us)	E/D ratio (dB)		
	3/4; 1/16; 2K (0,1s)	3/4; 1/16; 4K (0,1s)	3/4; 1/16; 8K (0,1s)
-0,01	0	0	0
-0,068	0	0	0
-0,069	-0,6	-0,5	-0,5
-0,1	-0,8	-0,9	-0,8
-0,5	-0,8	-0,7	-0,7
-1	-0,9	-0,9	-0,7
-2	-1,7	-0,9	-1,1
-3	-3,5	-0,9	-1,0
-4	-4,6	-1,1	-1,0
-5	-5,6	-2,1	-0,9
-6	-6,2	-3	-1,0
-8	-7,4	-4,3	-1,2
-12	-9,1	-6,1	-3,2
-16	-10,1	-7,3	-4,5
-20	-11,0	-8,2	-5,4
-24	-11,8	-8,9	-6,2
-28	-12,5	-9,6	-7,0
-32	-13,0	-10,1	-7,4
-36	-	-10,6	-
-40	-15,7	-11	-8,3
-48	-19,2	-11,7	-9,0
-56	-19,9	-12,4	-9,7
-64	-19,8	-12,9	-10,2
-80	-19,7	-15,5	-11,1
-96	-19,5	-19,2	-11,8
-112	-19,4	-19,9	-12,5
-128	-19,1	-19,9	-13,0
-170	-19,0	-19,6	-16,9

Figure 3.1.8.1: (E/D)dB *vs. Echo delay time* (us)

Note: D= main signal power; E= echo signal power

ATSC and DVB-T systems



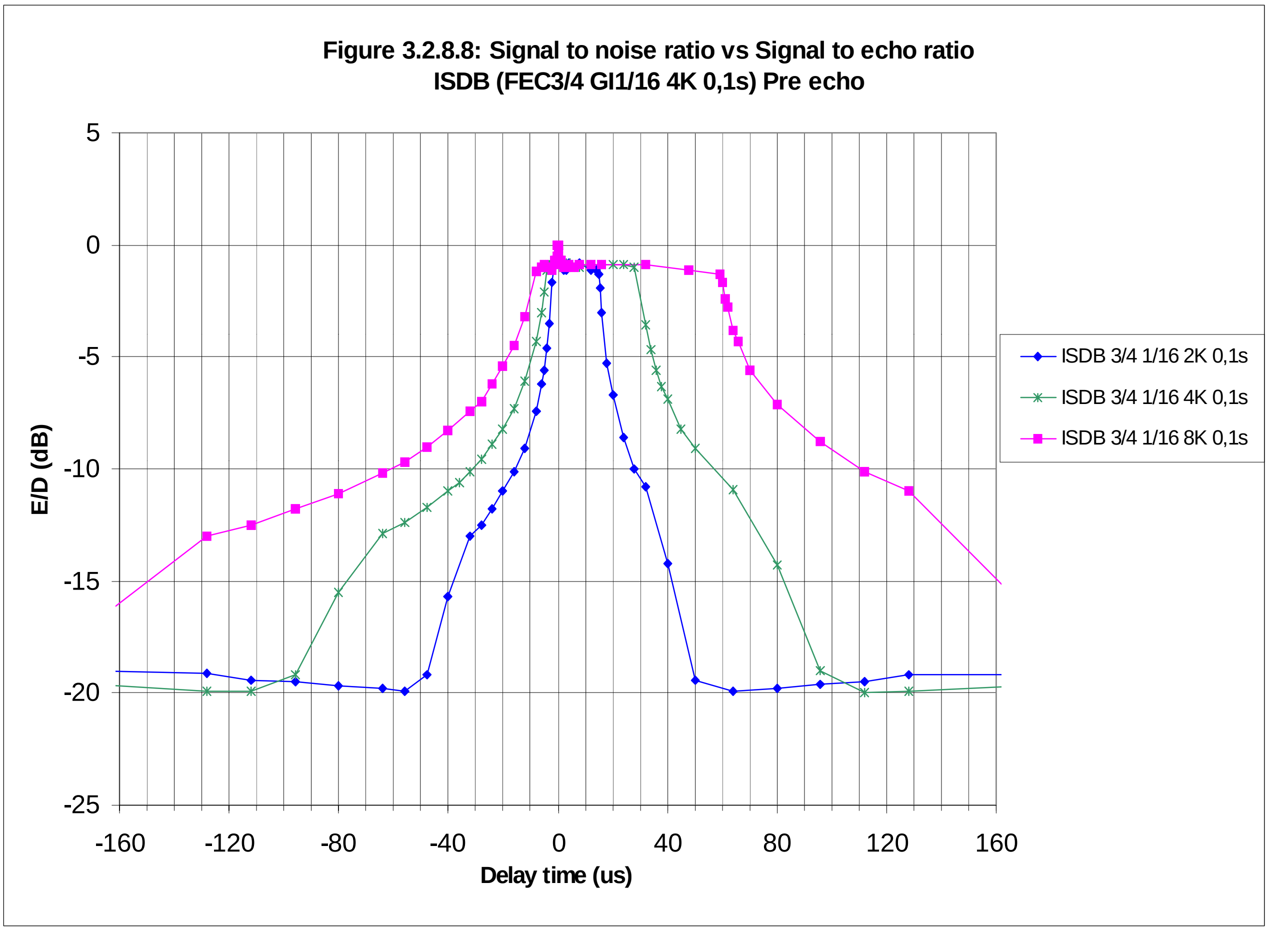


Figure 3.2.8.8: Signal to noise ratio vs Signal to echo ratio
ISDB (FEC3/4 GI1/16 4K 0,1s) Pre echo
E/D (dB)
5
0
-5
-10
-15
-20
-25
-160
-120
-80
-40
0
40
80
120
160
Delay time (us)
ISDB 3/4 1/16 2K 0,1s
ISDB 3/4 1/16 4K 0,1s
ISDB 3/4 1/16 8K 0,1s

3.2 Multipath Interference (echo or ghosting) with interfering noise.

3.2.1 Aim

The test described on item 3.1 shows the performance of the digital receiver facing echo signals in a non noise condition (C/N higher than 50 dB).
The aim of this analysis is to verify both ATSC and DVB-T systems performances when interfering echo is present and the signal-to-noise ratio is reduced.

3.2.2 Basic parameters characteristics

3.2.2.1 D = main signal power level.
3.2.2.2 E = echo signal power level.
3.2.2.3 D/E = ratio between main signal and echo signal.
D/E (dB) = D (dBm) – E (dBm).
3.2.2.4 N = Gaussian noise power level at the receiver input
3.2.2.5 D/N = main signal to noise ratio.
3.2.2.6 C/N = total signal (main signal + echo signal) to noise ratio.
3.2.2.7 BER = bit error rate

3.2.3 Initial figures and characteristics

3.2.3.1 Main signal power level = approximately -39dBm.
3.2.3.2 Signal to noise ratio C/N where C is the digital signal (main signal + echo signal) power level measured at the receiver input → higher than 50dB (will be variable during the tests).

3.2.4 Measurement general description

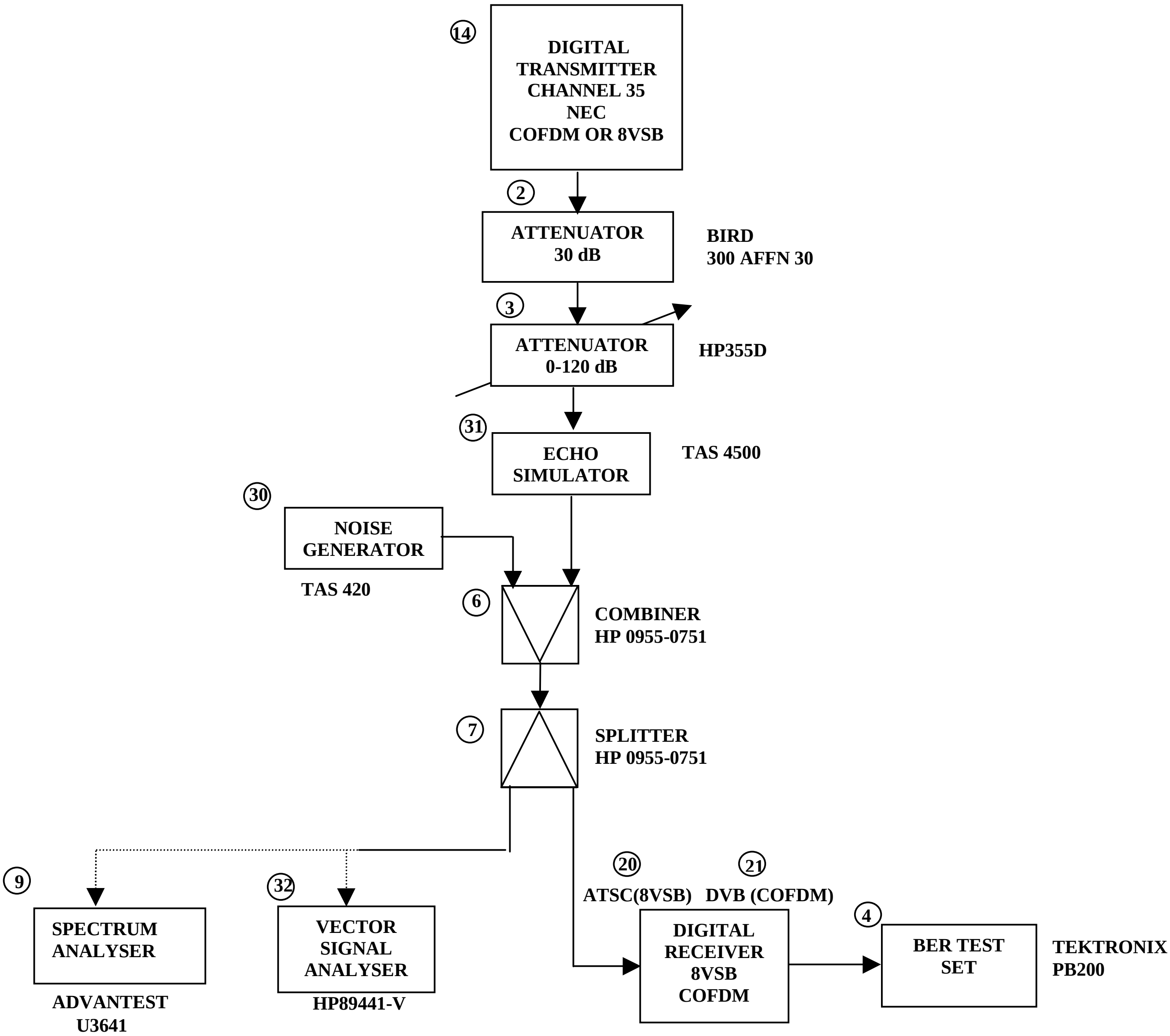
Adjust the main signal to 0dB (approximately – 39dBm)
Increase the echo level until the reading on the bit error rate meter indicates BER threshold.
Attenuate the echo signal in consecutive steps of 1dB. For each dB attenuated on the echo signal, increase the noise level until the reading on the bit error rate meter indicates BER threshold.
Draw the graph D/N vs D/E.

3.2.5 Equipment used

(14) Digital Transmitter fitted with COFDM and 8VSB modulators, tuned to channel 35.
(3) HP Attenuator 0-120dB, model 355
(31) TAS Echo Simulator, model 4500.
(6) HP Signal Combiner, model 0955-0751.
(30) TAS Noise Generator, model 420.
(7) HP Signal Splitter, model 0955-0751.
(20) Digital Receiver ATSC - Zenith.
(21A) Digital Receiver DVB-T - NDS.

(21B) Digital Receiver ISDB.
(4A) TEKTRONIX Bit Error Rate Meter, model PB200.
(4B) HP Bit Error Rate Meter, model 3764 A (only for ISDB).
(32) HP Vector Signal Analyzer, model 89441-V.
(4) HP Attenuator 0-12dB, model 355C.
(13) Rohde Schwarz Attenuator 0-110dB (in steps of 0,1dB), model RSP.
(43) HP 50 Ohm Load, model 909C.

3.2.6 Measurement block diagram



3.2.7 Test procedures

3.2.7.1 Adjust the attenuators (5) and (3) so that the signal level at TAS 4500 echo simulator (31) be approximately – 20dBm.

3.2.7.2 Set attenuator (13) for “maximum attenuation”.

3.2.7.3 At the echo simulator, turn off the echo signals. Observe that in this condition the signal level at the echo simulator output will be approximately 27dBm. Consequently, the signal level at the digital receiver input will be approximately – 39dBm. Write down the measured level because this will be the D reference for the rest of the measurements.

3.2.7.4 At point B disconnect the cable arriving from the echo simulator and replace this cable by a 50 Ohm load.

3.2.7.5 Set attenuator (13) for “minimum attenuation”.

3.2.7.6 The signal level at the output of TAS 420 noise generator (30) is approximately – 14dBm. In this case the noise level at the digital receiver input will be aproximately – 26dBm. Using the vector signal analyser (32) measure the noise power level in the channel bandwidth (6MHz) at the digital receiver input. This will be the reference value for the rest of the noise measurements (N).

3.2.7.7 Set attenuator (13) for “maximum attenuation”. Disconnect the 50 Ohm load from point B and connect again the cable arriving from the echo simulator (31).

3.2.7.8 Adjust the echo simulator for a single echo signal with a 1 μs delay time (post echo).

3.2.7.9 Turn on the echo signal and adjust its level until the reading on the bit error rate meter (4) indicates that BER threshold has been reached.

3.2.7.10 At the echo simulator attenuate the echo signal by 1dB. Write down the related D/E ratio.

3.2.7.11 Adjust attenuator (13) until the bit error rate meter (4) indicates BER threshold.

3.2.7.12 By reading the value at attenuator (13) referred to the noise power level value found on item 3.2.7.6, calculate N in dBm.

3.2.7.13 Calculate D/N ratio by subtracting the value for N obtained on item 3.2.7.12 from the value for D obtained on item 3.2.7.3. This D/N ratio in dB will correspond to D/E value found on item 3.2.7.10.

3.2.7.14 Successively attenuate the echo signal in steps of 1dB and repeat the measurements as shown in items 3.2.7.10 to 3.2.7.13. When the variation is not significant, increase the steps to 2 or 5dB. Carry on with the measurements until it is noticed that the echo influence is negligible.

3.2.7.15 Draw the graph signal-to-noise ratio D/N vs the echo level D/E.

3.2.7.16 Repeat the items 3.2.7.8 to 3.2.7.15 for the following delays:
2µs, 4µs, 8µs, 16µs, 32µs, 64µs, 128µs, and 170µs.

3.2.7.17 Repeat all the procedures described on items 3.2.7.8 to 3.2.7.16,

3.2.8 Results

Figure 3.2.8.1: Signal to noise ratio vs signal to echo ratio – Post echo (ATSC)

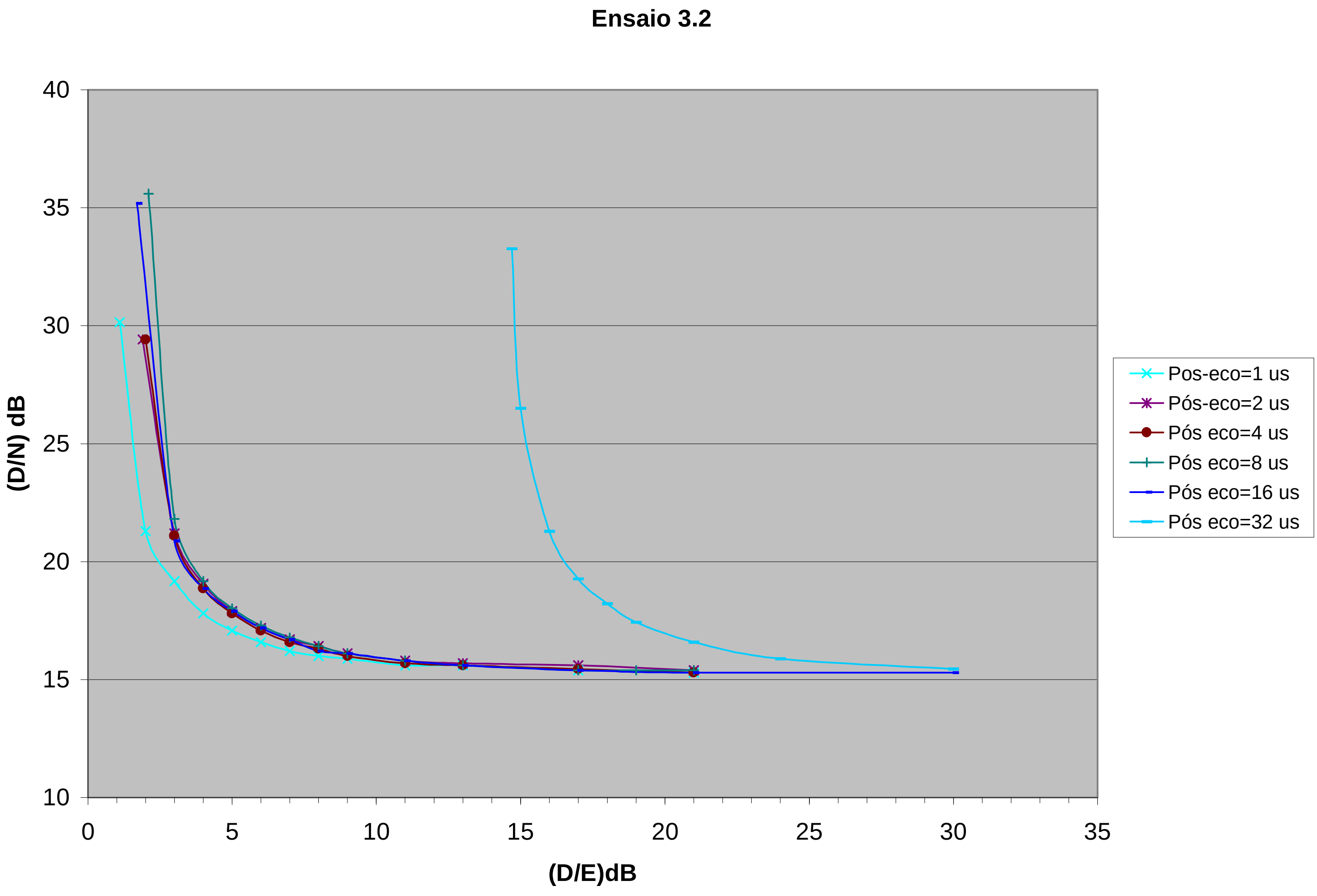


Figure 3.2.8.2: Signal to noise ratio vs signal to echo ratio – Pre echo (ATSC)

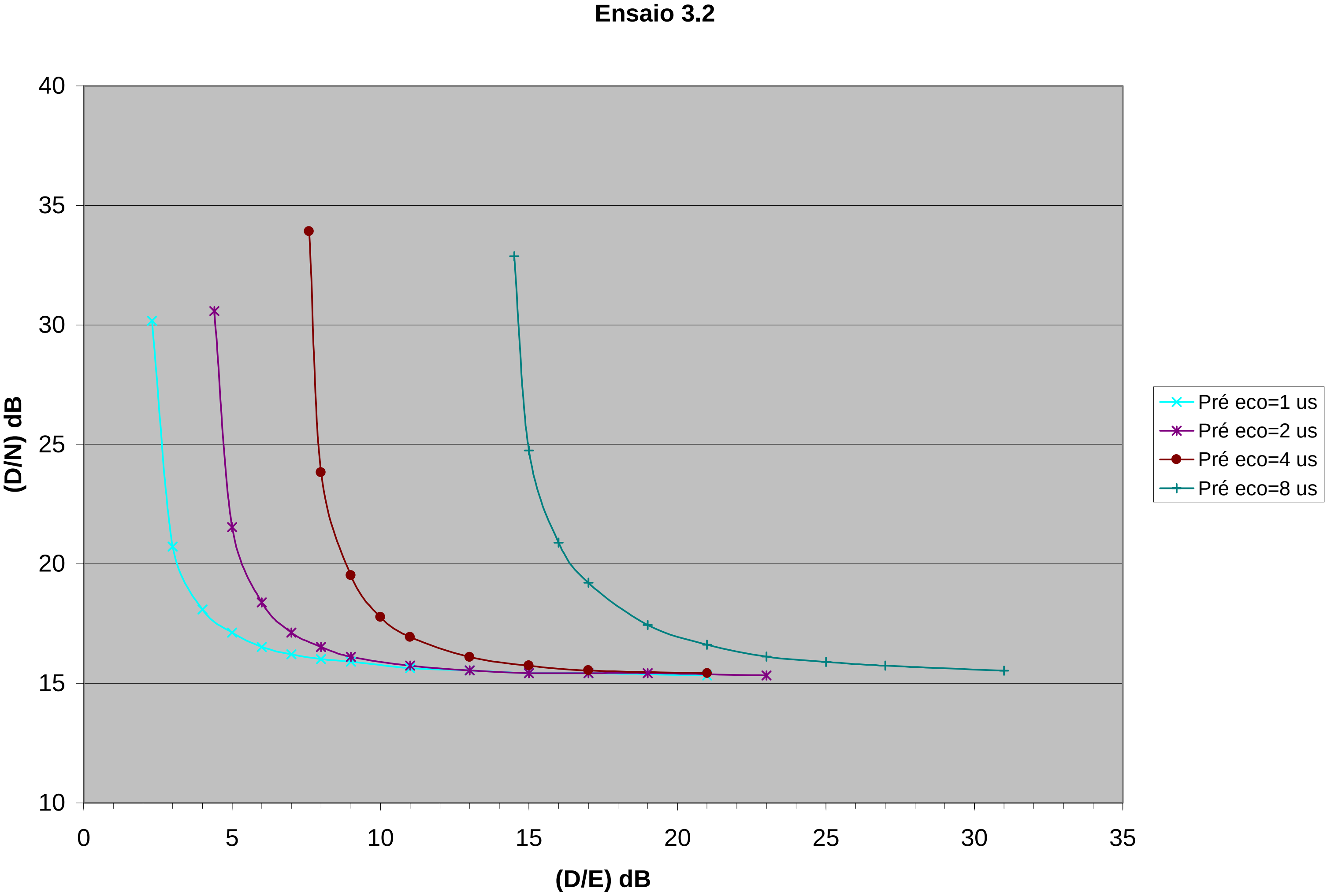


Figure 3.2.8.3: Signal to noise ratio vs signal to echo ratio DVB (FEC3/4 GI1/16 2K) Pós Eco

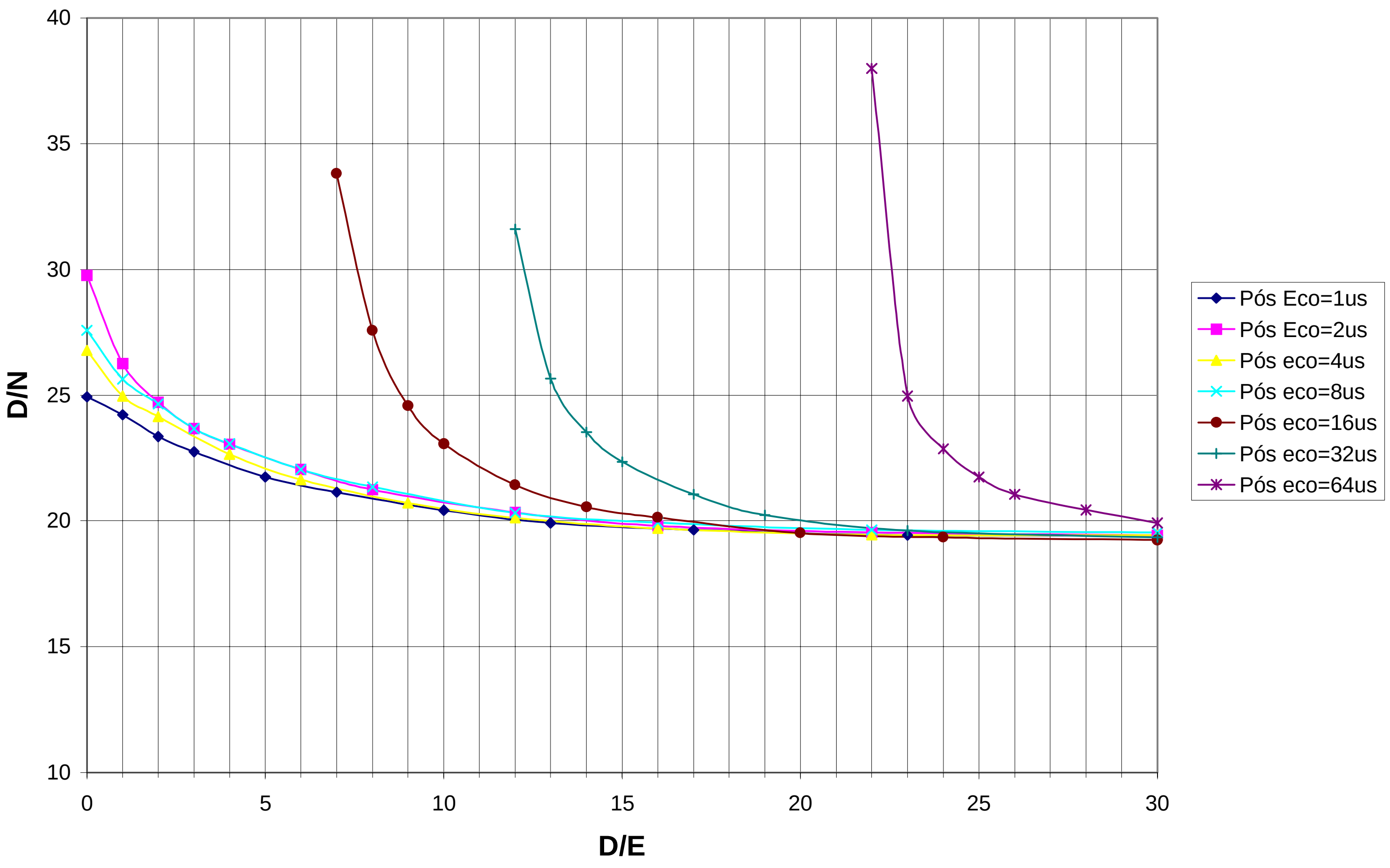


Gráfico 3.2.8.4: Signal to noise ratio vs signal to echo ratio
DVB (FEC3/4 GI1/16 2K) - Pre Echo

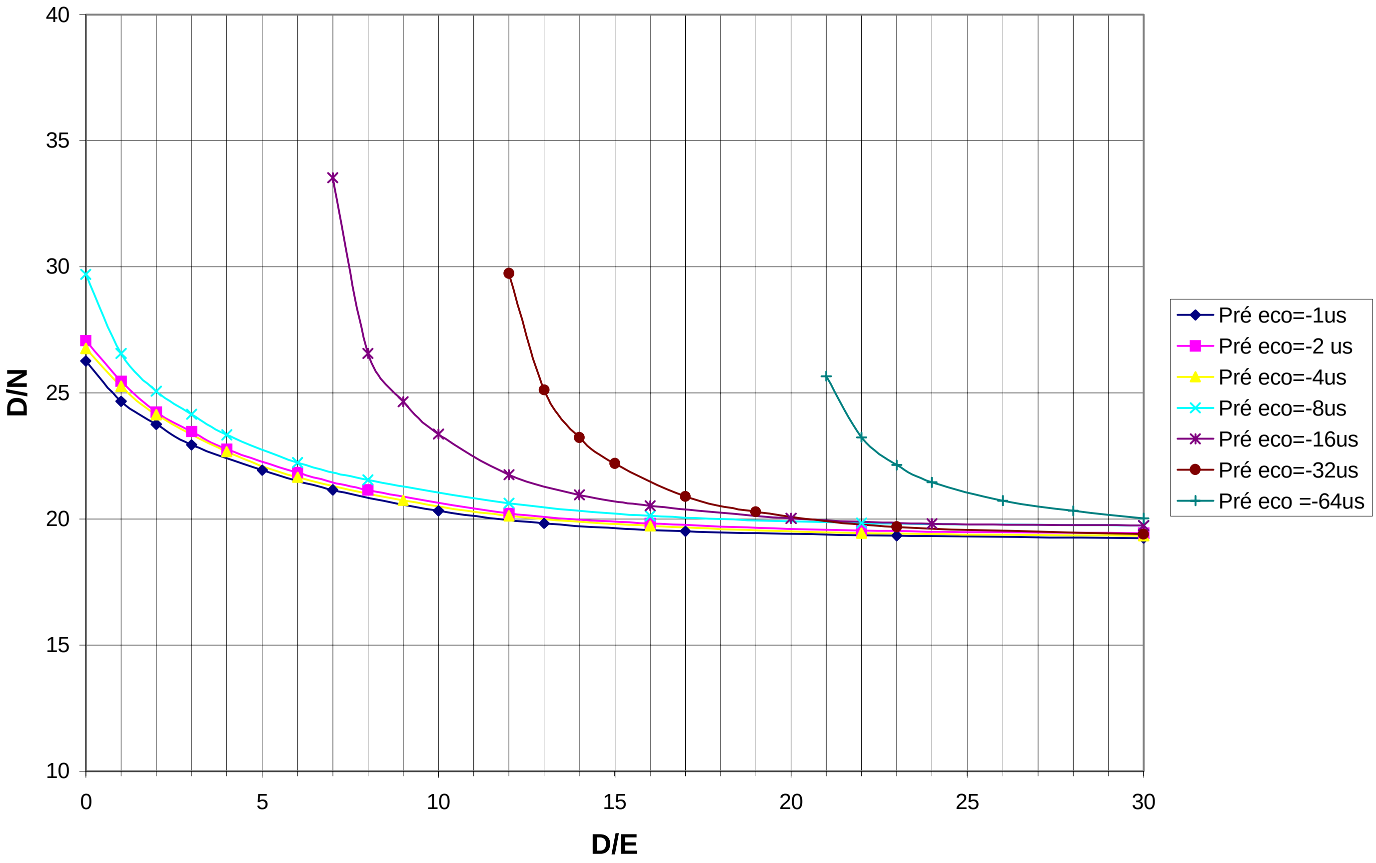


Figure 3.2.8.5: Signal to noise ratio vs signal to echo ratio
DVB (FEC3/4 GI1/16 8K) - Post echo

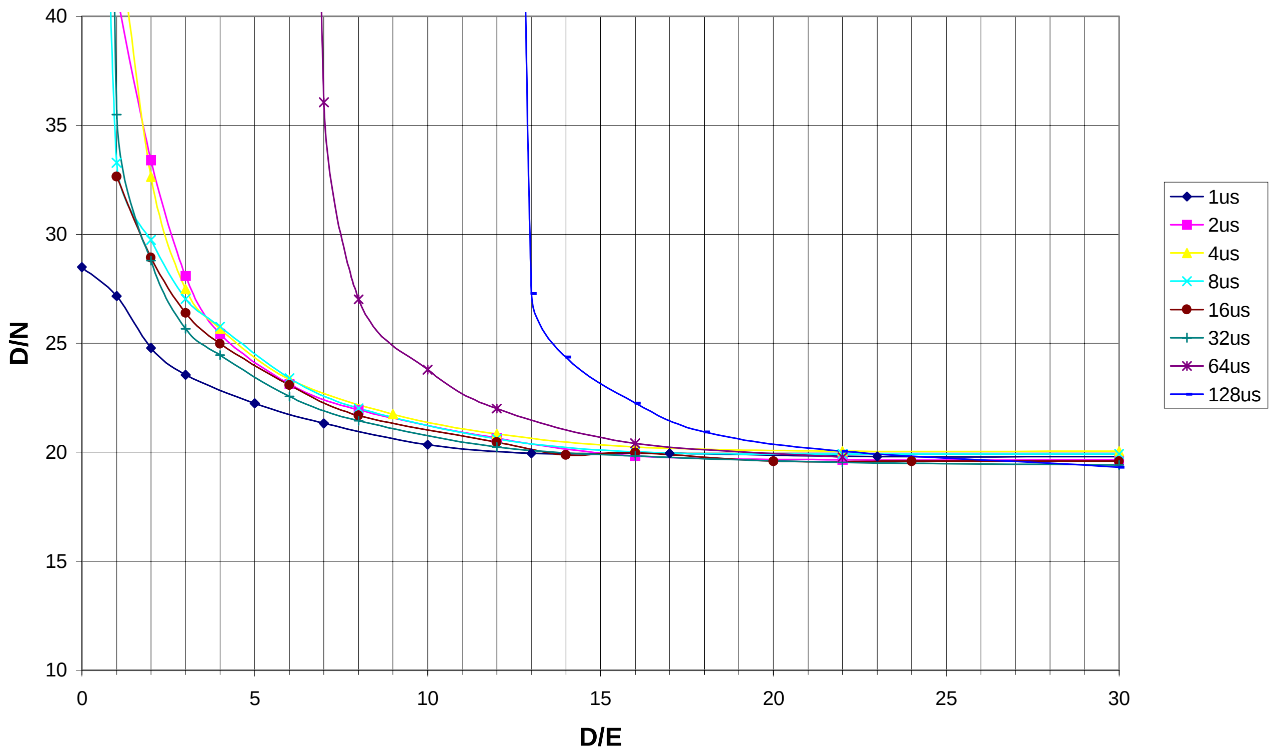


Figure 3.2.8.6: Signal to noise ratio vs signal to echo ratio DVB (FEC3/4 GI1/16 8K) - Pre echo

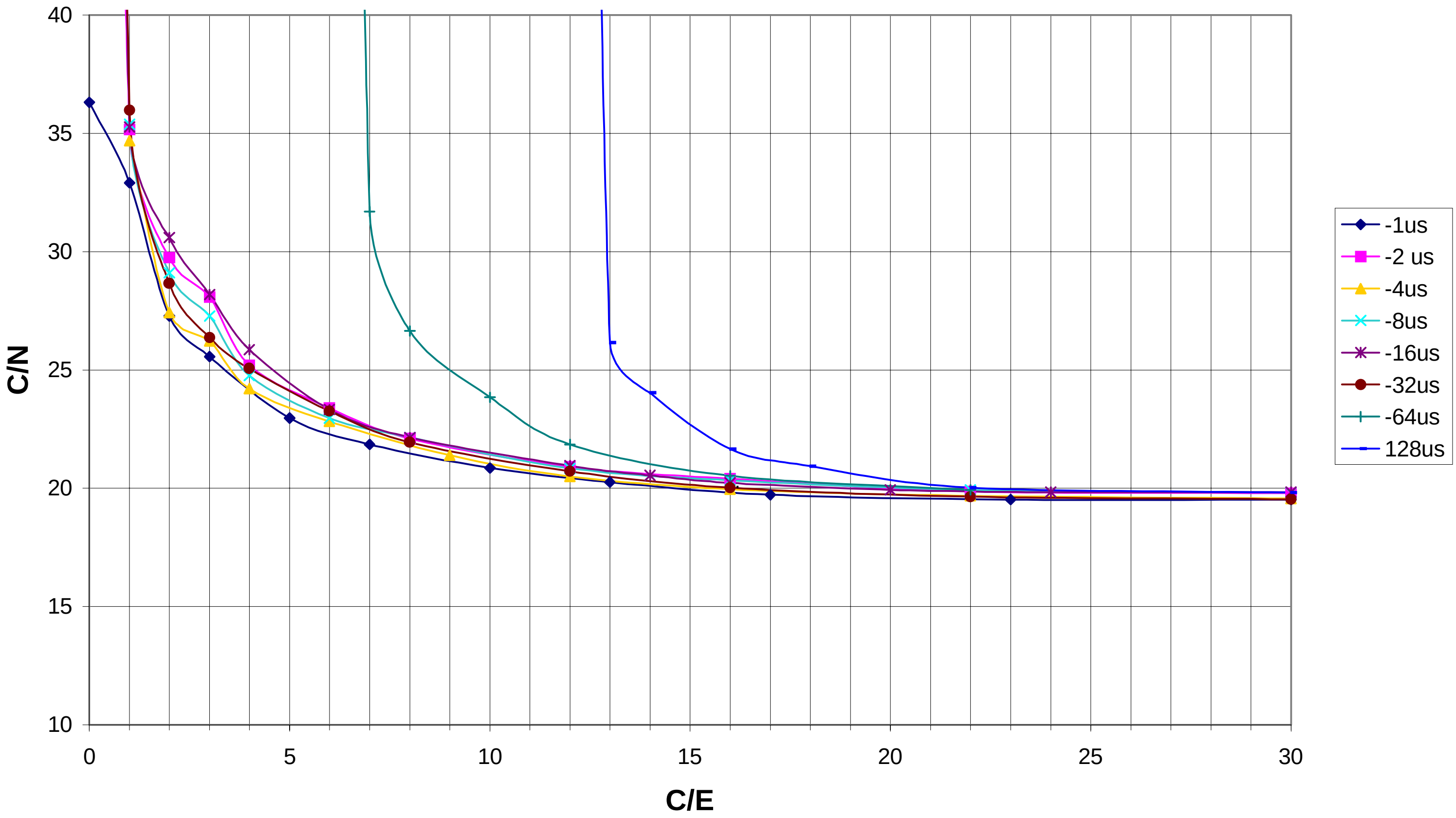


Figure 3.2.8.7: Signal to noise ratio vs signal to echo ratio ISDB (FEC3/4 GI1/16 4K 0,1s) - Post echo

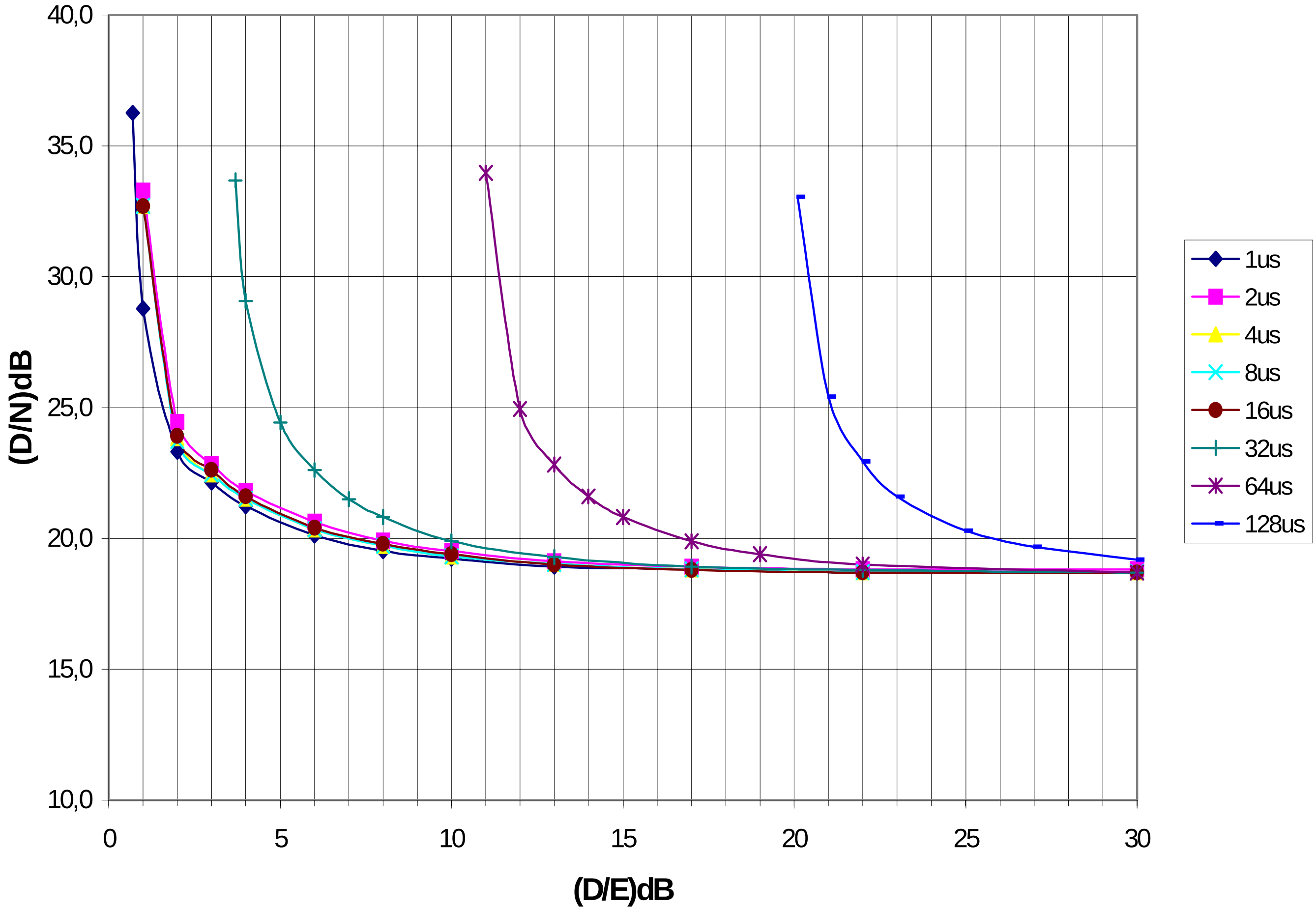
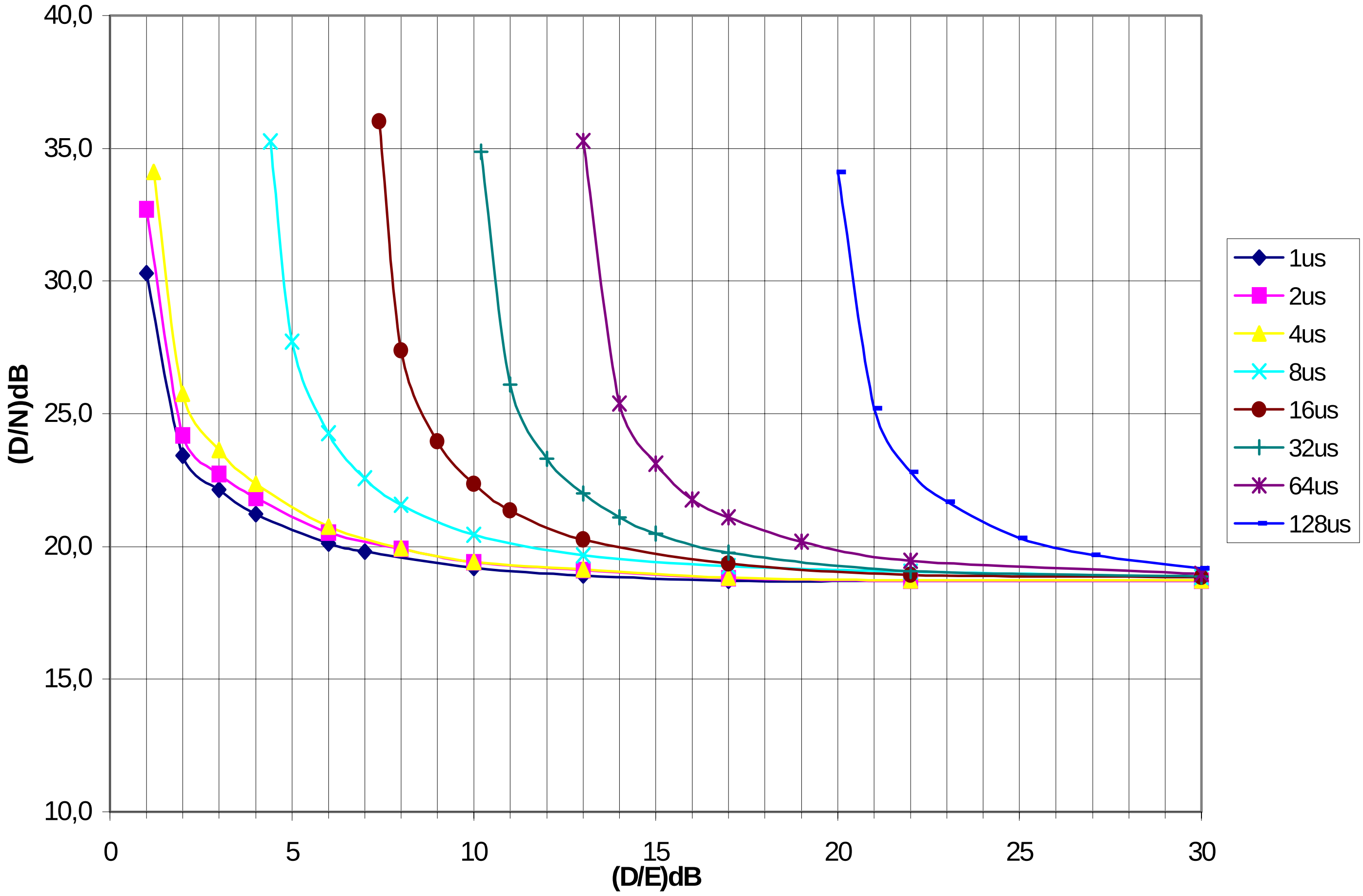


Figure 3.2.8.8: Signal to noise ratio vs signal to echo ratio ISDB (FEC3/4 GI1/16 4K 0,1s) - Pre echo



3.3 Multipath interference – Simulation for channels with multiple echos

3.3.1 Aim

The tests described on items 3.1 and 3.2 show the performance of the digital receiver facing a single echo signal. The aim of the tests described in this chapter is to check the performance of ATSC, DVB-T and ISDB systems in case of several echo signals (up to 5) arriving at the receiver's input.

3.3.2 Characteristics of the basic parameters

3.3.2.1 C = total signal power (main signal + echo signals)

3.3.2.2 Signal frame

3.3.2.2.a Type "A" channel

Simulated condition: signal composed by several weak multiple echos and small delay times.

	Signal	Relative Amplitude	Amplitude dB	Delay Time (µs)
Main	0	1,00	0	0
E	1	0,2045	-13,8	0,15
C	2	0,1548	-16,2	2,22
H	3	0,1790	-14,9	3,05
O	4	0,2078	-13,6	5,86
S	5	0,1509	-16,4	5,93

3.3.2.2.b Type “B” channel

Simulated condition: signal composed by multiple echos (attenuation higher than 4 dB) and big delay times.

	Signal	Relative Amplitude	Amplitude dB	Delay Time (μs)
Main	0	1,00	0	0,00
E	1	0,2512	-12,0	0,30
C	2	0,6310	-4,0	3,50
H	3	0,4467	-7,0	4,40
O	4	0,1778	-15,0	9,50
S	5	0,0794	-22,0	12,70

3.3.2.2.c Type “C” channel

Simulated condition: signal composed by multiple strong echos and small delay times.

Signal	Relative Amplitude	Amplitude dB	Delay time (μs)
0	0,7263	-2,8	0,000
1	1,0000	0,0	0,089
2	0,6457	-3,8	0,419
3	0,9848	-0,1	1,506
4	0,7456	-2,5	2,322
5	0,8616	-1,3	2,799

3.3.2.2.d Type “D” channel

Signal	Relative Amplitude	Amplitude dB	Delay Time (µs)
0	0,2045	-0,1	0,15
1	0,1341	-3,8	0,63
2	0,1548	-2,6	2,22
3	0,1789	-1,3	3,05
4	0,2077	0	5,86
5	0,1509	-2,8	5,93

3.3.2.2.e Type “E” channel

Simulated condition: simulates the receiving condition in a point located at roughly the same distance of three transmitters in “SFN”.

Signal	Relative Amplitude	Amplitude dB	Delay Time (µs)
0	1,00	0	0,00
1	1,00	0	1,00
2	1,00	0	2,00

3.2.2.3 N= Gaussian noise power at the receiver’s input.

3.2.2.4 C/N = signal to noise ratio

3.2.2.5 BER = bit error rate

3.3.3 Initial figures and characteristics

3.3.3.1 Main signal power = approximately –40 dB.

3.3.3.2 Signal to noise ratio C/N: higher than 50 dB.

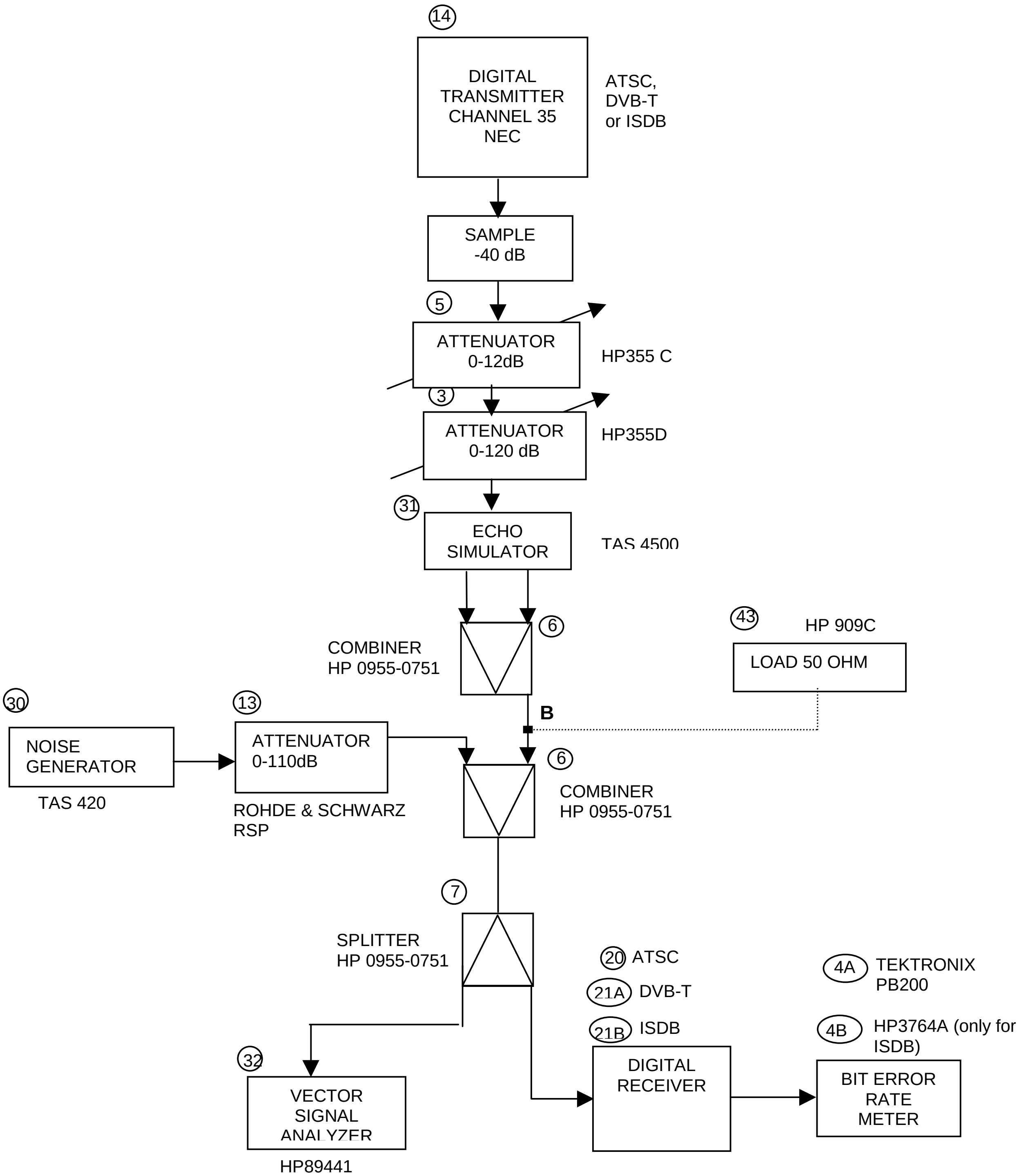
3.3.4 Measurement general description

In a no noise condition (signal to noise ratio higher than 50 dB) adjust the total signal C to 0 dB (approximately – 40 dBm) and measure the bit error rate (BER). If the BER is lower than the BER threshold, start applying noise until BER threshold is reached. From this point start increasing and diminishing noise and draw the graph BER vs C/N.

3.3.5 Equipment used

(14) Digital Transmitter, channel 35 – NEC.
(5) HP Attenuator 0-12dB, model 355C.
(3) HP Attenuator 0-120 dB, model 355D.
(31) TAS Echo Simulator, model TAS4500.
(6) 2 HP Signal Combiners, model HP0955-0751.
(30) TAS Noise Generator, model TAS420.
(13) Rohde & Schwarz RSP Attenuator 0-110 dB (0,1 dB steps).
(7) HP Signal Splitter, model 0955-0751.
(20) Digital Receiver ATSC – Zenith.
(21A) Digital Receiver DVB – NDS.
(21B) Digital Receiver ISDB.
(4A) TEKTRONIX Bit Error Rate Meter, model PB200.
(4B) HP Bit Error Rate Meter, model 3764A (only for ISDB).
(32) HP Vector Signal Analyzer, model 89441-V.
(43) HP 50 Ohm load, model 909C.

3.3.6 Block diagram



3.3.7 Test procedures

Note: The procedures described below are valid for all the configurations indicated on item 3.2.2.2, either for ATSC system or for DVB-T and ISDB systems.

3.3.7.1 Adjust attenuators (5) and (3) so that the signal level at the echo simulator input TAS 4500 (31) be approximately –10 dBm.

3.3.7.2 Set attenuator (13) for “maximum attenuation”.

3.3.7.3 At the echo simulator adjust the desired configuration according to the tables shown on item 3.3.2.2.

3.3.7.4 Using the vector signal analyzer (32) measure the total signal power level (C) at the digital receiver input. Record the signal spectrum.

3.3.7.5 Measure the bit error rate using bit error rate meter (04). If the measured value is lower than bit error rate threshold, go to item 3.3.7.6.

3.3.7.6 At point “B” disconnect the cable arriving from the echo simulator and replace it by a 50 Ohm load.

3.3.7.7 Set attenuator (13) for “minimum attenuation”.

3.3.7.8 Using vector signal analyzer (32) measure the noise power level in the channel bandwidth (6 MHz) at the digital receiver input. Observe that this will be the reference value for the rest of the noise measurements.

3.3.7.9 Set attenuator (13) for “maximum attenuation”, disconnect the 50 Ohm load and connect again the cable arriving from echo simulator at point “B”.

3.3.7.10 Adjust attenuator (13) until bit error rate meter indicates threshold value.

3.3.7.11 Calculate the noise power level (N) at the digital receiver input, using the value set in attenuator (13) after the adjustment described on item 3.3.7.10 and the noise power level reference value measured according to item 3.3.7.8.

3.3.7.12 Subtract the (N) value calculated on item 3.3.7.11 from the C value measured according to item 3.3.7.4. This gives the C/N value for threshold BER. Write down this value on table 3.3.8.2.

3.3.7.13 Starting from the adjustment performed according to item 3.3.7.10, increase and reduce successively the attenuation in attenuator (13) in steps of 0,1 dB. Write down each bit error rate value. For each step calculate (N) and (C/N), as described on items 3.3.7.11 and 3.3.7.12.

3.3.7.14 Using the values obtained according to the calculations described on items 3.3.7.12 and 3.3.7.13, draw the graphs BER vs C/N.

3.3.8 Results

Type of Channel	(C/N)dB for threshold BER								
	ATSC	DVB- 3/4 -1/16 2K	DVB - 3/4 -1/16 8K	DVB - 3/4 - 1/8 2K	DVB - 2/3 -1/32 8K	ISDB - 3/4; 1/16; 4K; 0,1s	ISDB - 3/4; 1/16; 2K; 0,1s	ISDB - 3/4; 1/16; 8K; 0,1s	ISDB - 3/4; 1/32; 2K; 0,1s
A	15,8	19,6	20,3			20,3	20,5	20,4	20,4
B	DW	23,2	*			24,4	24,3	24,5	24,4
C	NT	NT	NT			24,3	24,6	24,4	24,2
D	DW	23	*			25,3	DW**	25,6	25,5
E	DW	32,4	*			DW	DW	DW	NF

Table 3.3.8.: (C/N)dB for threshold BER

Notes: *a)* DW = *Doesn't work*

*b) * = It was not possible to measure bit error rate due to lack of synchronism at the receiver even for C/N = ∞.*

For "B" channel lack of synchronism occurred every 2 minutes in average.

For "D" channel lack of synchronism occurred every minute in average.

For "E" channel lack of synchronism occurred every 3 seconds in average

*c) **) BER = $1,4.10^{-5}$ (no noise).*

d) NT = Not tested.

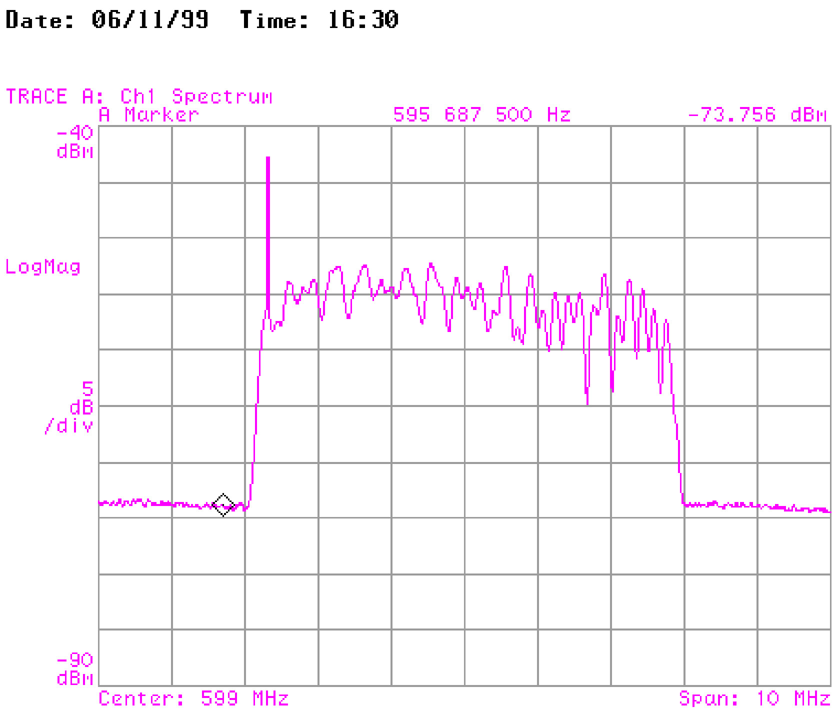


Figure 3.3.8.1 : Spectrum for type "A" channel (ATSC).

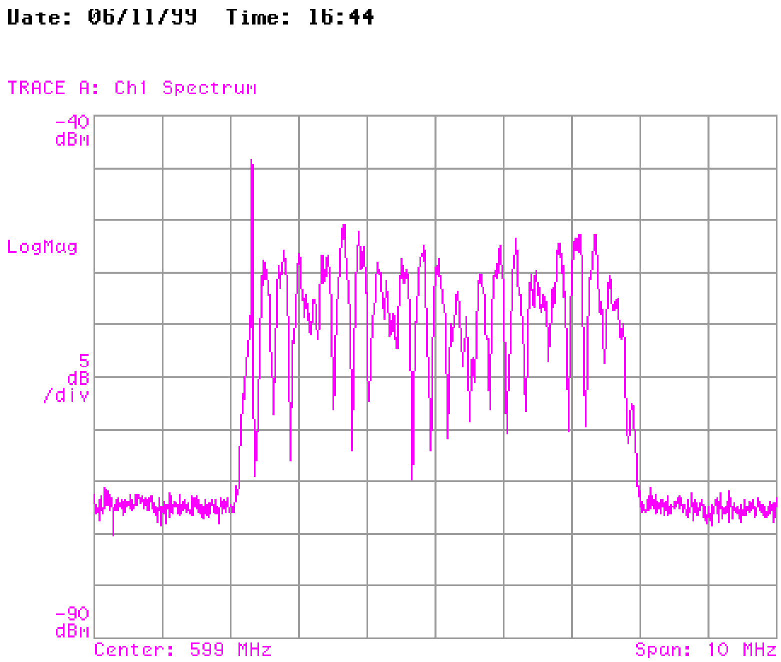


Figure 3.3.8.2 : Spectrum for type "B" channel (ATSC).

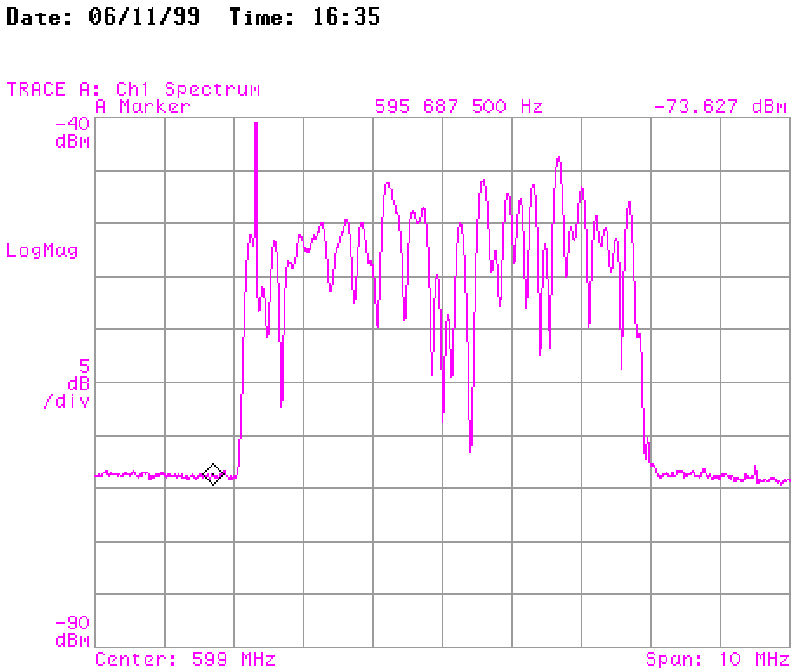


Figure 3.3.8.3 – Spectrum for type "D" channel (ATSC).

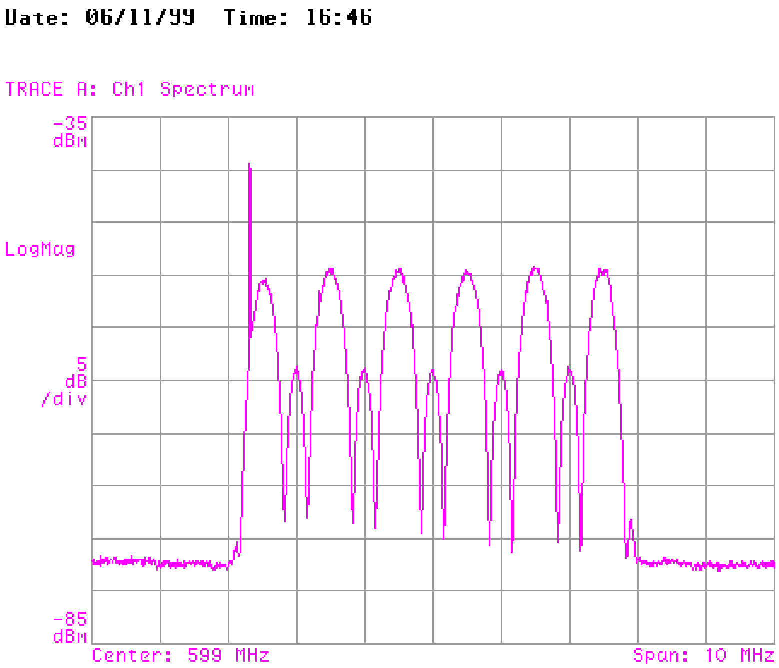


Figure 3.3.8.4 – Spectrum for type "E" channel (ATSC).

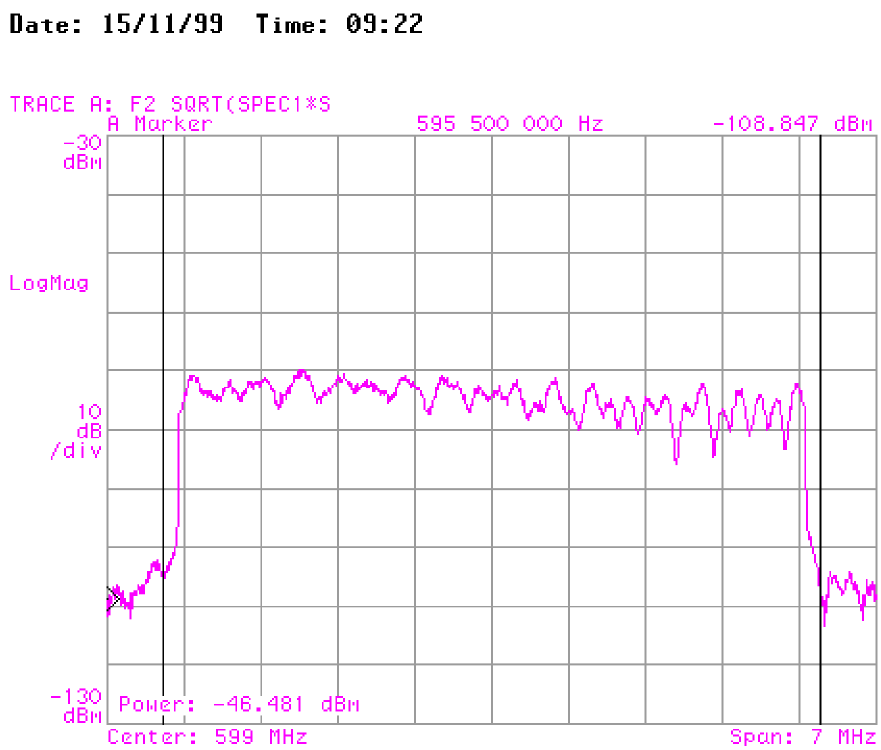


Figure 3.3.8.5 – Spectrum for type "A" channel (DVB).

Date: 15/11/99 Time: 09:34

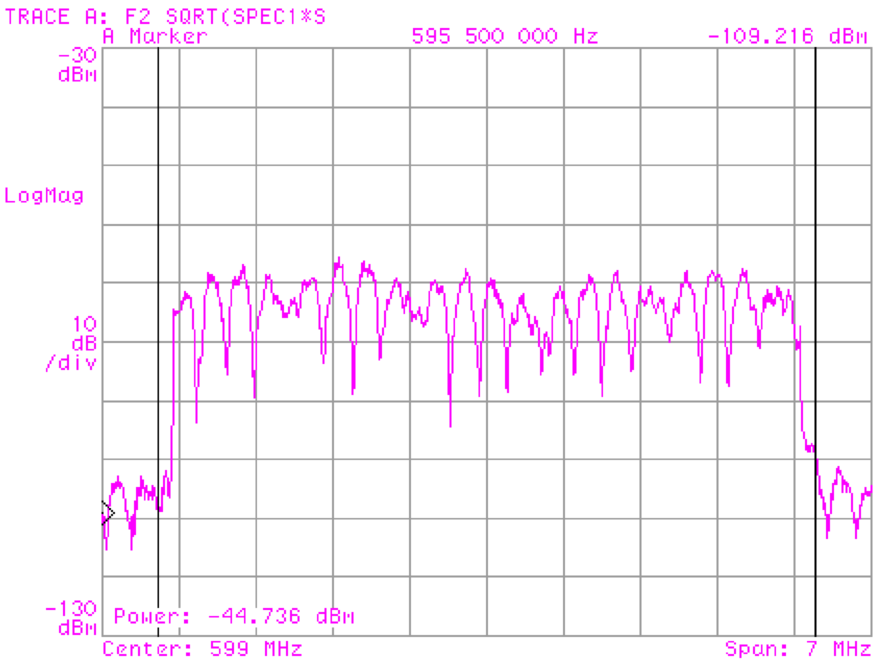


Figure 3.3.8.6 – Spectrum for type "B" channel (DVB).

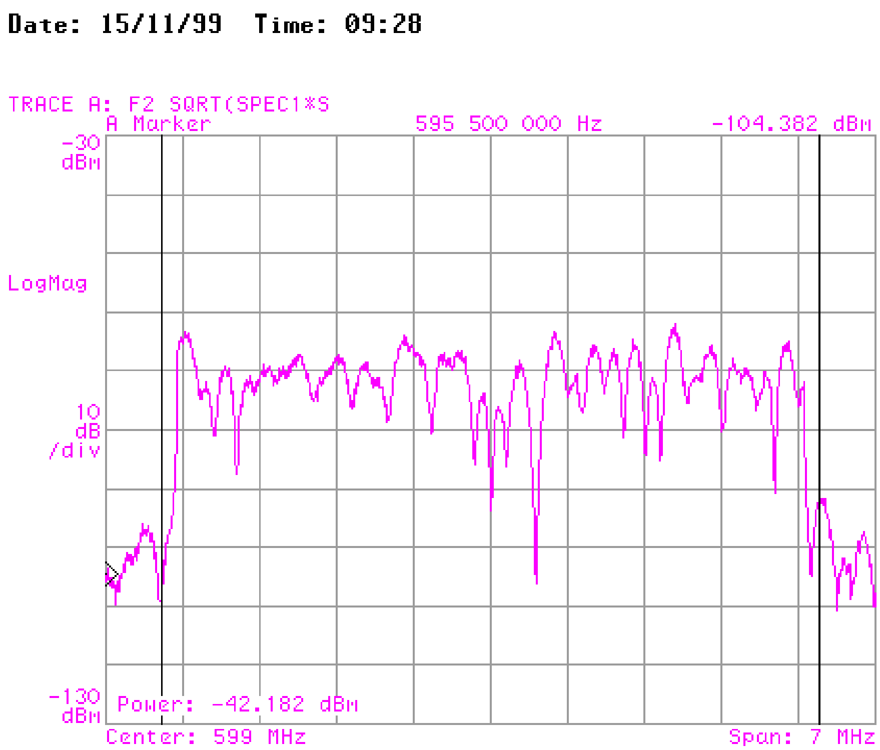


Figure 3.3.8.7 – Spectrum for type "D" channel (DVB).

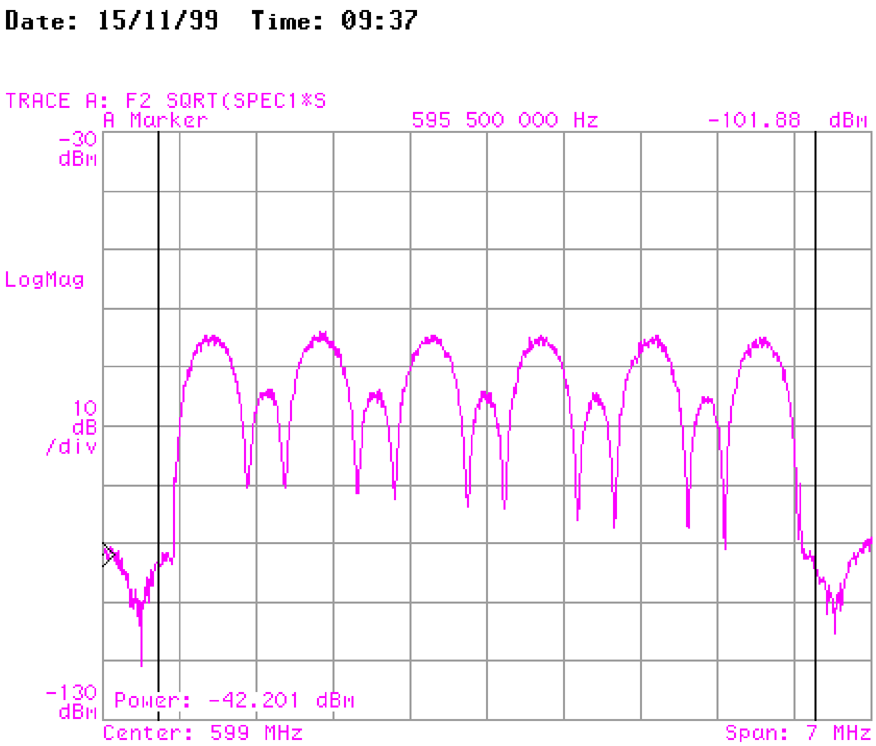


Figure 3.3.8.8 – Spectrum for type "E" channel (DVB).

Figure 3.3.8.9: Bit error rate vs signal to noise ratio for channels with several multipath levels - Channel A

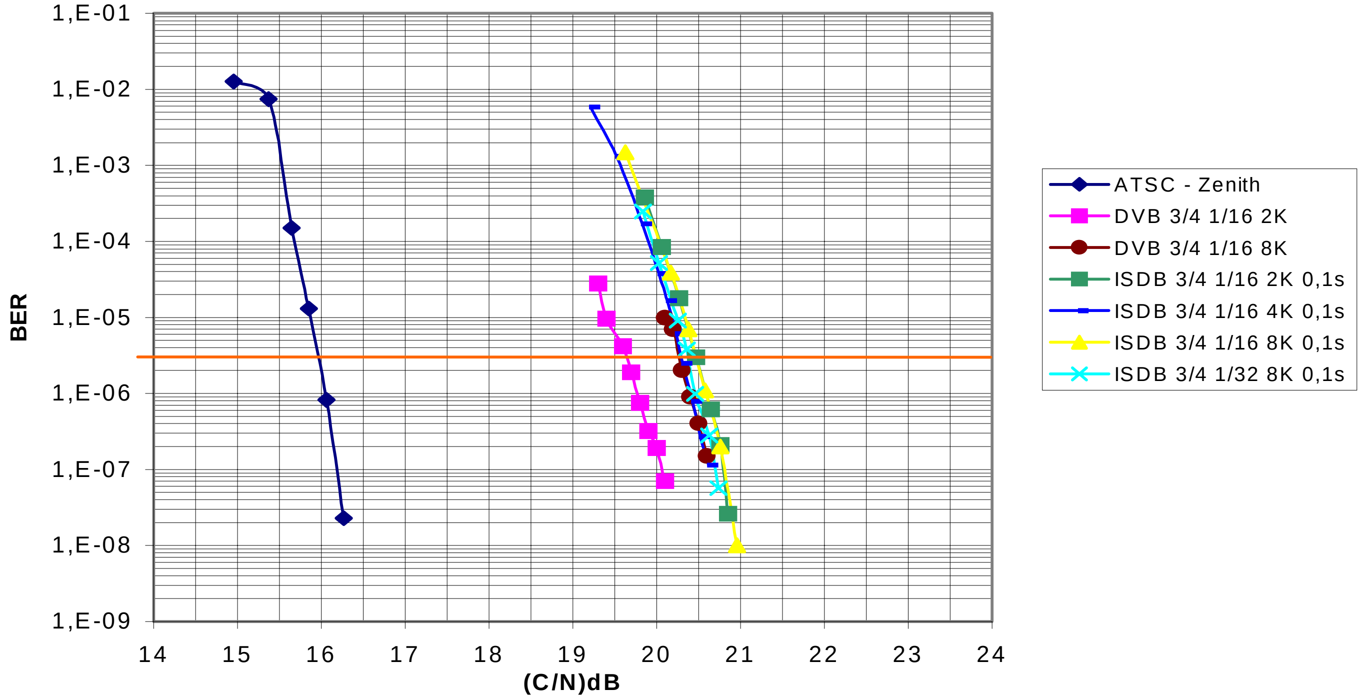


Figure 3.3.8.10: Bit error rate vs signal to noise ratio for channels with several multipath levels - Channel B

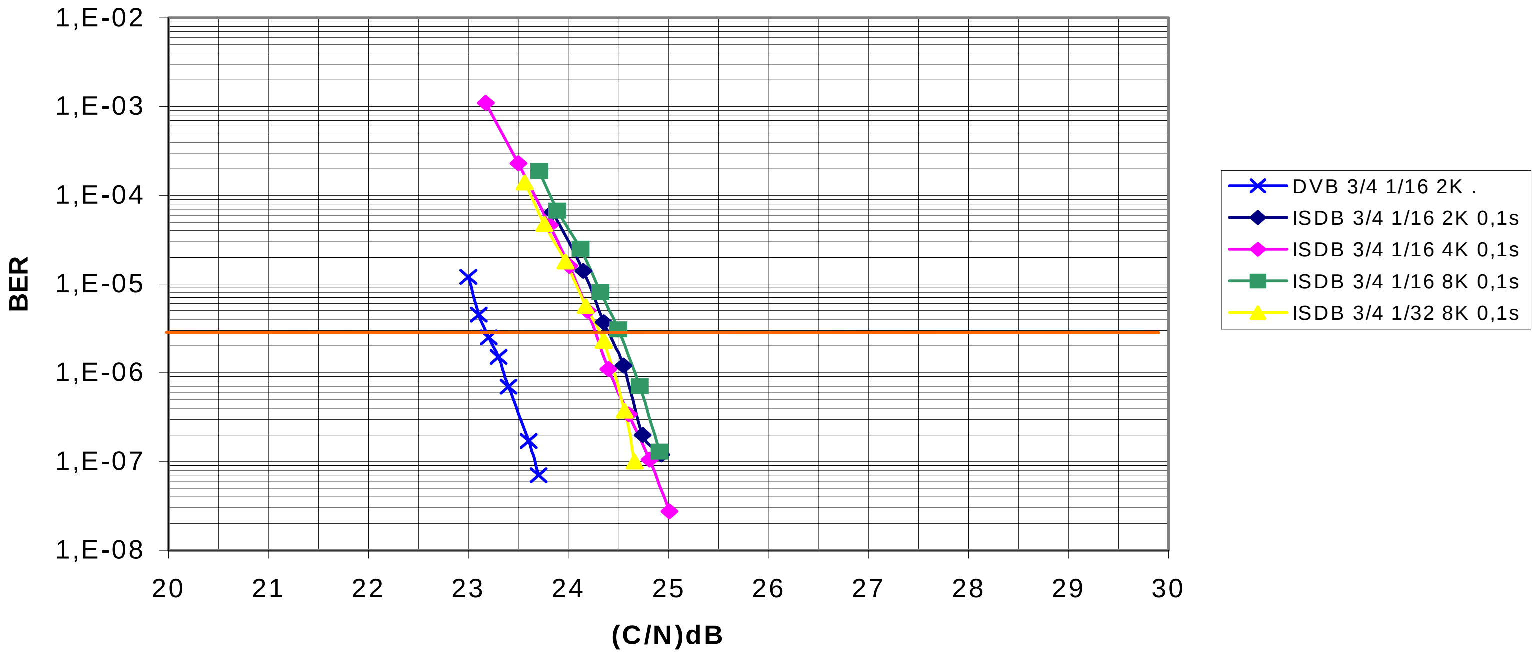


Figure 3.3.8.11: Bit error rate vs signal to noise ratio for channels with several multipath levels - Channel C

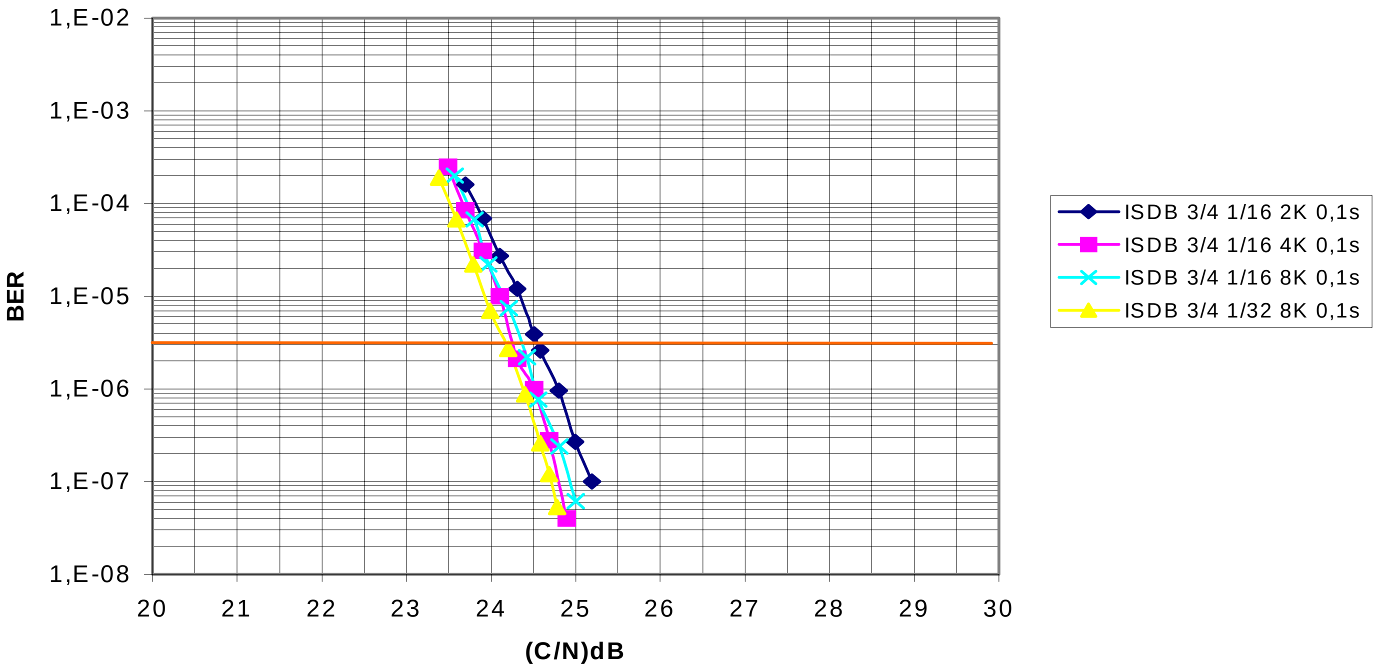


Figure 3.3.8.12: Bit error rate vs signal to noise ratio for channels with several multipath levels - Channel D

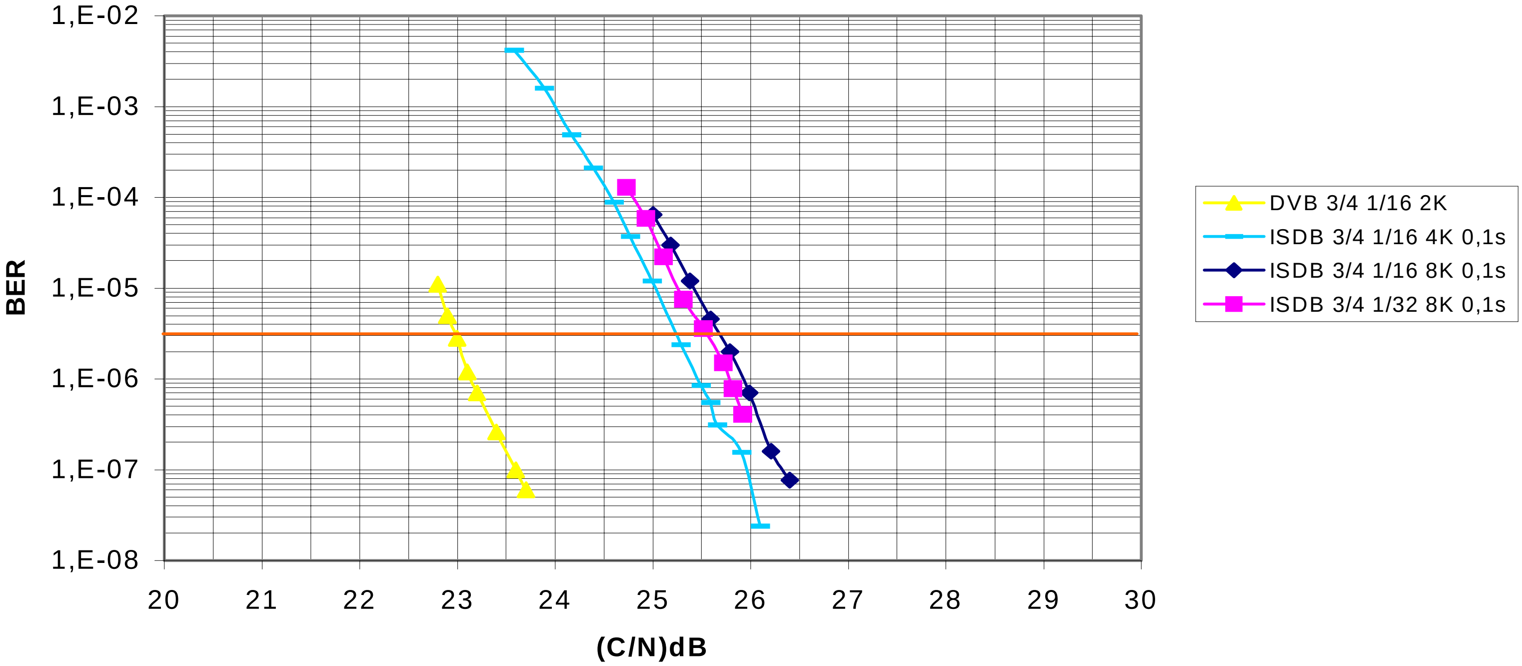
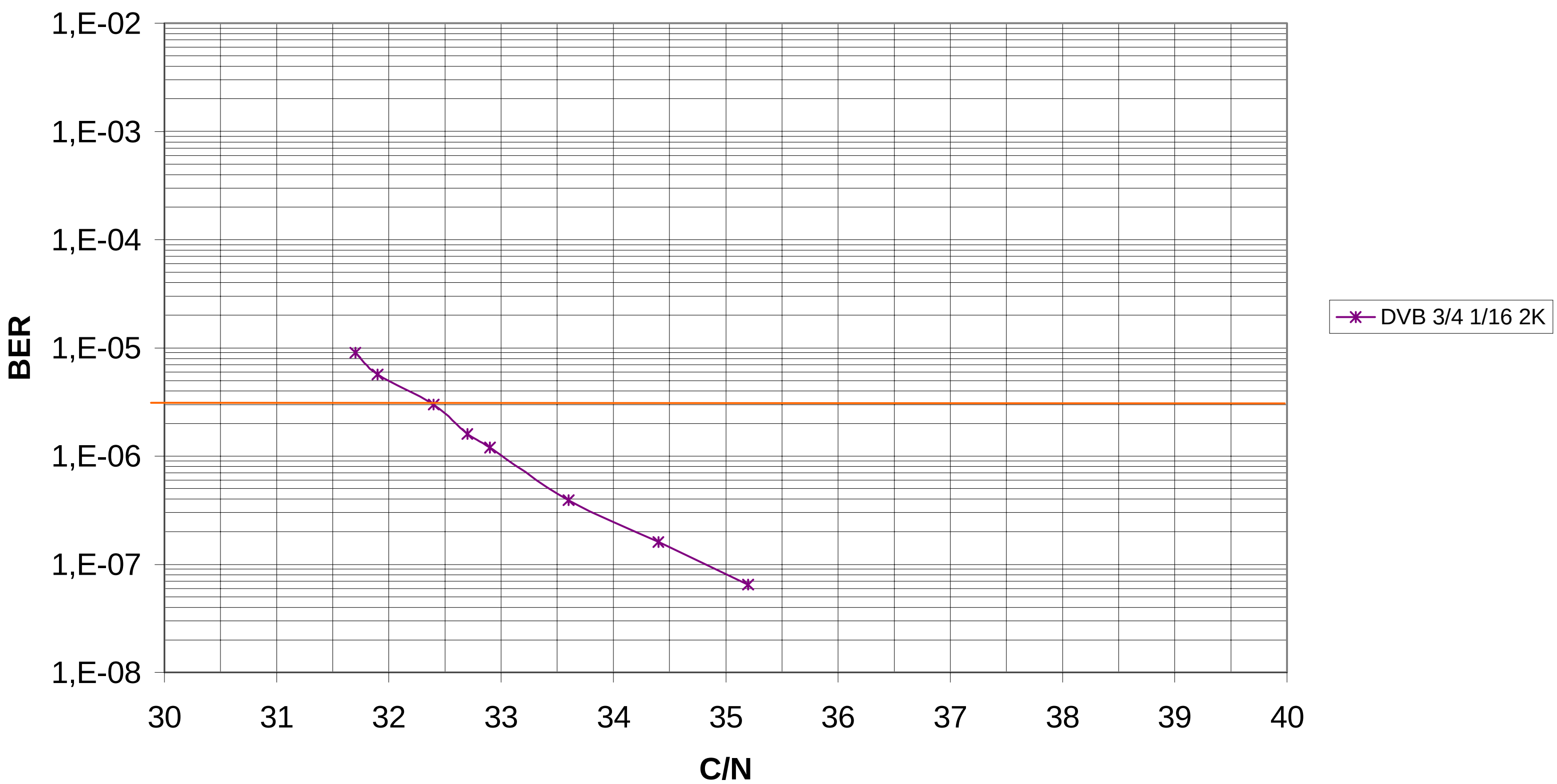


Figure 3.3.8.13: Bit error rate vs signal to noise ratio for channels with several multipath levels - Channel E



4.1 Carrier-to Noise Ratio Threshold

4.1.1 Aim

This test method aims to evaluate the tolerance of the systems ATSC, DVB-T and ISDB-T to white (Gaussian) noise. This tolerance will be measured by the C/N, i.e. the ratio between the wanted (useful) signal power and the noise power at the receiver input until the BER threshold is reached at the output of the receiver. This ratio is expressed in dB and can be written as:

$$C/N\ (dB) = C\ (dBm) - N\ (dBm)$$

In this expression, the smaller the C/N value the more tolerant the system under test is to this kind of noise and therefore the better it is.

NOTE: This test focus on the system performance and not on the receivers in test. For this reason, the measurements are carried out with a high signal level at the input of the receiver, where the receiver noise figure no longer interferes in the results.

4.1.2 Basic Parameter Characteristics

4.1.2.1 C = modulated wanted (useful) signal power, measured in dBm at the receiver input.
4.1.2.2 N = Gaussian noise power, within the useful bandwidth, measured in dBm at the receiver input.
4.1.2.3 BER = Bit error rate.

4.1.3 Initial figures and characteristics

4.1.3.1 Wanted (useful) signal power (C): -30 dBm at the receiver input
4.1.3.2 C/N: greater than 50dB

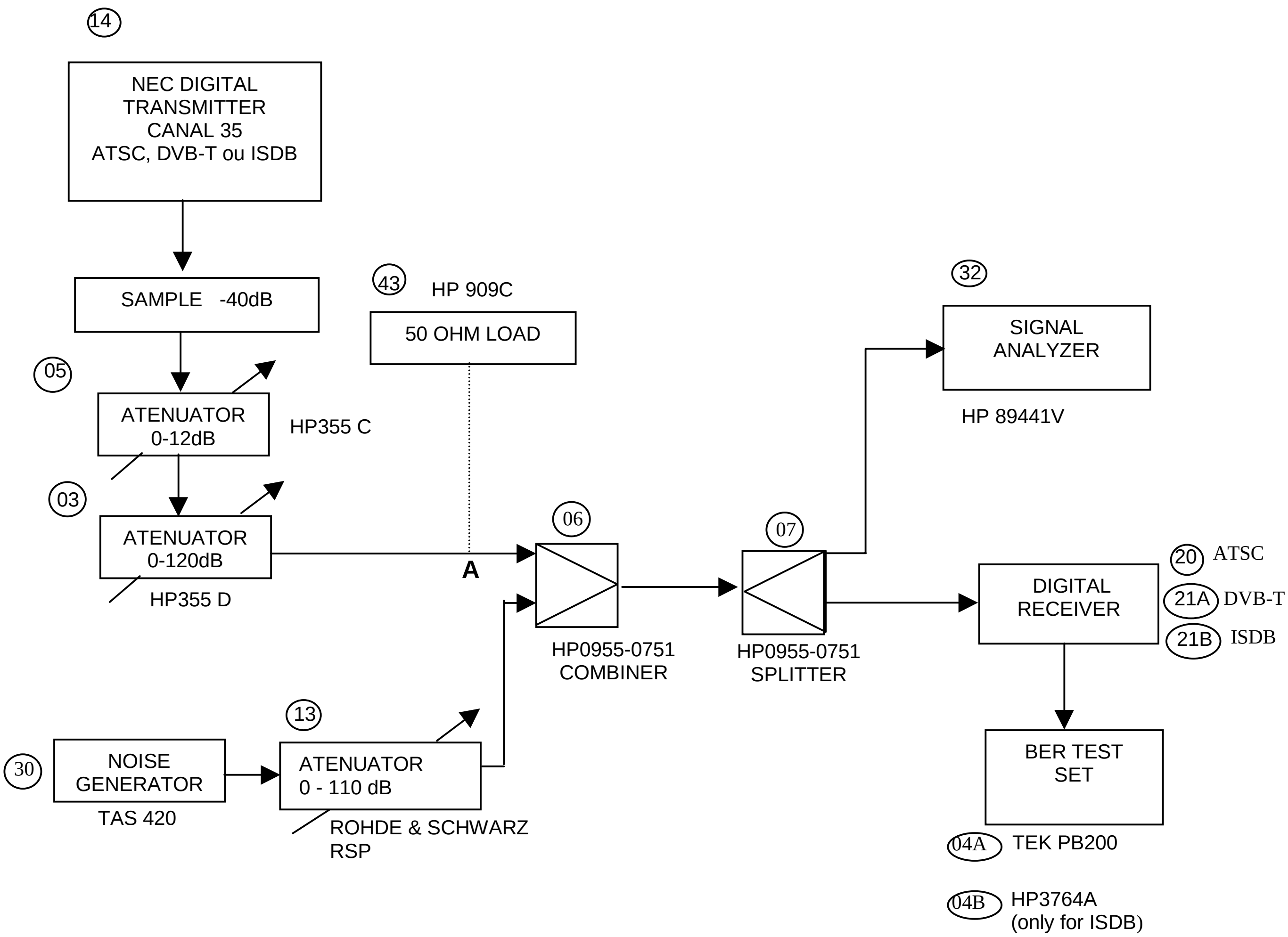
4.1.4 General description of measurement

Vary the C/N until the BER threshold is reached

4.1.5 Equipment used

.
(3) HP 355D 0-120 dB attenuator
(4A) TEKTRONIX PB200 BER test set
(4B) HP3764A (only for ISDB)
(5) HP 355C 0-12 dB attenuator
(30) TAS 420 wide band noise generator
(06) HP 0955-0751 combiner
(07) HP 0955-0751 splitter
(13) R&S 0-110 dB, 0.1 dB steps attenuator, model RSP
(14) Digital transmitter (fitted with COFDM and 8VSB modulators), tuned to channel 35
(20) Zenith ATSC digital receiver
(21A) NDS DVB-T digital receiver
(21B) ISDB-T digital receiver
(32) HP 89441 - V Signal Analyzer
(43) HP 909C Load, 50 ohm

4.1.6 Basic lay out



4.1.7 Tests procedures

4.1.7.1 With the noise generator turned on and wiyh the attenuator(13) adjusted to the maximum attenuation, act on the attenuators (03) and (05) to read –30 dBm at the signal analyzer (32). Measure and record this figure. It will be the C value.

4.1.7.2 Through the attenuator 13, adjust the noise generator (30) output level until the BER threshold is reached.

4.1.7.3 At the point A, disconnect the signal cable, connect the 50 ohm load (43) in the input of the combiner (06)and read the noise power within the 6 MHz bandwidth shown in the signal analyzer (32). This is the value for N.

4.1.7.4 Calculate the C/N (in dB) using the expression given by 4.1.1 and record the result in table 4.1.8.

4.1.7.5 Carry out the procedures above described for the ATSC system, for the DVB-T system in the for modes indicated in the table 4.1.8 as well as for ISDB-T system.

4.1.8 Results table

Digital Receiver	C (dBm)	N (dBm)	C/N Ratio (dB)
ATSC	-31,75	-46,25	14,50
DVB-T: 3/4;1/16;2K	-35,80	-54,80	19,00
DVB-T: 3/4;1/16;8K	-36,30	-55,60	19,30
DVB-T: 3/4;1/8;2K	-36,60	-55,40	18,80
DVB-T: 2/3;1/32;8K			
ISDB: 3/4;1/16;2K;0,1s	-37,60	-56,10	18,50
ISDB: 3/4;1/16;4K;0,1s	-36,60	-55,10	18,50
ISDB: 3/4;1/16;8K;0,1s	-37,60	-56,10	18,50
ISDB: 3/4;1/32;8K;0,1s	-37,60	-56,20	18,60

4.2 Minimum signal level

4.2.1 Aim

The object of this test is to compare ATSC, DVB-T and ISDB-T digital systems concerning the minimum permissible signal level at the input of the receiver's antenna. Minimum signal level (in dBμV) is the effective signal voltage at the input of the receiver when the signal level at the output of the detector reaches the BER threshold.

4.2.2 Basic Parameters characteristics

4.2.2.1 C = modulated wanted (useful) signal power, measured in dBm at the receiver input.

4.2.2.2 V = effective wanted (useful) signal voltage at the input of the receiver (in dBμV), calculated from C.

4.2.2.3 BER = bit error rate.

4.2.3 Initial figures and characteristics

4.2.3.1 Useful signal power (C) = -30 dBm

4.2.3.2 Signal-to-noise ratio (C/N): greater than 50 dB

4.2.4 Measurements General description

Vary the input signal level until the BER threshold is reached.

4.2.5 Equipment used

(04A) TEKTRONIX PB200 BER test set

(04B) HP 3764 A BER test set (only for ISDB)

(05) HP 355C 0-12dB attenuator

(07) HP 0955-0751 splitter

(13) R&S 0-110dB, 0.1dB steps attenuator, model RSP

(20) Zenith ATSC receiver

(21A)) NDS DVB-T receiver

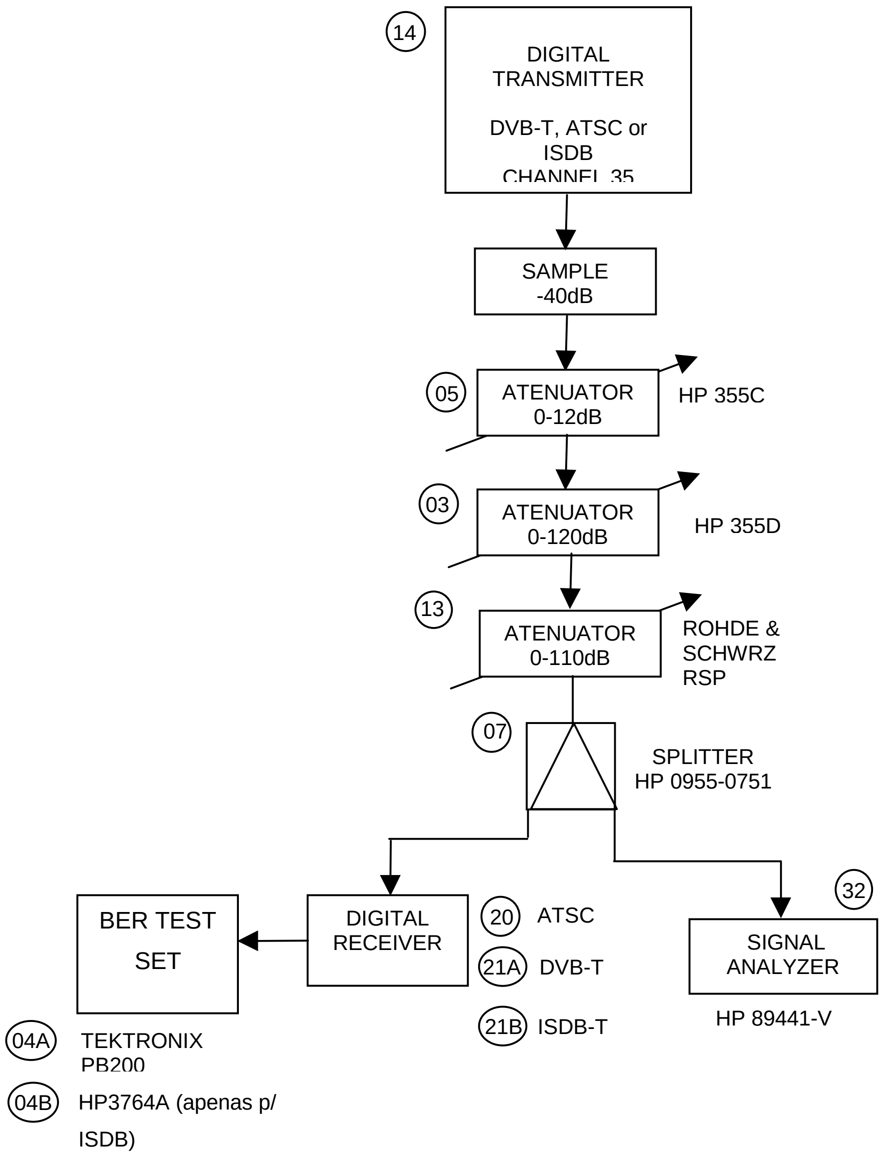
(21B) ISDB-T receiver

(14) NEC Digital transmitter (fitted with ATSC, DVB-T and ISDB-T modulators), tuned to channel 35.

(32) HP 89441-V Signal Analyzer

(03) HP attenuator 0 - 120 dB, model 355D

(33) 4.2.6 Basic lay out



4.2.7 Test Procedures

4.2.7.1 Adjust the input signal level to -30 dBm. The signal should have signal to noise ratio (C/N) higher than 50 dB and should be free from interference. Record the reading from the attenuators.

4.2.7.2 Attenuate10 dB the input signal.

4.2.7.3 Measure the receiver BER.

4.2.7.4 If the receiver BER is lower than the BER threshold go to 4.2.7.5.

4.2.7.5 Increase the input signal level in 1 dB steps to make the BER higher than BER threshold.

4.2.7.6 Attenuate the input signal level in 0.1 dB steps to make the BER as near BER threshold as possible.

4.2.7.7 Calculate the attenuation obtained in item 4.2.7.6 in respect to the result from item 4.2.7.1 and subtract the figure obtained of -30 dBm.

4.2.7.8 Using the result from item 4.2.7.7 calculate the minimum signal level in dBµV.

4.2.8 Table of Results

DVB-T SIGNAL								ATSC SIGNAL		ISDB-T SIGNAL	
3/4;1/16; 2K		3/4;1/16; 8K		3/4;1/8; 2K		2/3;1/32; 8K				3/4; 1/16; 4K; 0,1s	
dBm	dBµV	dBm	dBµV	dBm	dBµV	dBm	dBµV	dBm	dBµV	dBm	dBµV
-80,9	26,1							-81,4	25,6	-78,6	28,4

Table 4.2.8 : Minimum signal level

4.3 Measurement of BER as a function of signal level variation

4.3.1 Aim

This test intends to analyse the BER variation of ATSC, DVB-T and ISDB-T digital systems in the region close to the minimum signal level.

4.3.2 Basic parameters characteristics

4.3.2.1 C = modulated wanted (useful) signal power, measured in dBm at the receiver input.

4.3.2.2 BER = bit error rate

4.3.3 Initial figures and characteristics

4.3.3.1 Wanted (useful) signal power (C) corresponding to the BER threshold.

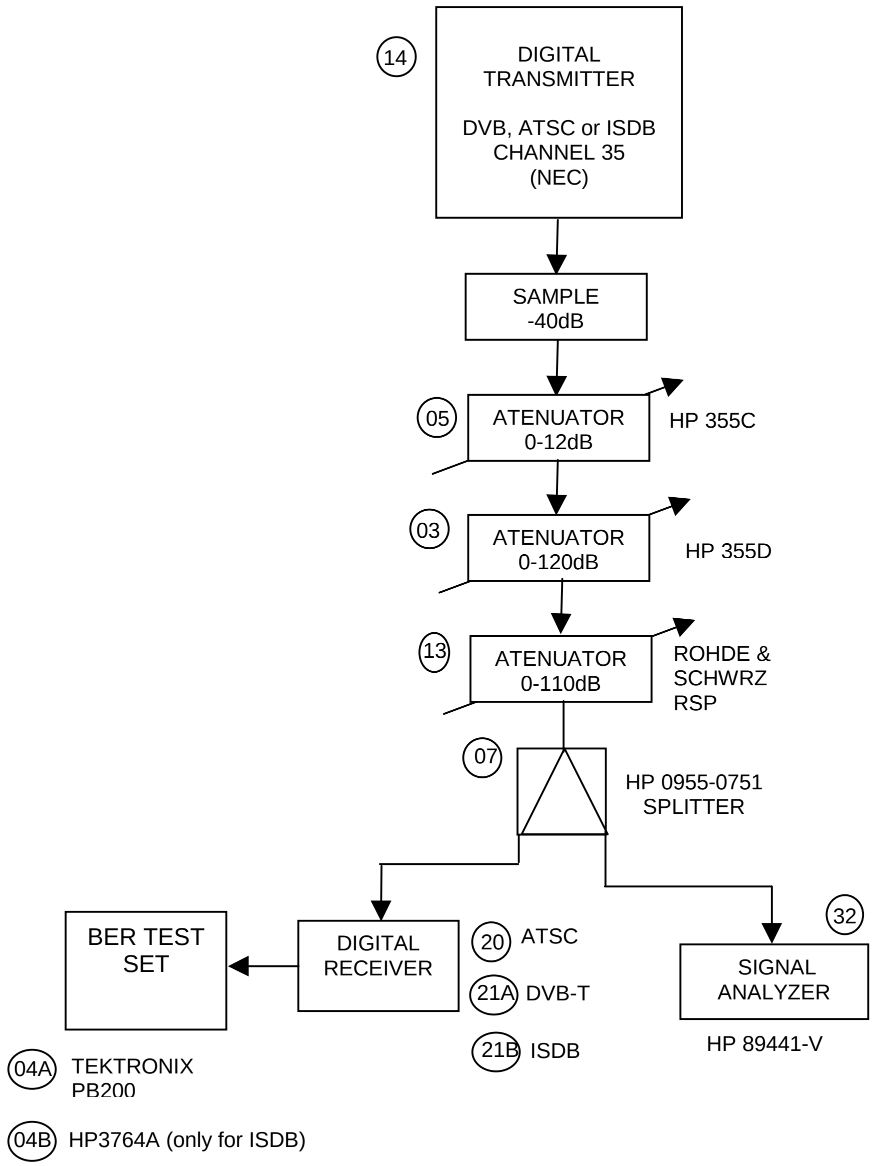
4.3.4 Measurement General description

Vary the input signal level in the region near to the minimum signal level, recording the corresponding BER.

4.3.5 Equipment used

(04A) TEKTRONIX PB200 BER test set.
(04B) HP 3764 A BER test set (only for ISDB-T)
(05) HP attenuator 0-12 dB, model 355 C
(07) HP 0955-0751 splitter
(13) R&S 0-110 dB, 0.1 dB steps attenuator, model RSP
(20) Zenith ATSC receiver
(21A) NDS DVB-T receiver
(21B) ISDB-T receiver
(14) NEC Digital transmitter (fitted with ATSC, DVB-T and ISDB-T modulators), tuned to channel 35.
(32) HP 89441-V signal analyzer
(03) HP 0-120 dB attenuator, model 355D

4.3.6 Basic lay out



4.3.7 *Test procedures*

4.3.7.1 Determine the minimum signal level (in dBm) as shown in item 4.2 of the “General Description of Laboratory Tests”. Record this value in dBm for the corresponding BER threshold. For better precision measure the BER with samples of 10^9 bits.

4.3.7.2 Attenuate the input signal level by 2 dB, recording the respective BER.

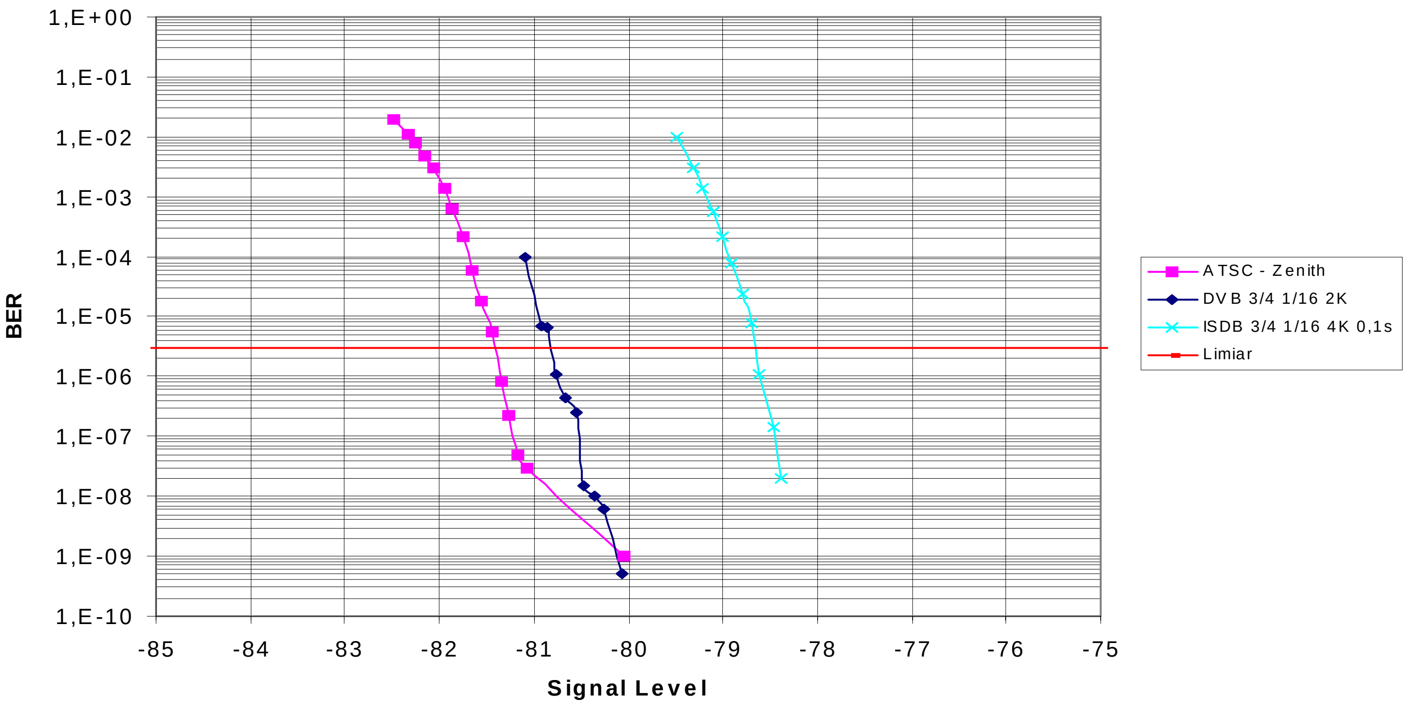
4.3.7.3 Increase the input signal level in steps of 0.1 dB, always recording the BER readings.

4.3.7.4 Repeat the measurements until the input signal exceeds the minimum signal level (obtained in 4.3.7.1) by 0.5 dB.

4.3.7.5 Draw the curve “BER” against “input level” (in dBm) for ATSC, DVB-T and ISDB-T systems (figure 4.3.8.1).

4.3.8 Results

Figure 4.3.8.1: BER as a function of the minimum signal level



4.4 BER as function of C/N

4.4.1 Aim

This method aims to evaluate the immunity performance of ATSC, DVB-T AND ISDB-T systems when white (gaussian) noise is present. This performance will be evaluated by the BER against the "signal-to-noise ratio at the input of the receiver". The C/N in dB can be expressed as:

C/N (dB) = C (dBm) – N (dBm)

See item 4.1.1 for more details.

4.4.2 Basic Parameters Characteristics

4.4.2.1 C = modulated wanted (useful) signal power, measured in dBm at the receiver input

4.4.2.2 N = Gaussian noise power measured in dBm at the receiver input

4.4.2.3 BER = Bit error rate

4.4.3 Initial figures and characteristics

4.4.3.1 C/N (dB) corresponding to the BER threshold measured as shown in item 4.1 of "General Conditions of Laboratory Tests".

4.4.4 Measurement General description

Vary the C/N, recording the respective BER.

4.4.5 Equipment used

Same as described in item 4.1.5 of "General Conditions of Laboratory Tests".

4.4.6 Measurement basic lay-out

Same as described in item 4.1.6.

4.4.7 Tests procedures

4.4.7.1 Find the C/N (dB) corresponding to the BER threshold as shown in item 4.1. For better precision measure the BER with samples of 10^9 bits.

4.4.7.2 Increase the noise level by 3 dB in steps of 0.1dB, recording for each step the respective BER.

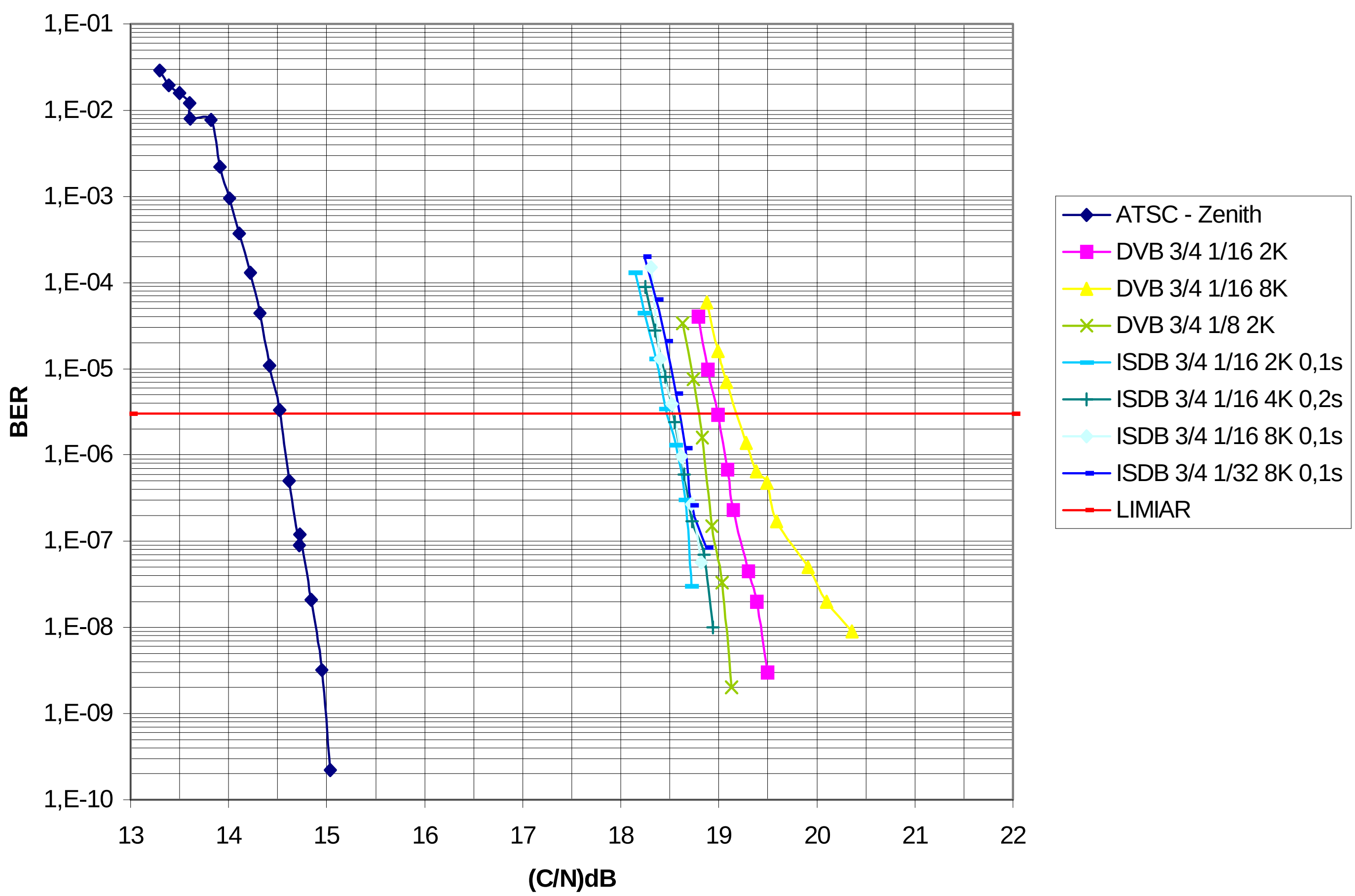
4.4.7.3 Return to the initial conditions described in item 4.4.7.1.

4.4.7.4 From previous item, attenuate the noise level by 2 dB in steps of 0.1 dB, recording for each step the respective BER.

4.4.7.5 With the obtained results draw the curves: BER as a function of C/N for ATSC, DVB-T and ISDB-T systems.

4.4.8 **Results**

Figure 4.4.8.1 : BER as a function of C/N



4.5 C/N threshold as function of the signal level

4.5.1 Aim

This analysis main purpose is to evaluate the sensitivity of the digital receivers. Measurements will be taken near the “ minimum signal level” (see item 4.2).

4.5.2 Basic Parameters Characteristics

4.5.2.1 C = modulated wanted (useful) signal power, measured in dBm at the receiver input.
4.5.2.2 N = Gaussian noise power, within the useful bandwidth, measured in dBm at the receiver input.
4.5.2.3 BER = Bit error rate.

4.5.3 Initial figures and characteristics

(See item 4.5.6 layout).

In the absence of white gaussian noise, i.e. with the attenuator (13) at the condition of maximum attenuation, find the signal as close as possible to the minimum signal level obtained in item 4.2. This is the initial value for the execution of the measurements.

4.5.4 Measurements General description

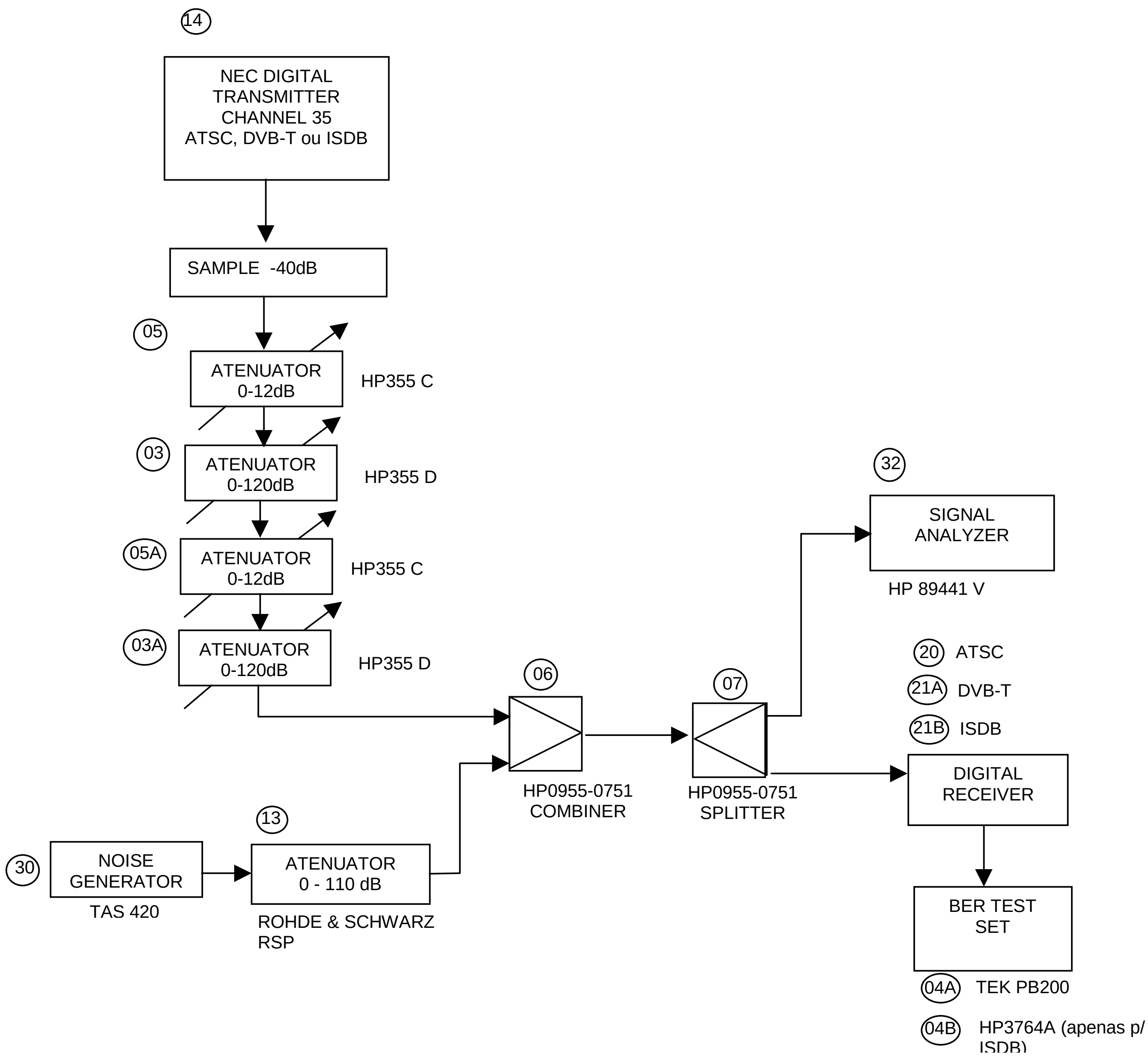
From the value obtained in item 4.5.3, increase the signal power (C) and add noise (N) until BER threshold is reached.

4.5.5 Equipment used

(3) HP Attenuator 0-120 dB model 355D
(3a) HP Attenuator 0-120 dB model 355D
(5) HP Attenuator 0-12 dB model 355C
(5a) HP Attenuator 0-12 dB model 355C
(4A) TEKTRONIX PB200 BER test set
(4B) HP3764A BER test set (only for ISDB)
(30) TAS broadband noise generator model TAS 420
(6) HP combiner model 0955-0751
(7) HP signal splitter model 0955-0751

(13) Rohde & Schwarz Attenuator 0-110 dB step 0.1 dB model RSP
(14) NEC Digital Transmitter channel 35
(20) Zenith ATSC digital receiver
(21A) NDS DVB digital receiver
(21B) ISDB digital receiver
(32) HP 89441-V Signal Analyzer

4.5.6 Measurement basic lay-out



4.5.7 Test Procedures

4.5.7.1 With the noise generator (30) turned on adjust the attenuator (13) to maximum attenuation. With the attenuators (05 A) and (03A) adjusted to zero attenuation, adjust the attenuators (05) and (03) until the signal power level read from the signal analyzer (32) is near -30 dBm. Measure and record this value. This is the reference value of C for all the other signal measurements.

4.5.7.2 Through the attenuator (13) adjust the noise level added from the noise generator (30) until the BER threshold is reached. Record the reading position of the attenuator (13).

4.5.7.3 Adjust the attenuators (05 A) and (03 A) to maximum attenuation and read the noise power within the channel bandwidth (6 MHz) at the signal analyzer (32). Measure and record this value of N. It is the reference value for all other noise measurements.

4.5.7.4 Adjust the attenuator (13) until the BER test set indicates a value as close as possible but lower than BER threshold. From the attenuator (05 A) and (03 A) reading calculate C value taking the value in 4.5.7.1 as a reference.

4.5.7.5 Act on the attenuator (13) until the BER test set indicates that BER threshold is reached. Calculate the value of N from the reading of the attenuator (13) in respect to the value read in item 4.5.7.2, taking the reading of N recorded in item 4.5.7.5 as a reference.

4.5.7.6 Calculate the C/N (dB) from the value of C in dBm (item 4.5.7.4) and from the value of N in dBm (item 4.5.7.5):

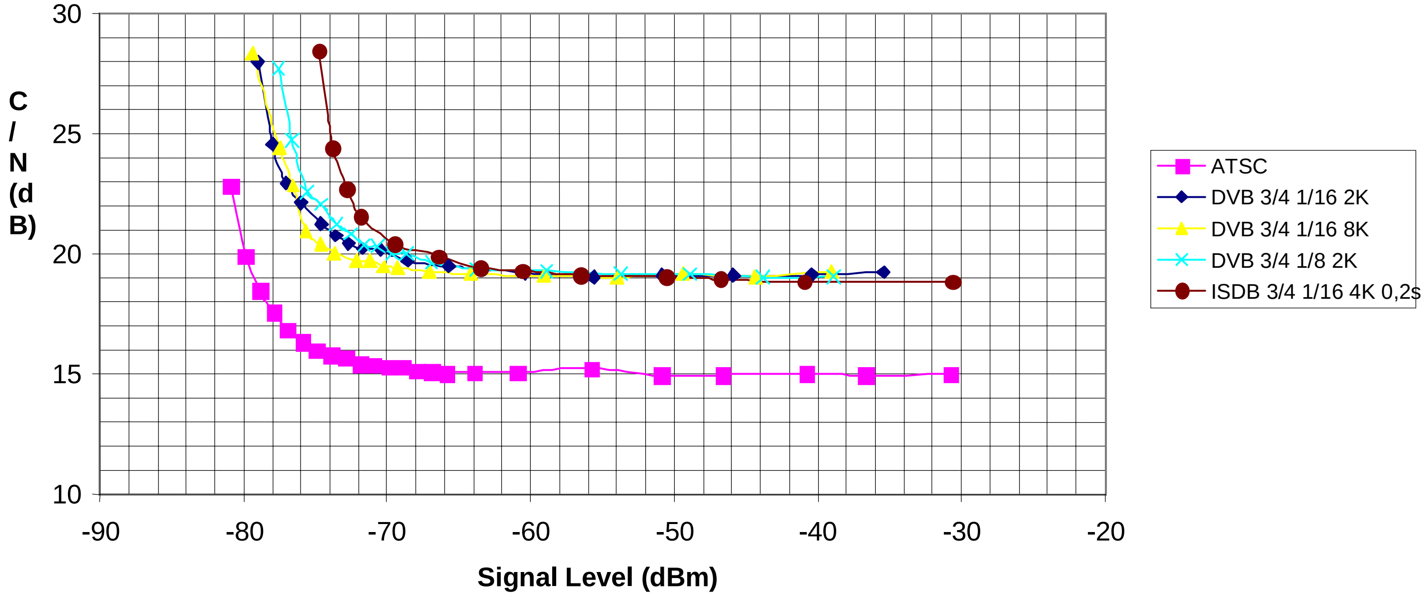
$$C/N\ (dB) = C\ (dBm) - N\ (dBm)$$

This will be the 1st point to draw the curve “C/N (dB)” against “C (dBm)”.

4.5.7.7 Acting on the attenuators (03 A) and (05 A) increase the level of signal C (dBm) in 1 dB steps as made in the items 4.5.7.5 and 4.5.7.6. Using the obtained values draw the curves C/N (dB) against C (dBm) for ATSC, DVB-T and ISDB-T systems.

4.5.8 Results

Figure 4.5.8.1: C/N threshold as a function of signal level



5.2 *“Peak Power Level” / “Average Power Level” ratio*

5.2.1 Aim

The purpose of the tests described in this chapter is to evaluate the “Peak power level” to “Average power level” ratio for each one of the digital TV systems ATSC, DVB-T and ISDB.

R (dB) = Pp/Pa (dB) = Pp (dB) – Pa (dB)

Where:
R = (Peak power level/Average power level) ratio
Pp = Peak power level
Pa = Average power level

Observe that the lower R (dB) the lower the transmitter cost.

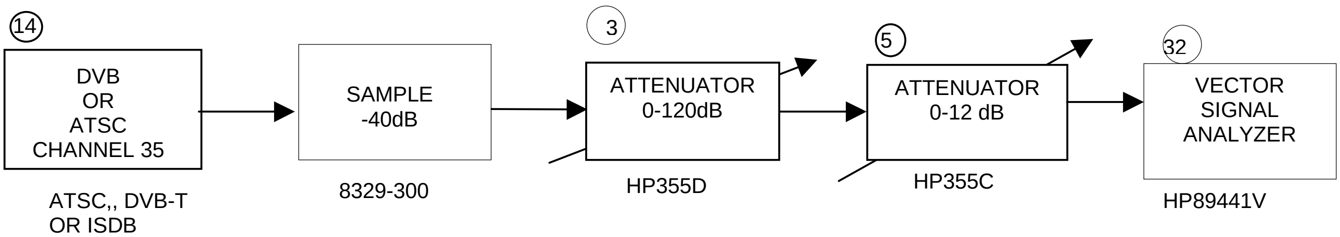
5.2.2 Measurement general description

The “Peak power level”/ “Average power level” ratio can be evaluated directly by using HP89441-V vector signal analyzer. This vector analyzer can draw a graph which shows how R (dB) varies as a function of the percent probability, in time, for R to be exceeded. This vector analyzer feature is known as CCDF (Complementary Cumulative Density Function).

5.2.3 Equipment used

(14) Digital transmitter, channel 35 – NEC
(3) HP Attenuator 0-120 dB, model 355D
(21) DVB-T receiver
(5) HP Attenuator 0-12 dB, model 355C
(32) HP Vector Signal Analyzer, model 89441-V

5.2.4 Measurement block diagram



5.2.5 Test Procedures

5.2.5.1 Set the NEC transmitter to nominal power. Observe that this transmitter has been designed to handle without compression the peak power of any of the systems ATSC, DVB-T or ISDB.

5.2.5.2 Adjust attenuators 3 and 5 in order to obtain a reading between – 10 dBm and – 20 dBm at the HP 89441-V (32) vector signal analyzer input.

5.2.5.3 Adjust vector signal analyzer (32) for reading CCDF.

5.2.5.4 For each system (ATSC, DVB-T and ISDB) record the graphs “percent probability” as a function of “Peak power level/Average power level” ratio R (dB).

5.2.5.5 Read R (dB) value for the condition 0,01%. Write down this fifure on table 5.2.6.

5.2.6 Results

Date: 07/11/99 Time: 13:52

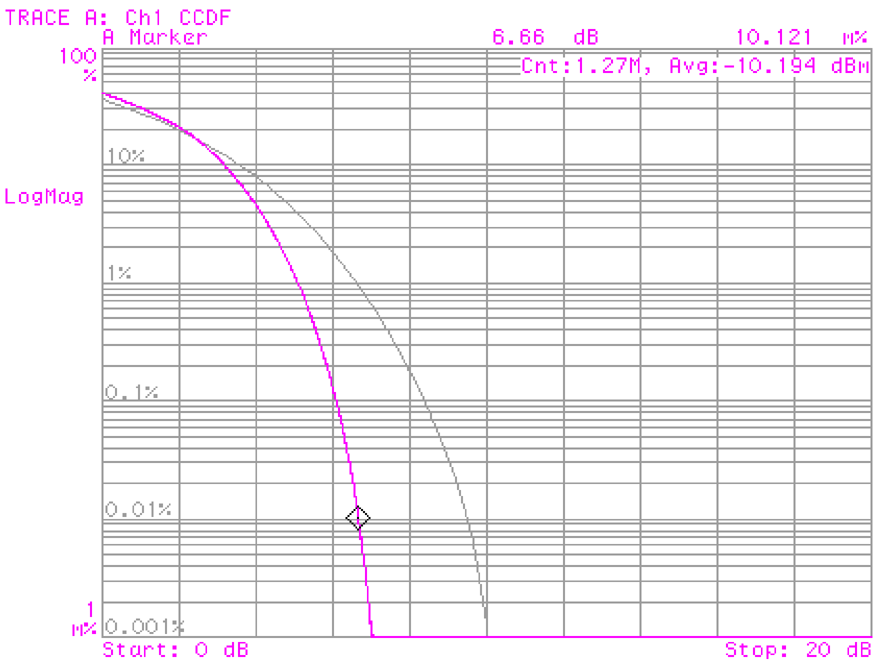


Figure 5.2.6.1 - Graph CCDF for ATSC system.

Date: 07/11/99 Time: 16:27

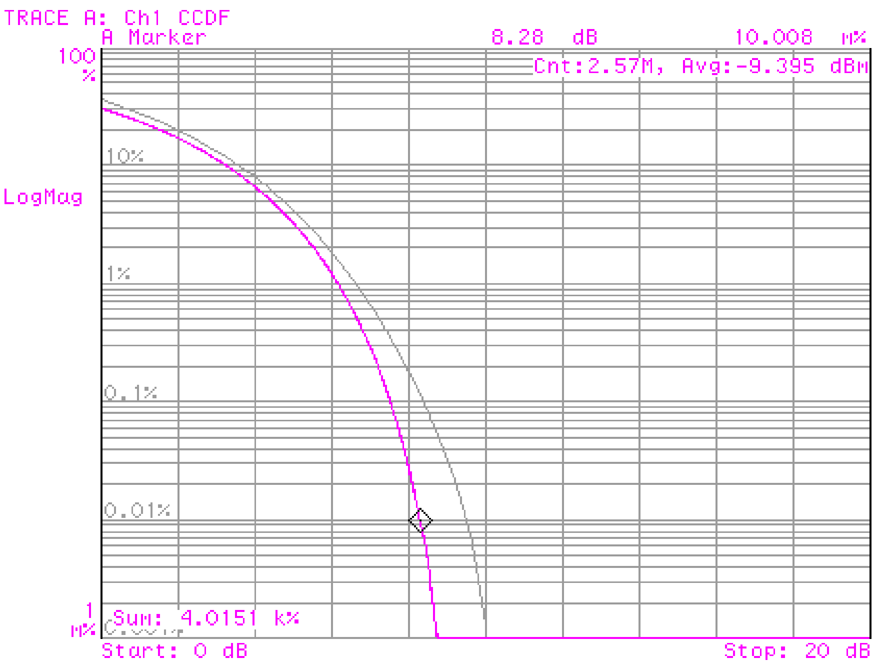


Figure 5.2.6.2 - Graph CCDF for DVB-T system.

Date: 12/01/00 Time: 17:06

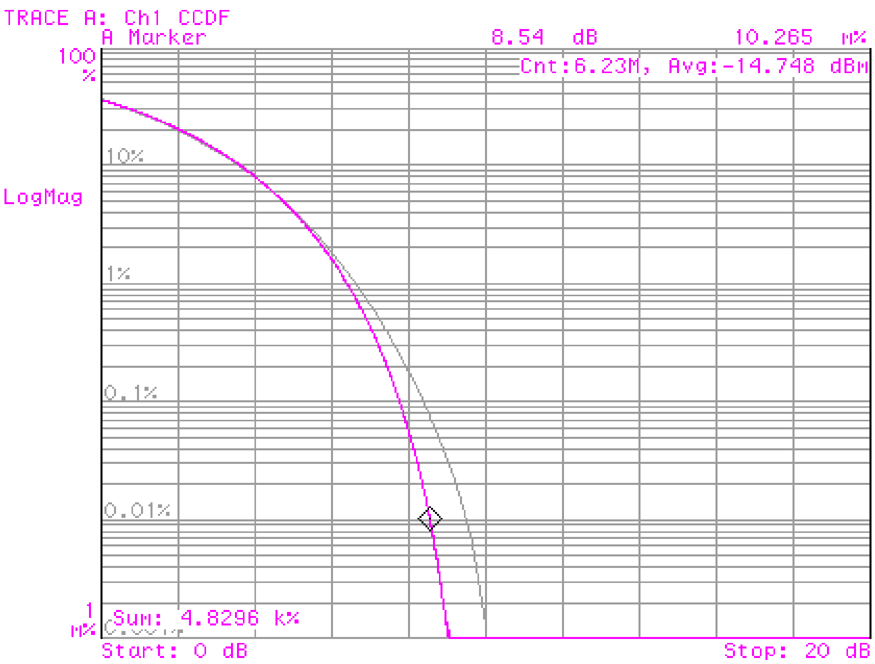


Figure 5.2.6.3 - Graph CCDF for ISDB system.

SYSTEM	R(dB)
ATSC	6,86
DVB-T	8,28
ISDB	8,54

Table 5.2.6 – “Peak power level”/ “Average power level” ratio – R(dB)

Note: The results on this table have been extracted from the CCDF probability graphs for the condition 0,01%.
That means that the probability for those figures not to be exceeded is 99,99%.

5.3 Emission of out of band spurious signals

5.3.1 **Aim**

The main purpose of the test described in this chapter is to adjust NEC transmitter in order that the transmitted signal spectrum be as much as possible within the limits of the FCC mask. It applies for ATSC, DVB-T and ISDB systems.

5.3.2 Basic parameters characteristics

Standard spectrum mask – FCC.

5.3.3 Initial figures

NEC transmitter power: 1kW.

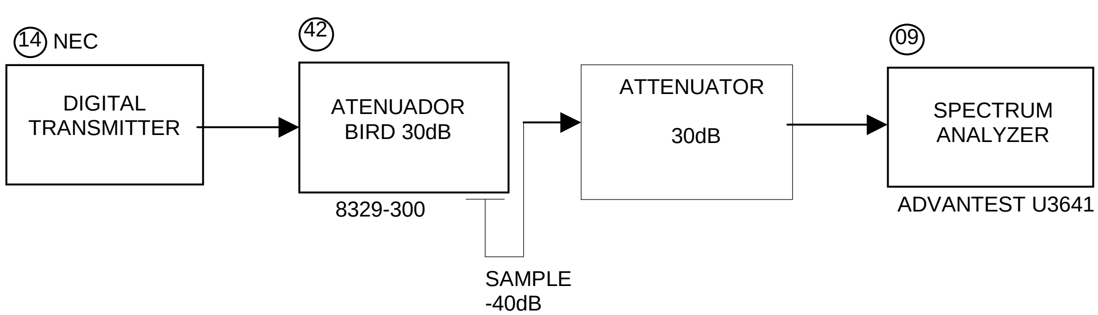
5.3.4 Measurement general description

With the help of the spectrum analyser (09), adjust NEC transmitter so that the transmitted signal spectrum fits as much as possible the FCC mask. This is valid for ATSC, DVB-T and ISDB systems.

5.3.5 Equipment used

(14) NEC Digital Transmitter
(42) NEC load
(9) Advantest Spectrum Analyzer, model U3641
(41) BIRD 30dB Attenuator, model 2AMFN-30

5.3.6 Measurements block diagram



5.3.7 Measurement procedures

5.3.7.1 Set the transmitter power level to nominal.

5.3.7.2 Set the spectrum analyser frequency span to 20MHz to be able to see the wanted signal and the adjacent channels (upper and lower).

5.3.7.3 Set the spectrum analyser amplitude span to 10dB/div.

5.3.7.4 Set the channel centre frequency in the centre of the window and the upper reference to 0 dBm.

5.3.7.5 Adjust the transmitter so that the spectrum fits as much as possible FCC mask.

5.3.7.6 Record the graphs obtained as shown in figures 5.3.8.1.a to 5.3.8.1.c for ATSC system, in figures 5.3.8.2.a and 5.3.8.2.b for DVB-T system and in figures 5.3.8.3.a and 5.3.8.3.b for ISDB system.

5.3.7.7 In table 5.3.8, write down the central frequency levels for $\Delta f \pm 3{,}25$MHz and $\Delta f \pm 3{,}5$MHz, either for ATSC system as for DVB-T and ISDB systems.

5.3.8 Results

Figure 5.3.8.1.a - ATSC

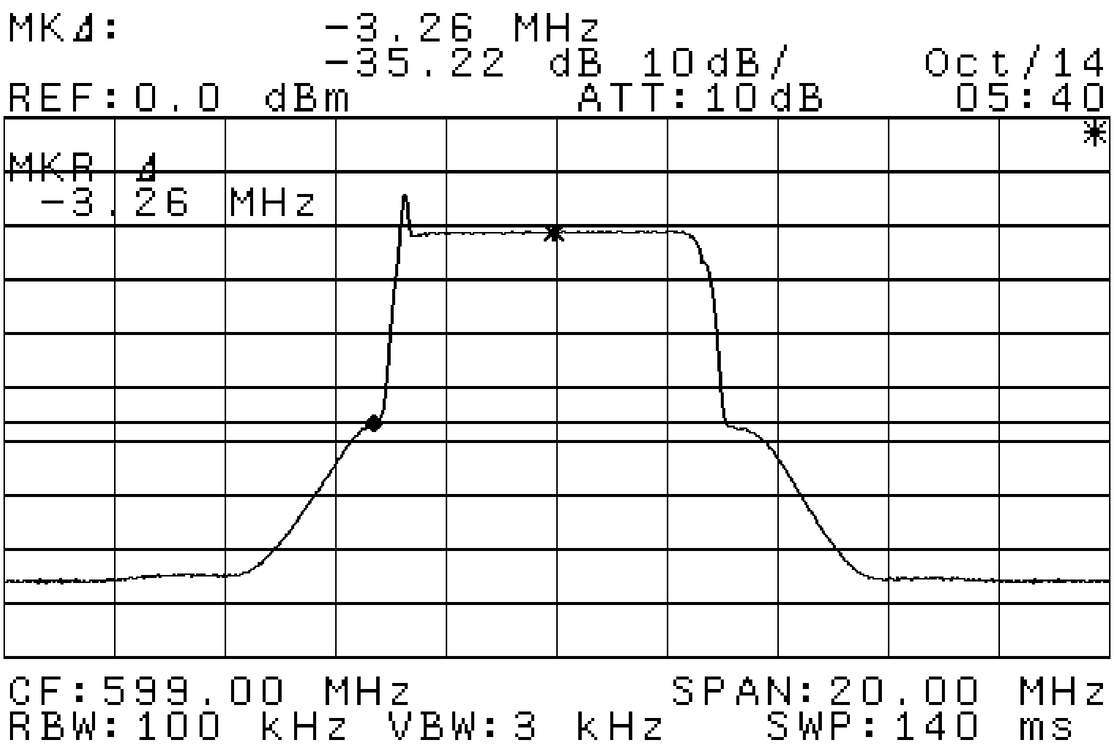


Figure 5.3.8.1.b - ATSC

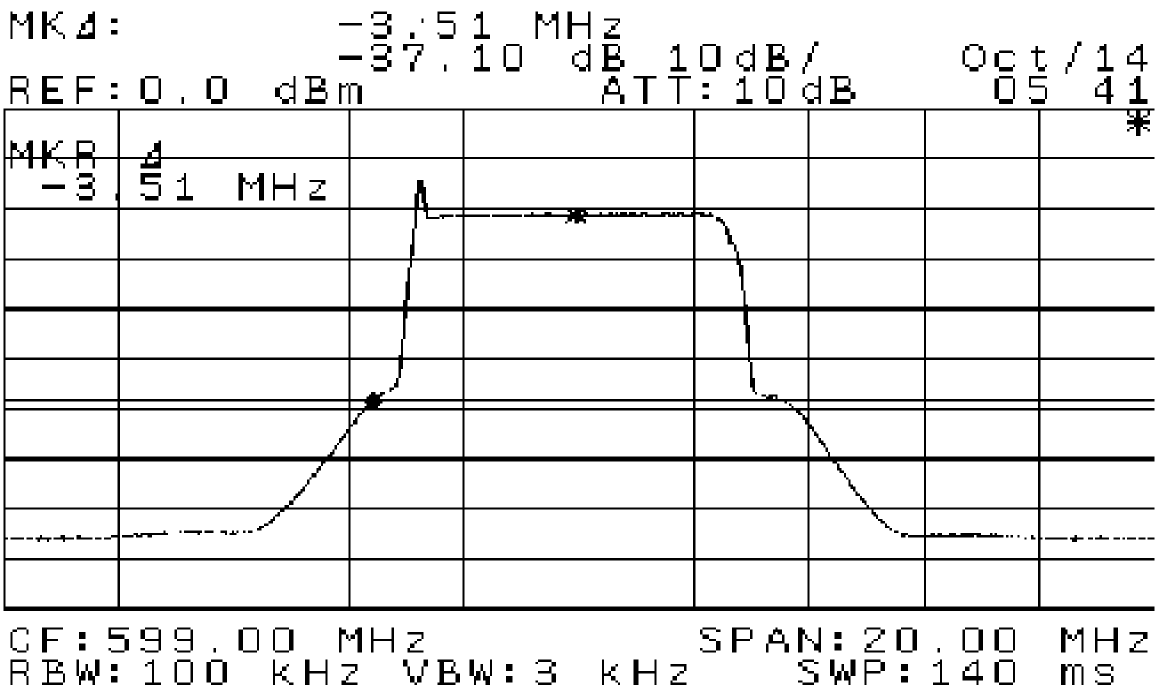


Figure 5.3.8.1.c - ATSC

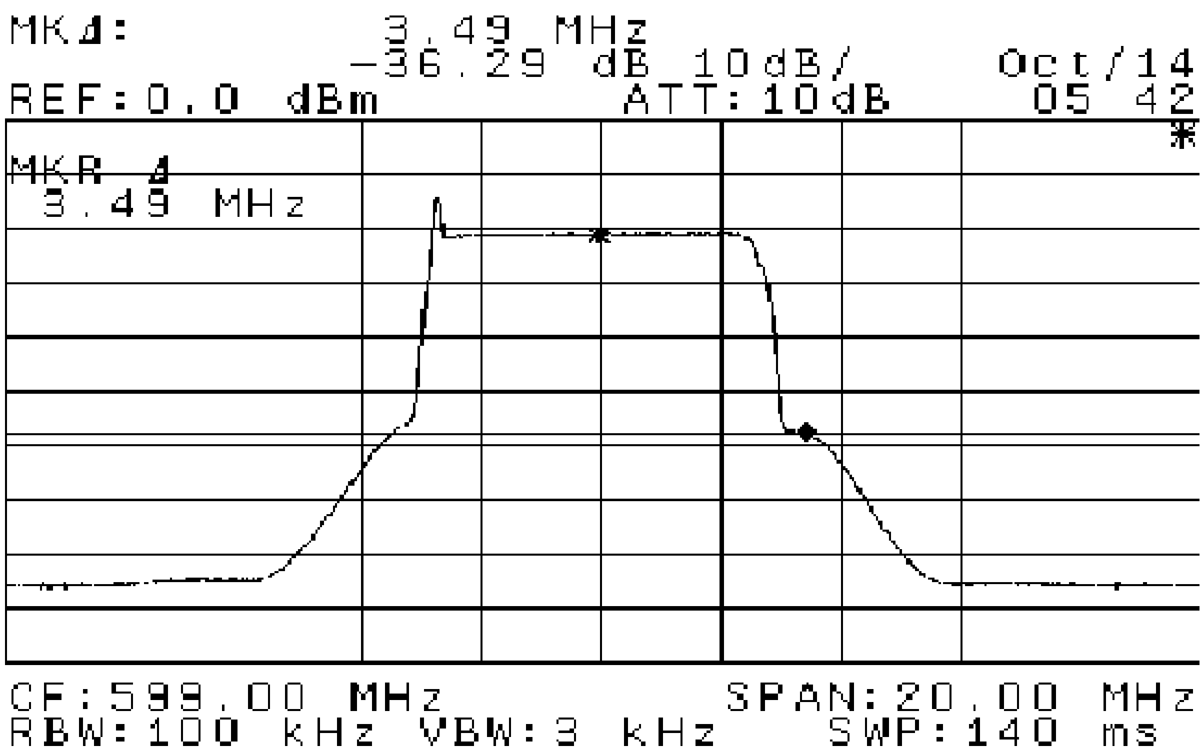


Figure 5.3.8.2.a - DVB-T

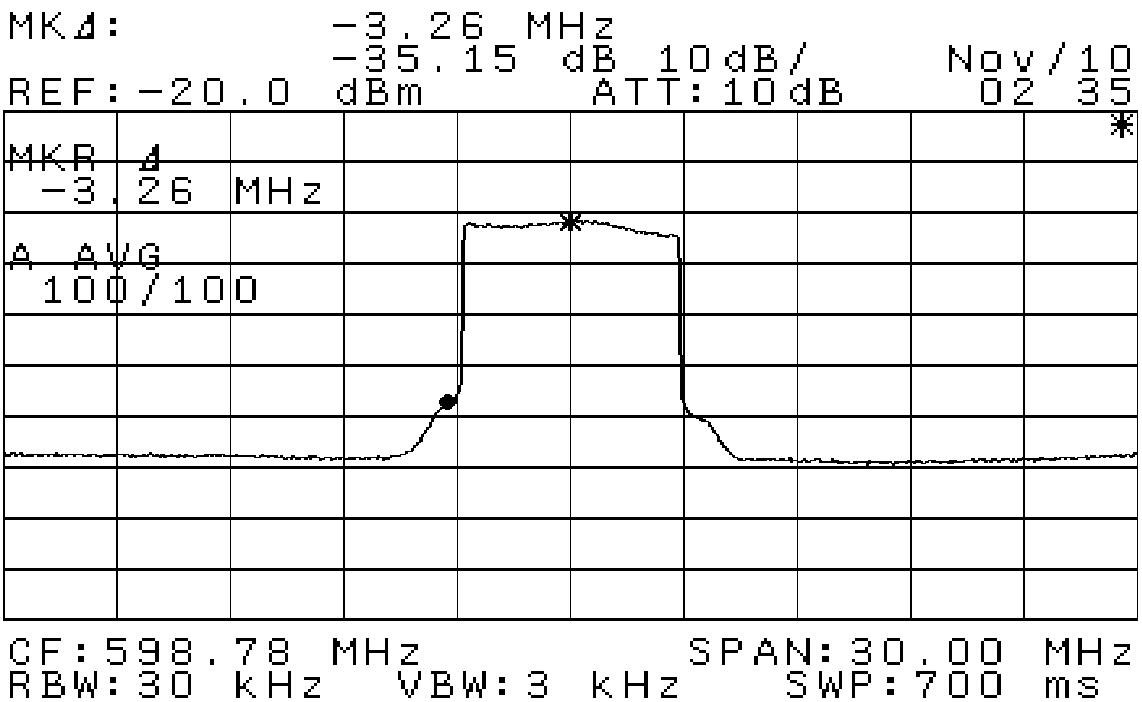


Figure 5.3.8.2.b - DVB-T

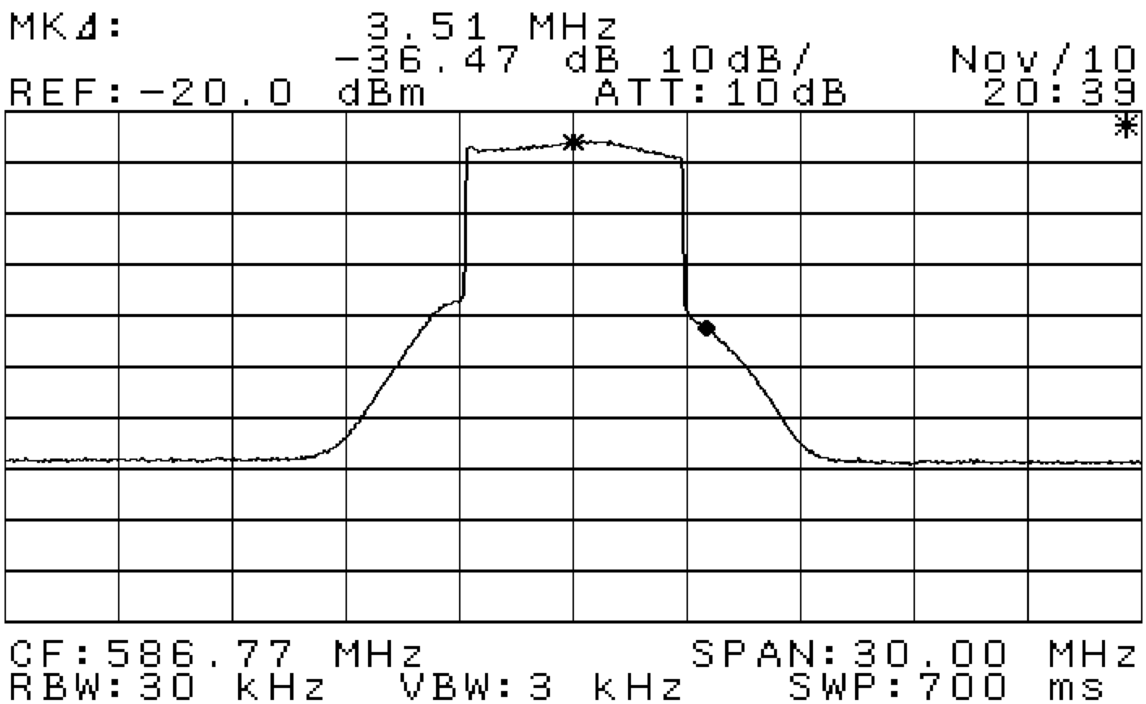


Figure 5.3.8.3 a: ISDB

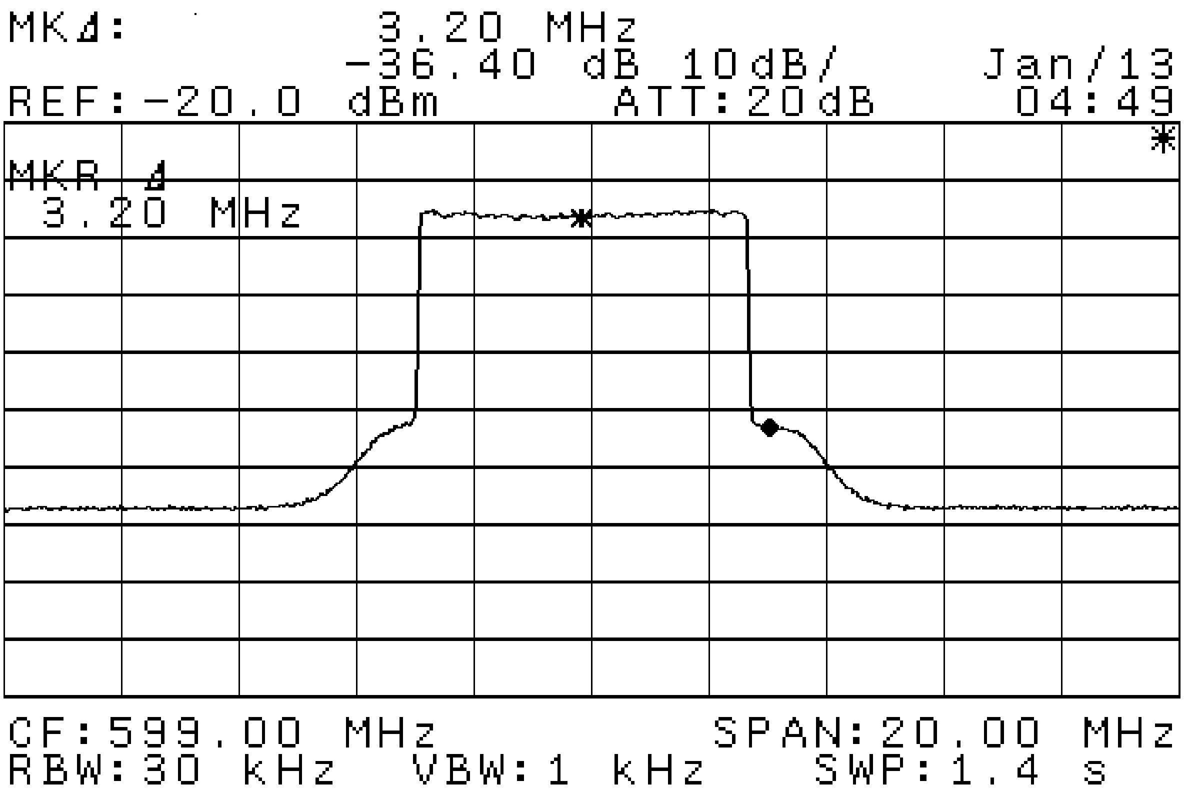
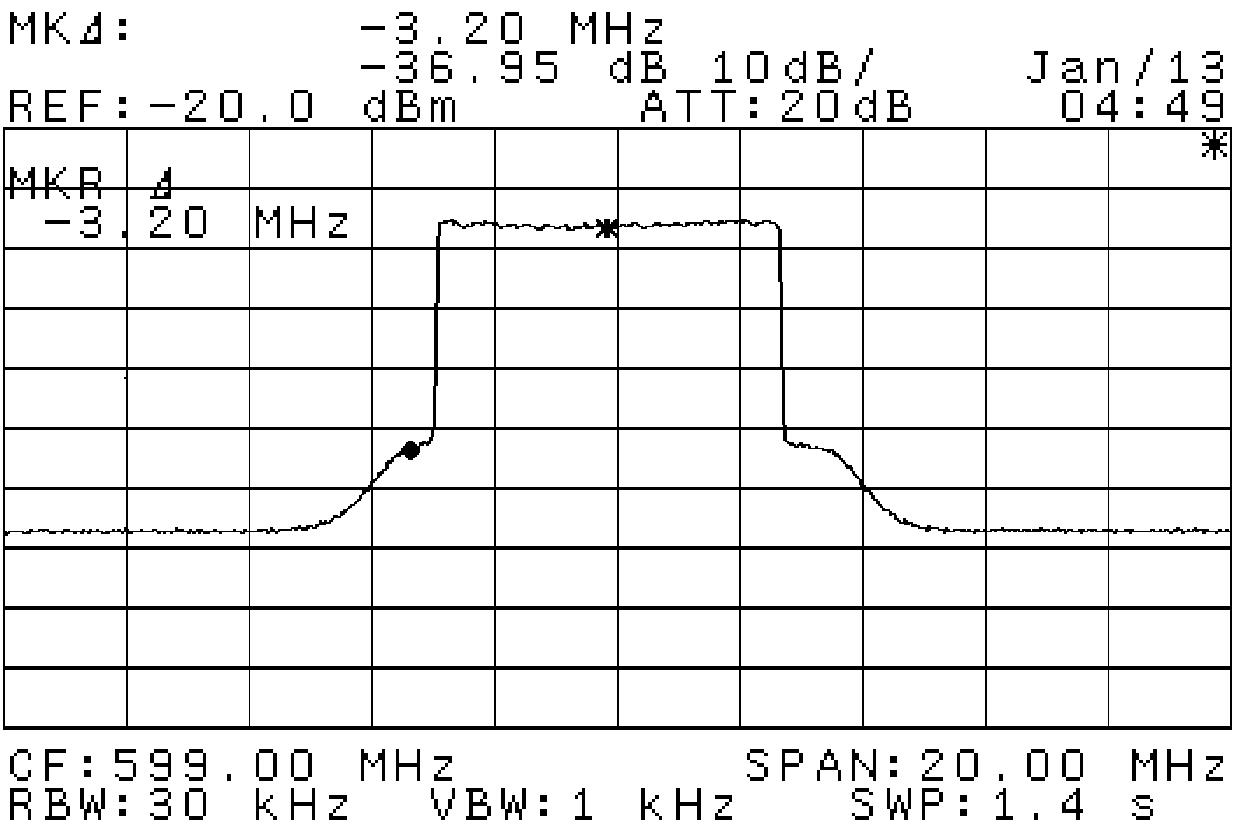


Figure 5.3.8.3 b: ISDB



System	NEC Transmitter			
	Lower shoulder(dB)		Upper shoulder(dB)	
	-3,5 MHz	-3,25 MHz	+3,25 MHz	+3,5 MHz
DVB	*Not measured*	-35,1	*Not measured*	-36,5
ATSC	-37,1	-35,2	*Not measured*	-36,3
ISDB	*Not measured*	-36,95	-36,4	*Not measured*

Table 5.3.8: "Shoulders" of NEC transmitter.

6. Characteristics of digital TV systems in the presence of reflections caused by moving objects (Doppler Effect)

6.1 Aim

The purpose of the tests described in this chapter is to evaluate the signal degradation at the reception, when the signal suffers reflections due to moving objects.

This degradation can be caused by a number of factors, namely:

- Delay (Post echo) with frequency shift of the spectra components of the reflected digital signal.
- Advance (Pre echo) with frequency shift of the spectra components of the reflected digital signal.

In the post-echo condition the later signal is the weaker.
In the pre-echo condition the opposite occurs, the earlier signal is the weaker.
In both cases, the positive and negative frequency shifts due to reflections caused by moving objects will be analysed.

6.2 Characteristics of the basic parameters

6.2.1 Δf = frequency shift, in Hertz.
6.2.2 Δt = reflected signal delay or advance, in μs .
6.2.3 BER: bit error rate
6.2.4 E/D (dB) = ratio between the reflected signal power level (dB) and the direct signal power level (dB).

6.3 Initial figures and characteristics

6.3.1 Direct signal power level: approximately -30dBm.
6.3.2 Signal to noise ratio (C/N): higher than 50dB

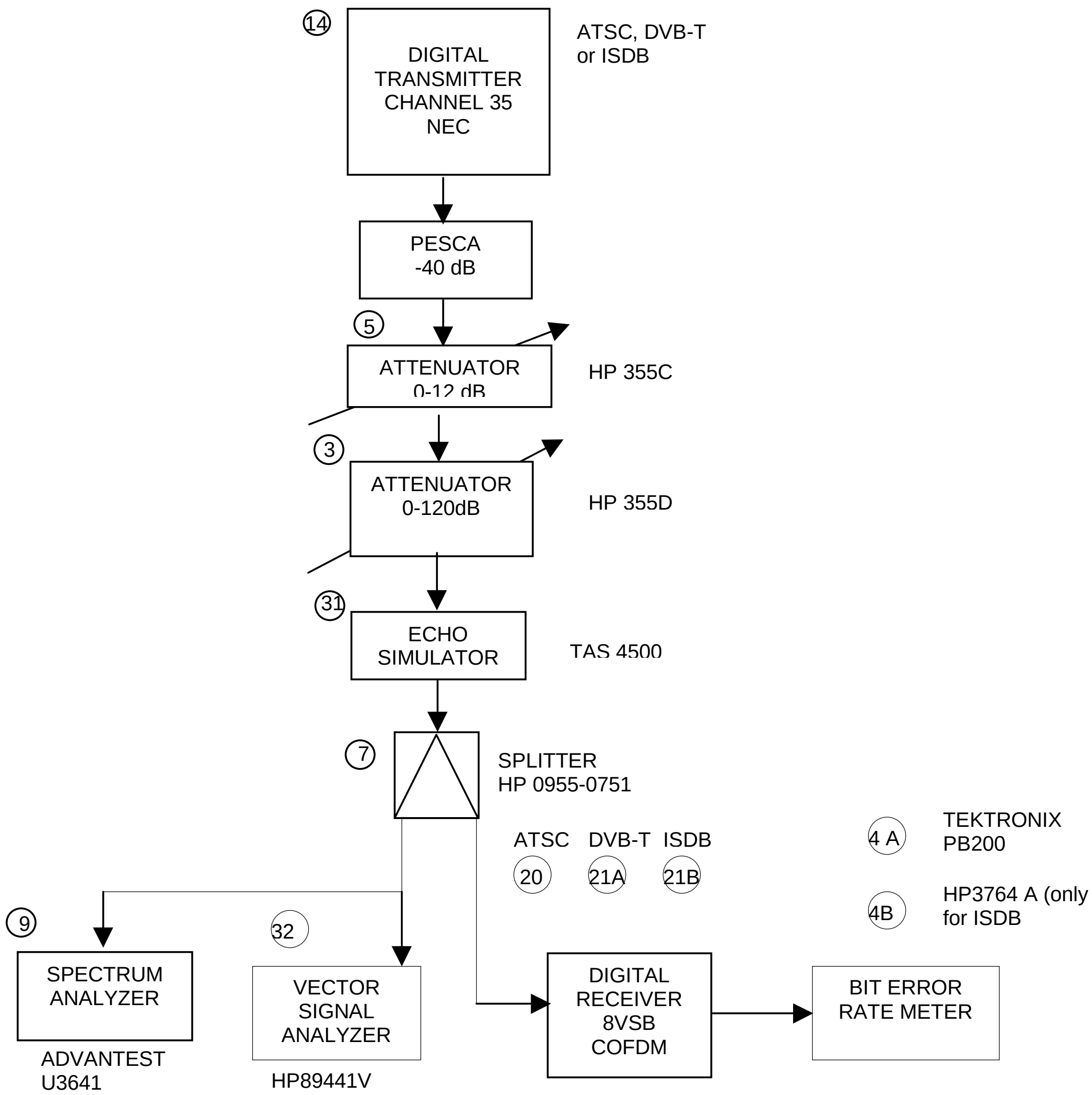
6.4 Measurement general description

6.4.1 For a given delay or advance value, adjust the E/D (dB) ratio as function of each frequency shift until the BER threshold is reached.

6.5 Equipment used

(14) NEC Digital transmitter, channel 35 (ATSC, DVB-T or ISDB)
(03) HP Attenuator 0-120 dB, model 355D
(31) TAS Echo Simulator, model 4500 Flex 4 plus
(07) HP Signal Splitter, model 0955-0751
(09) Advantest Spectrum Analyzer, model U3641
(20) ATSC Digital Receiver – Zenith
(21A) DVB-T Digital Receiver
(21B) ISDB Digital Receiver
(4A) Tektronix Bit Error Rate Meter, model PB200
(4B) HP Bit Error Rate Meter, model 3764^{A} A (only for ISDB)
(32) HP Vector Signal Analyzer, model 89411-V
(5) HP Attenuator 0 – 12 dB, model 355C

6.6 Measurement block diagram



6.7 Measurement procedures

6.7.1 Adjust attenuators (3) and (5), so that the main signal level at the TAS4500 (31) echo simulator input be approximately – 10dBm.

6.7.2 At the echo simulator (31) turn off the echo signals. Observe that in this condition the signal level at the echo simulator output will be approximately 27dBm. Consequently the signal level at the digital receiver input will be approximately – 33dBm.

6.7.3 Adjust the echo simulator to obtain a single echo with a 1µs delay (post echo)

6.7.4 Set the frequency shift for the echo obtained on item 6.7.3 to + 1Hz.

6.7.5 Turn on the echo signal and adjust its level until BER threshold is reached in the bit error rate meter. In the echo simulator (31), read the E/D (dB) ratio.

6.7.6 Repeat all the procedures described on items 6.7.4 and 6.7.5 for the following
shift frequency values (Δf):
-1Hz, ± 3Hz, ± 5Hz, ± 25Hz, ± 50Hz, ± 75Hz, ± 100Hz, ± 150Hz, ± 175Hz, ± 200Hz, ± 250Hz and ± 300Hz.
Write down all the results.

6.7.7 Set the delay at the echo simulator to 1µs.

6.7.8 Repeat all the procedures described by items 6.7.3 to 6.7.7 for the following values of delays: 2µs,4µs, 8µs, 16µs, 32µs, 64µs, 128µs e 170µs.

6.7.9 Repeat items 6.7.4 to 6.7.7, swapping the delay by “advance” .

6.7.10 With the results found on the preceding items, produce tables 1a to 1d for ATSC system, tables 2a to 2h for DVB-T system and tables 3a to 3l for ISDB system.

6.8 Results

ATSC

Table 1a - Post Echo $\Delta f > 0$

Delay $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1	-3,1	-2,6	-2,6	-3,7	-3,8	-18,3			
3	-3,6	-3,4	-3,2	-4,0	-3,8	-18,3			
5	-4,6	-4,0	-3,9	-4,4	-4,2	-18,3			
25	-9,9	-8,5	-8,8	-8,6	-8,7	-18,4			
50	-11,5	-11,7	-11,9	-11,6	-11,7	-18,7			
75	-13,5	-13,4	-13,8	-13,6	-13,7	-18,1			
100	-16,2	-16,7	-15,7	-16,4	-16,2	-16,3			
125	-16,6	-16,7	-16,6	-16,6	-16,5	-14,9			
150	-15,0	-15,2	-15,1	-15,1	-15,0	-15			
175	-15,1	-15,3	-15,2	-15,2	-15,1	-14,8			
200	-15,3	-15,4	-15,3	-15,3	-15,3	-14,8			
250	-16,1	-16,2	-16,1	-16,1	-16,0	-14,9			
300	-15,2	-15,3	-15,2	-15,2	15,2	-15,0			

E/D (dB) ratio for several delay times and positive frequency shifts.

ATSC

Table 1b - Post Echo $\Delta f < 0$

Delay $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1	-3,1	-2,6	-2,6						
3	-3,6	-3,5	-3,4						
5	-4,6	-4,1	-4,2						
25	-14,2	-8,4	-8,5						
50	-12,2	-11,7	-11,3						
75	-13,2	-13,7	-13,7						
100	-16,4	-15,9	-16,0						
125	-16,7	-16,6	-16,6						
150	-15,1	-15,2	-15,1						
175	-15,2	-15,2	-15,2						
200	-15,3	-15,4	-15,3						
250	-16,1	-16,1	-16,0						
300	-15,2	-15,3	-15,2						

E/D (dB) ratio for several delay times and negative frequency shifts.

ATSC

Table 1c - Pre Echo $\Delta f > 0$

Advance $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1	-3,4	-5,6	-9,1	-18,8					
3	-4,2	-5,9	-9,1	-18,7					
5	-4,9	-6,3	-9,2	-18,7					
25	-9,5	-9,5	-11,2	-18,6					
50	-11,4	-11,7	-12,3	-19,0					
75	-13,4	-13,5	-13,6	-19,0					
100	-16,4	-16,6	-15,5	-17,2					
125	-16,6	-16,5	-16,5	-14,9					
150	-15,0	-15,0	-15,0	-14,8					
175	-15,1	-15,1	-15,1	-14,8					
200	-15,3	-15,2	-15,2	-14,8					
250	-16,0	-16,0	-16,0	-14,9					
300	-15,2	-15,1	-15,1	-14,9					

E/D (dB) ratio for several advance times and positive frequency shifts.

ATSC

Table 1d - Pre Echo $\Delta f < 0$

Advance $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1	-3,4	-5,6	-9,1						
3	-4,2	-5,9	-9,1						
5	-5,0	-6,2	-9,2						
25	-9,2	-9,4	-11,3						
50	-11,4	-11,6	-12,3						
75	-13,4	-13,5	-13,5						
100	-16,3	-16,5	-15,6						
125	-16,5	-16,6	-16,5						
150	-14,9	-15,0	-15,0						
175	-15,0	-15,1	-15,0						
200	-15,2	-15,2	-15,2						
250	-16,0	-16,0	-16,0						
300	-15,1	-15,2	-15,1						

E/D (dB) ratio for several advance times and negative frequency shifts.

DVB-T (3/4; 1/16; 2K)

Table 2a - Post Echo Δf > 0

Delay Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1	0	0		0	-6,5	-11,7	-21,1	-20,8	
3	0	0		0	-6,2	-11,5	-22	-20,8	
5	0	0		0	-6,2	-11,5	-22	-20,7	
25	0	0		0	-6	-11,5	-21,9	-20,7	
50	-0,5	-0,5		-0,5	-6,2	-11,7	-21,8	-20,6	
75	-1,4	-1,4		-1,5	-6,8	-12,1	-21,8	-20,5	
100	-2,7	-2,7		-2,9	-8,2	-12,6	-21,6	-20,4	
125	-4,8	-5		-6,2	-8,8	-13,3	-21,5	-20,3	
150	-7	-6,5		-7,5	-9,3	-13,8	-21,3	-20,1	
175	-8,1	-7,8		-8,6	-10,1	-14,2	-21,1	-20	
200	-8,9	-8,9		-9	-10,6	-14,5	-21	-20	
250	-10,5	-10,7		-10,7	-11,7	-14,7	-20,7	-19,8	
300	-12,4	-12,4		-12,4	-13,1	-14,9	-20,3	-19,7	

E/D (dB) ratio for several delay times and positive frequency shifts.

DVB-T (3/4; 1/16; 2K)

Table 2b - Post Echo $\Delta f < 0$

Delay $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1	0			0					
3	0			0					
5	0			0					
25	0			0					
50	-0,6			-0,6					
75	-1,5			-1,6					
100	-2,7			-3,1					
125	-6,3			-6,3					
150	-7,6			-7,6					
175	-8,5			-8,5					
200	-8,9			-9,1					
250	-10,7			-10,6					
300	-12,5			-12,3					

E/D (dB) ratio for several delay times and negative frequency shifts.

DVB-T (3/4; 1/16; 2K)

Table 2c - Pre Echo $\Delta f > 0$

Advance $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1	0	0		0	-6,4	-11,4			
3	0	0		0	-6	-11,3			
5	0	0		0	-6	-11,2			
25	0	0		0	-6	-11,2			
50	-0,5	-0,5		-0,7	-6,4	-11,3			
75	-1,4	-1,5		-1,7	-7,2	-11,4			
100	-2,7	-3		-5,9	-8,2	-11,7			
125	-4,8	-5,1		-7,3	-9,2	-12			
150	-7	-6,9		-8	-9,8	-12,2			
175	-8,1	-8		-9	-10,2	-12,5			
200	-8,9	-8,8		-9,6	-10,9	-12,7			
250	-10,5	-10,8		-10,9	-11,9	-13,3			
300	-12,4	-12,4		-12,6	-13,2	-14			

E/D (dB) ratio for several advance times and positive frequency shifts.

DBB-T (3/4; 1/16; 2K)

Table 2d - Pre Echo Δf < 0

Advance Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1	0			0					
3	0			0					
5	0			0					
25	0			-0,1					
50	-0,5			-0,7					
75	-1,5			-1,7					
100	-2,8			-5,9					
125	-5,2			-7,2					
150	-7,4			-7,9					
175	-8,4			-8,8					
200	-8,8			-9,5					
250	-10,8			-10,9					
300	-12,4			-12,6					

E/D (dB) ratio for several advance times and negative frequency shifts.

DVB-T (3/4; 1/16; 8K)

Table 2e - Post Echo $\Delta f < 0$

Advance $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1	-0,5	-0,7	-1,3	-1,1	-1,2	-1,3	-6,4	-11,7	
3	-1	-1,3	-1,2	-1,5	-1,1	-1,5	-6,6	-11,8	
5	-1,6	-1,8	-0,9	-1,1	-1,5	-1,6	-6,7	-11,7	
25	-5,2	-4,9	-4,8	-4,6	-4,6	-5,3	-7,8	-12,8	
50	-10,5	-10,9	-11,1	-10,2	-10,4	-10,8	-11,6	-14,8	
75	-14,7	-14,8	-14,7	-14,7	-14,9	-14,7	-15,1	-18,3	
100	-17,3	-17,3	-17,4	-17,6	-17,3	-17,5	-17,5	-17,8	
125	-19,0	-19,0	-18,8	-18,9	-19,1	-19,1	-19	-19	
150	-20,2	-19,9	-20	-19,7	-20,2	-20,1	-19,8	-20	
175	-20,8	-20,6	-20	-20,6	-20,7	-20,6	-20,5	-20,4	
200	-20,8	-20,7	-20,5	-20,5	-20,7	-20,8	-20,6	-20,6	
250	-20,1	-20,7	-20,3	-20,1	-20	-20	-19,9	-20	
300	-19,4	-20,2	-19,7	-14,7	-19,8	-19,9	-19,8	-19,8	

E/D (dB) ratio for several advance times and positive frequency shifts.

DVB-T (3/4; 1/16; 8K)

Table 2f - Post Echo Δf < 0

Advance Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1	**-0,5**								
3	**-1**								
5	**-1,3**								
25	**-4,7**								
50	**-10,6**								
75	**-15**								
100	**-17,4**								
125	**-19**								
150	**-20,4**								
175	**-20,7**								
200	**-20,7**								
250	**-20**								
300	**-19,5**								

E/D (dB) ratio for several advance times and negative frequency shifts.

DVB-T (3/4; 1/16; 8K)

Table 2g - Pre Echo $\Delta f > 0$

Advance Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1		**-0,6**	**-1**			**-1,4**	**-6**	**-11,3**	
3		**-0,6**	**-1**			**-1,6**	**-5,9**	**-11,3**	
5		**-1,4**	**-1**			**-1,6**	**-6,1**	**-11,5**	
25		**-4,7**	**-4,7**			**-4,8**	**-7,3**	**-11,6**	
50		**-10,7**	**-10,5**			**-10,3**	**-11,5**	**-13,4**	
75		**-15,3**	**-14,8**			**-15,1**	**-15,3**	**-16**	
100		**-17,5**	**-17,4**			**-18,4**	**-18,1**	**-17,9**	
125		**-19,2**	**-18,8**			**-19,4**	**-19,3**	**-19,3**	
150		**-19,9**	**-20**			**-20,4**	**-20,5**	**-20,2**	
175		**-20,5**	**-20**			**-21,2**	**-21,1**	**-21**	
200		**-20,7**	**-20,5**			**-21,3**	**-21,5**	**-21,2**	
250		**-20,1**	**-20,3**			**-20,9**	**-20,5**	**-20,6**	
300		**-19,9**	**-19,7**			**-19,9**	**-20,1**	**-20,2**	

E/D (dB) ratio for several advance times and positive frequency shifts.

DVB-T (3/4; 1/16; 8K)

Table 2h - Pre ehco $\Delta f < 0$

Advance $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1		-0,7							
3		-0,7							
5		-0,9							
25		-4,9							
50		-10,8							
75		-14,6							
100		-17,6							
125		-19,1							
150		-19,9							
175		-20,5							
200		-20,6							
250		-20,1							
300		-19,8							

E/D (dB) ratio for several advance times and negative frequency shifts.

ISDB (3/4; 1/16; Mode 1 (2K); INT 4 (0,1s))

Table 3a - Post Echo $\Delta f > 0$

Delay $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1			**-0,9**			**-3,7**			
3			**-1,0**			**-3,7**			
5			**-1,2**			**-3,7**			
25			**-1,0**			**-3,7**			
50			**-1,0**			**-4,1**			
75			**-1,0**			**-4,8**			
100			**-1,2**			**-6,1**			
125			**-1,3**			**-7,9**			
150			**-1,7**			**-9,8**			
175			**-2,5**			**-11,6**			
200			**-3,2**			**-13,1**			
250			**-5,3**			**-15,7**			
300			**-8,0**			**-17,7**			

E/D (dB) ratio for several delay times and positive frequency shifts.

ISDB (3/4; 1/16; Mode 1 (2K); INT 4 (0,1s))

Table 3b - Post Echo $\Delta f < 0$

Delay $\Delta t(\mu s)$ / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1			-1,0						
3			-1,0						
5			-1,1						
25			-1,0						
50			-1,2						
75			-1,1						
100			-1,2						
125			-1,3						
150			-1,8						
175			-2,7						
200			-3,2						
250			-5,3						
300			-8,1						

E/D (dB) ratio for several delay times and negative frequency shifts.

ISDB (3/4; 1/16; Mode 1 (2K); INT 4 (0,1s))

Table 3c - Pre Echo Δf > 0

Advance Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1			-4,6			-10,2			
3			-4,6			-10,2			
5			-4,6			-10,2			
25			-4,6			-10,1			
50			-4,8			-10,2			
75			-4,8			-10,3			
100			-4,8			-10,5			
125			-4,9			-11,1			
150			-5,2			-12			
175			-5,7			-13			
200			-6,1			-14,1			
250			-7,3			-15,9			
300			-9,1			-17,6			

E/D (dB) ratio for several advance times and positive frequency shifts.

ISDB (3/4; 1/16; Mode 1 (2K); INT 4 (0,1s))

Table 3d - Pre Echo $\Delta f < 0$

Advance $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1			-4,6						
3			-4,6						
5			-4,7						
25			-4,6						
50			-4,7						
75			-4,7						
100			-4,8						
125			-4,9						
150			-5,2						
175			-5,7						
200			-6,1						
250			-7,3						
300			-9,1						

E/D (dB) ratio for several advance times and negative frequency shifts.

ISDB (3/4; 1/16; Mode 2 (4K); INT 2 (0,1s))

Table 3e - Post Echo Δf > 0

Delay Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1	-0,9				-1			-20	
3	-1				-1,1			-20	
5	-0,9				-1			-20	
25	-1				-1,1			-20	
50	-1,2				-1,2			-19,9	
75	-1,9				-1,8			-19,7	
100	-3,2				-3,2			-19,4	
125	-5,1				-5,8			-19,2	
150	-8				-8,4			-19	
175	-10,5				-10,8			-18,9	
200	-12,5				-12,7			-18,7	
250	-15,4				-15,6			-18,6	
300	-17,6				-17,6			-18,6	

E/D (dB) ratio for several delay times and positive frequency shifts.

ISDB (3/4; 1/16; Mode 2 (4K); INT 2 (0,1s))

Table 3f - Post Echo Δf < 0

Delay Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1	**-1**								
3	**-1**								
5	**-0,9**								
25	**-1**								
50	**-1,2**								
75	**-1,8**								
100	**-3,2**								
125	**-5,1**								
150	**-7,9**								
175	**-10,4**								
200	**-12,5**								
250	**-15,4**								
300	**-17,6**								

E/D (dB) ratio for several delay times and negative frequency shifts.

ISDB (3/4; 1/16; Mode 2 (4K); INT 2 (0,1s))

Table 3g - Pre Echo Δf > 0

Advance Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1	-0,9		-1,2	-4,3	-7,4			-20	
3	-0,9		-1,2	-4,3	-7,4			-20	
5	-0,9		-1,3	-4,3	-7,4			-20	
25	-1		-1,3	-4,4	-7,3			-19,9	
50	-1,2		-1,9	-4,6	-7,4			-19,8	
75	-1,8		-2,5	-5,1	-7,6			-19,6	
100	-3,2		-3,7	-6	-8,1			-19,4	
125	-5,1		-5,6	-7,2	-9,1			-19,2	
150	-7,9		-8,2	-9,1	-10,4			-19	
175	-10,5		-10,7	-11,1	-11,9			-18,9	
200	-12,5		-12,6	-12,9	-13,4			-18,8	
250	-15,4		-15,5	-15,6	-15,8			-18,7	
300	-17,6		-17,6	-17,6	-17,7			-18,9	

E/D (dB) ratio for several advance times and positive frequency shifts.

ISDB (3/4; 1/16; Mode 2 (4K); INT 2 (0,1s))

Table 3h - Pre Echo ∆f < 0

Advance ∆t(µs) / Frequency Shift ∆f(Hz)	1	2	4	8	16	32	64	128	170
1	**-1**								
3	**-0,9**								
5	**-1**								
25	**-1**								
50	**-1,2**								
75	**-1,8**								
100	**-3,2**								
125	**-5,1**								
150	**-7,9**								
175	**-10,4**								
200	**-12,5**								
250	**-15,4**								
300	**-17,6**								

E/D (dB) ratio for several advance times and negative frequency shifts.

ISDB (3/4; 1/16; Mode 3 (8K); INT 1 (0,1s))

Table 3i - Post Echo Δf > 0

Delay Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1			**-0,9**				**-11**		
3			**-0,9**				**-11**		
5			**-1,0**				**-11**		
25			**-1,2**				**-11**		
50			**-3,3**				**-11**		
75			**-8,0**				**-11**		
100			**-12,5**				**-11,3**		
125			**-15,5**				**-11,7**		
150			**-17,5**				**-12,5**		
175			**-18,9**				**-13,5**		
200			**-19,7**				**-14,3**		
250			**-19,9**				**-16,2**		
300			**-19,0**				**-17,8**		

E/D (dB) ratio for several delay times and positive frequency shifts.

ISDB (3/4; 1/16; Mode 3 (8K); INT 1 (0,1s))

Table 3j - Post Echo $\Delta f < 0$

Delay $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1			**-1,0**						
3			**-0,9**						
5			**-1,0**						
25			**-1,3**						
50			**-3,3**						
75			**-7,8**						
100			**-12,3**						
125			**-15,3**						
150			**-17,5**						
175			**-18,9**						
200			**-19,7**						
250			**-19,9**						
300			**-19,0**						

E/D (dB) ratio for several delay times and negative frequency shifts.

ISDB (3/4; 1/16; Mode 3 (8K); INT 1 (0,1s))

Table 3k - Pre Echo $\Delta f > 0$

Advance $\Delta t(\mu s)$ / Frequency Shift $\Delta f(Hz)$	1	2	4	8	16	32	64	128	170
1			-0,9				-13		
3			-0,9				-13		
5			-1,0				-13		
25			-1,2				-13		
50			-3,3				-12,9		
75			-7,9				-12,9		
100			-12,3				-13		
125			-15,3				-13,3		
150			-17,5				-13,8		
175			-18,9				-14,4		
200			-19,7				-15,2		
250			-19,8				-16,5		
300			-19,0				-18		

E/D (dB) ratio for several advance times and positive frequency shifts.

ISDB (3/4; 1/16; Mode 3 (8K); INT 1 (0,1s))

Table 3l - Pre Echo Δf < 0

Advance Δt(μs) / Frequency Shift Δf(Hz)	1	2	4	8	16	32	64	128	170
1			-0,9						
3			-0,9						
5			-0,9						
25			-1,2						
50			-3,3						
75			-7,9						
100			-12,2						
125			-15,3						
150			-17,4						
175			-18,9						
200			-19,7						
250			-19,8						
300			-19,0						

E/D (dB) ratio for several advance times and negative frequency shifts.

Figure 6.8.1 - Signal to echo ratio vs frequency offset
ATSC - Zenith - Post Echo

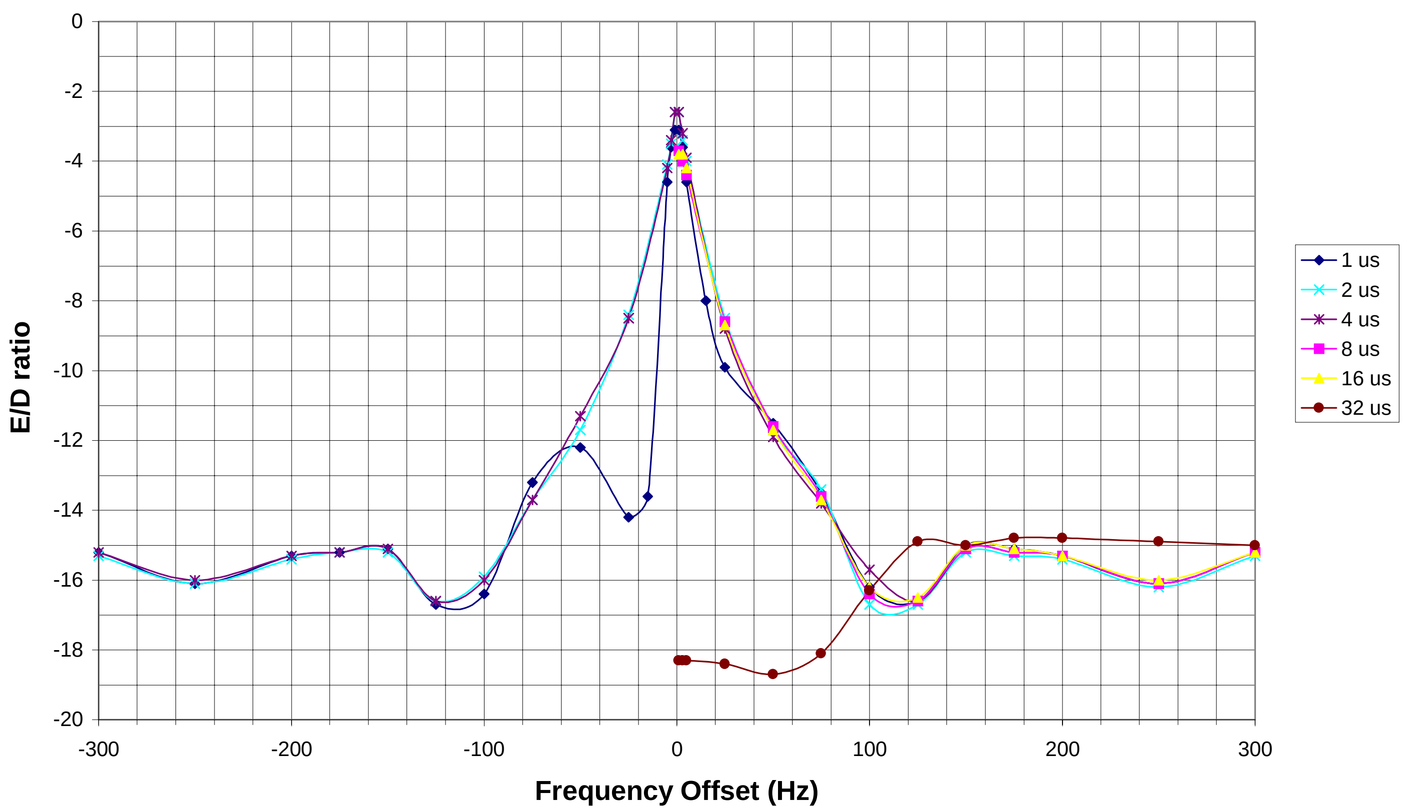


Figure 6.8.2 - Signal to echo ratio vs frequency offset
ATSC - Zenith - Pre Echo

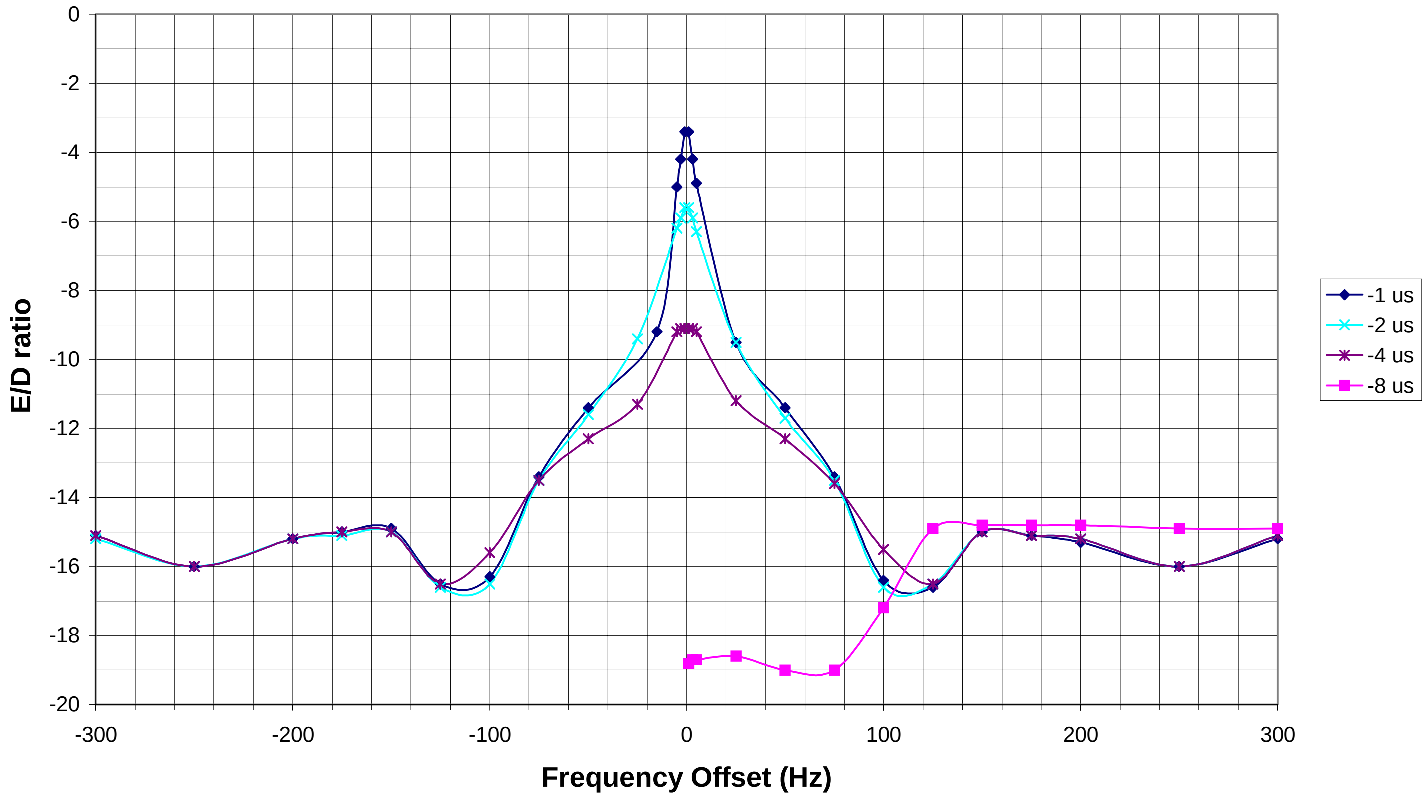


Figure 6.8.3 - Signal to echo ratio vs frequency offset
DVB-T (FEC3/4 GI1/16 2K) - Post Echo

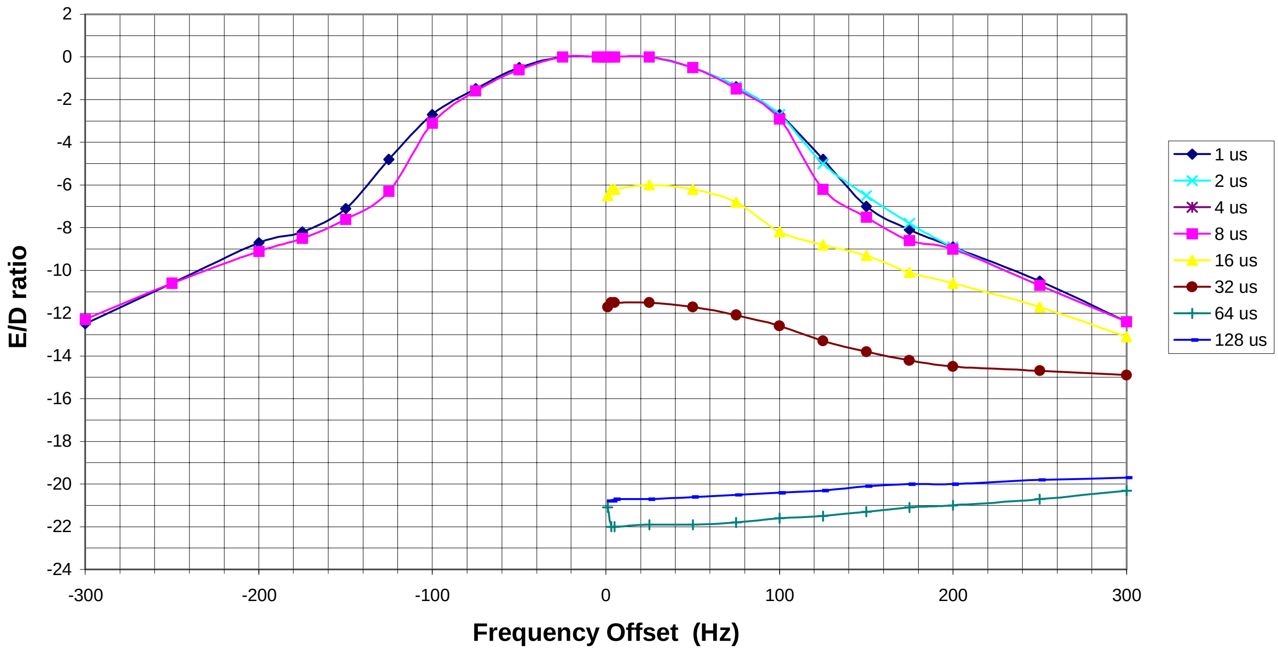


Figure 6.8.4 - Signal to echo ratio vs frequency offset
DVB-T (FEC3/4 GI1/16 2K) - Pre Echo

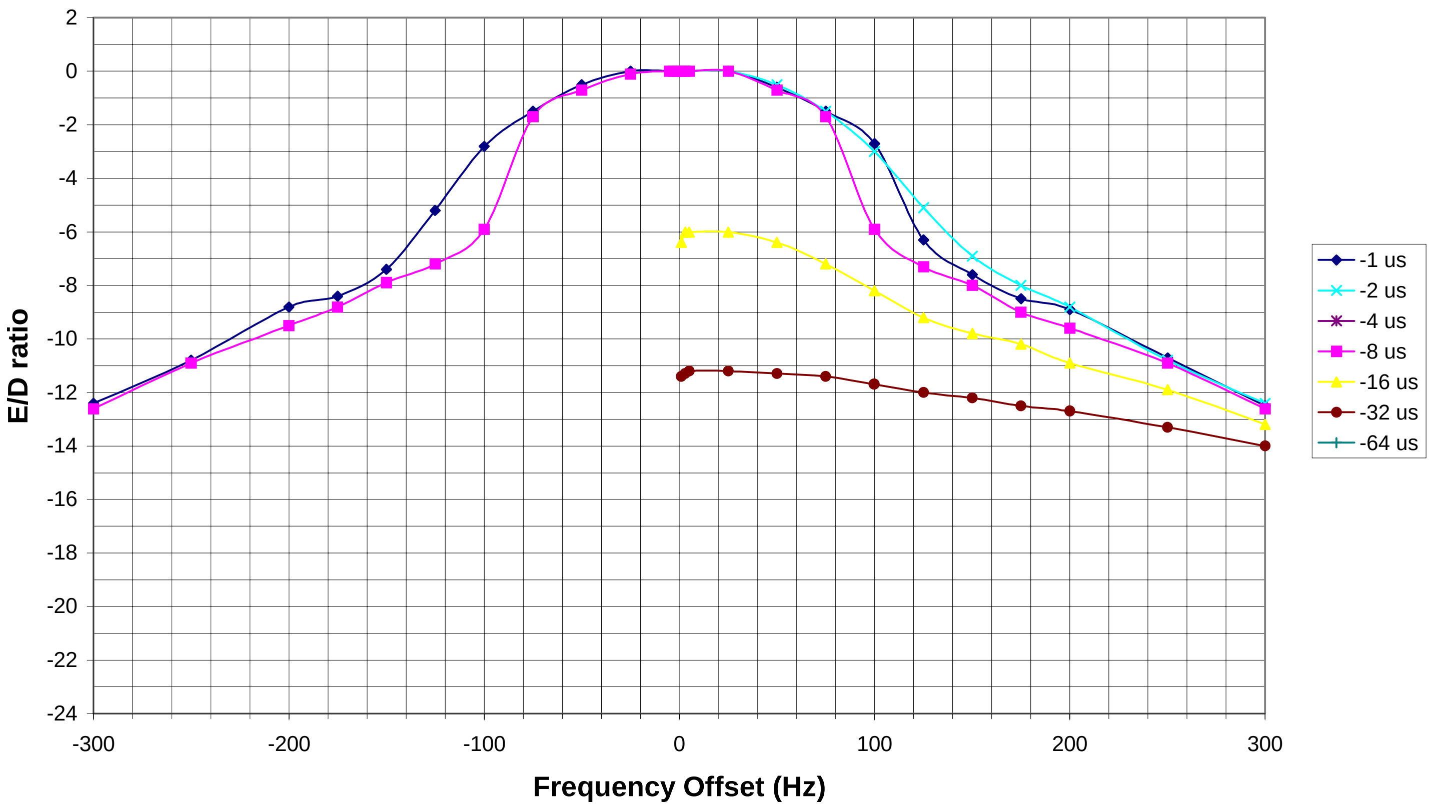


Figure 6.8.5 - Signal to echo ratio vs frequency offset DVB-T (FEC3/4 GI1/16 8K) - Post Echo

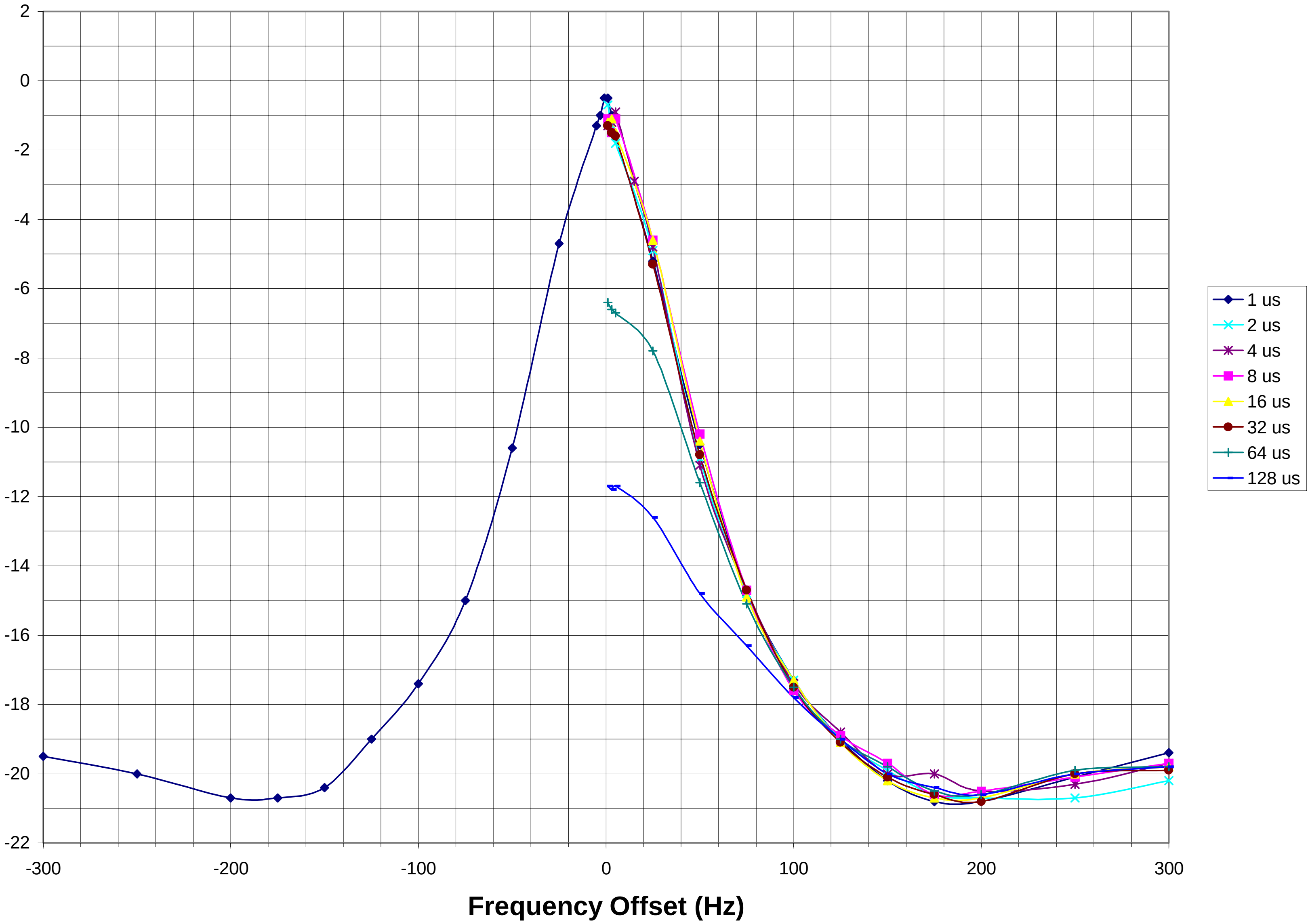


Figure 6.8.6 - Signal to echo ratio vs frequency offset DVB-T (FEC3/4 GI1/16 8K) - Pre Echo

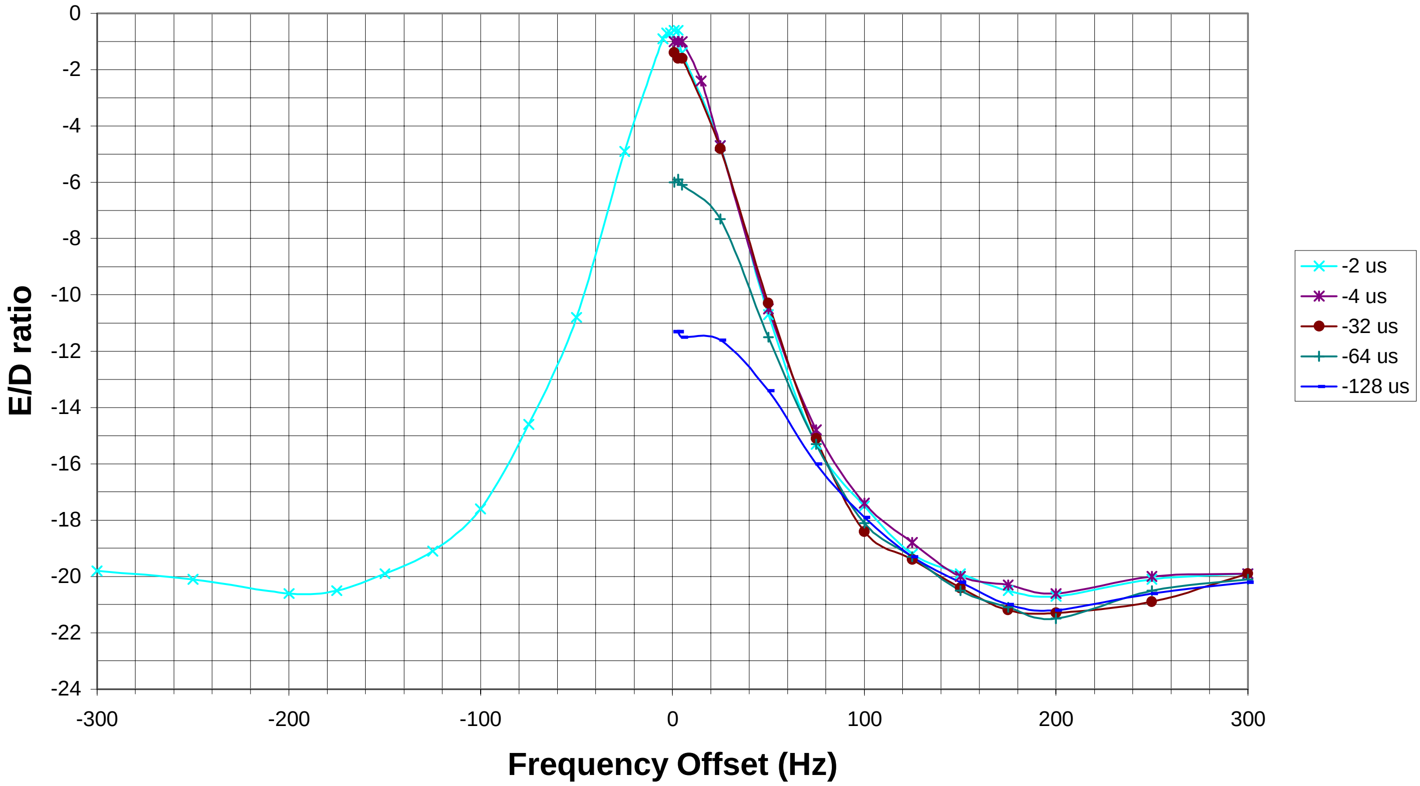


Figure 6.8.7 - Signal to echo ratio vs frequency offset
ISDB (64 QAM FEC3/4 GI1/16 - INT0,1s) - Post Echo

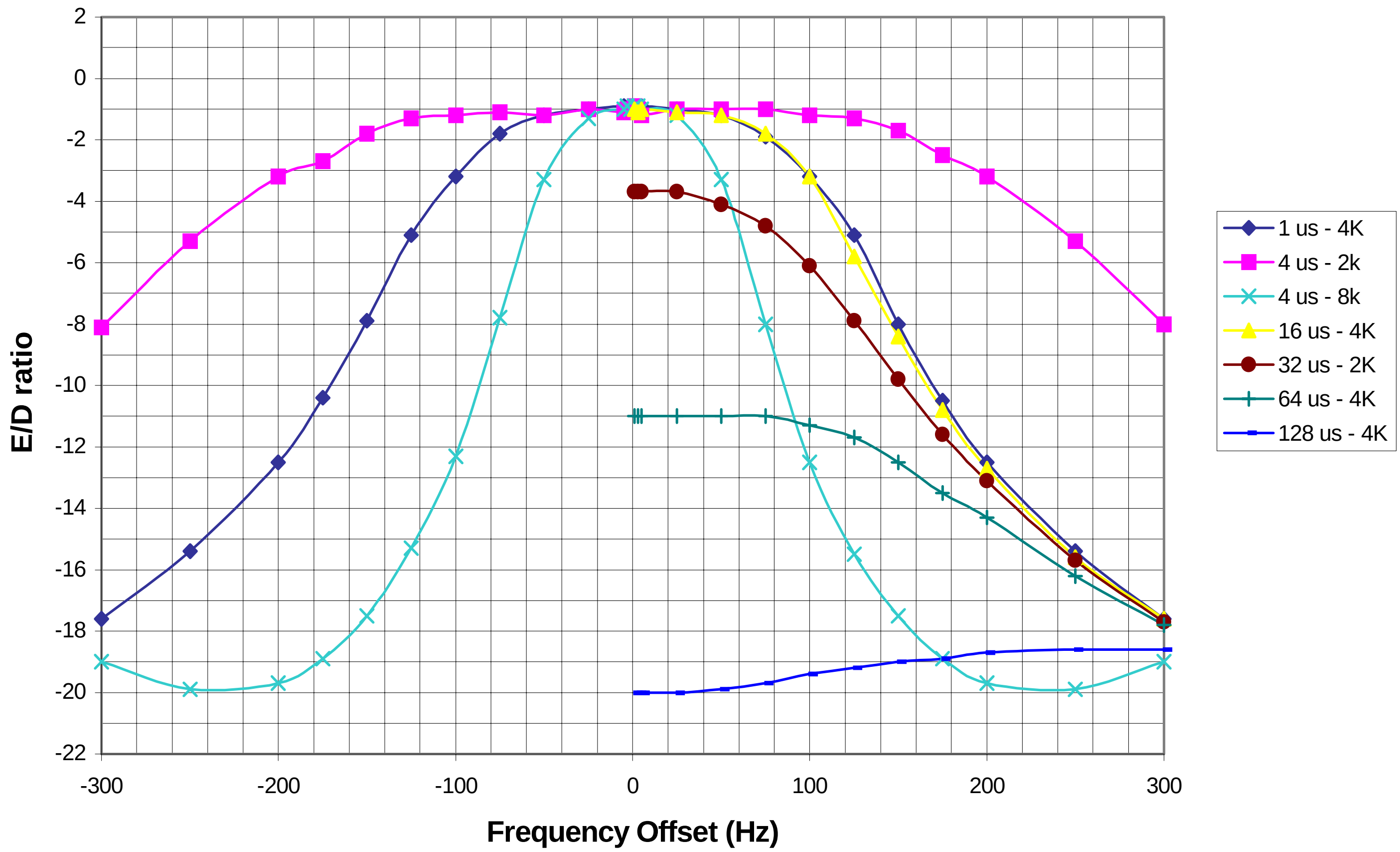


Figure 6.8.8 - Signal to echo ratio vs frequency offset
ISDB (64 QAM FEC3/4 GI1/16 INT 0,1s) - Pre Echo

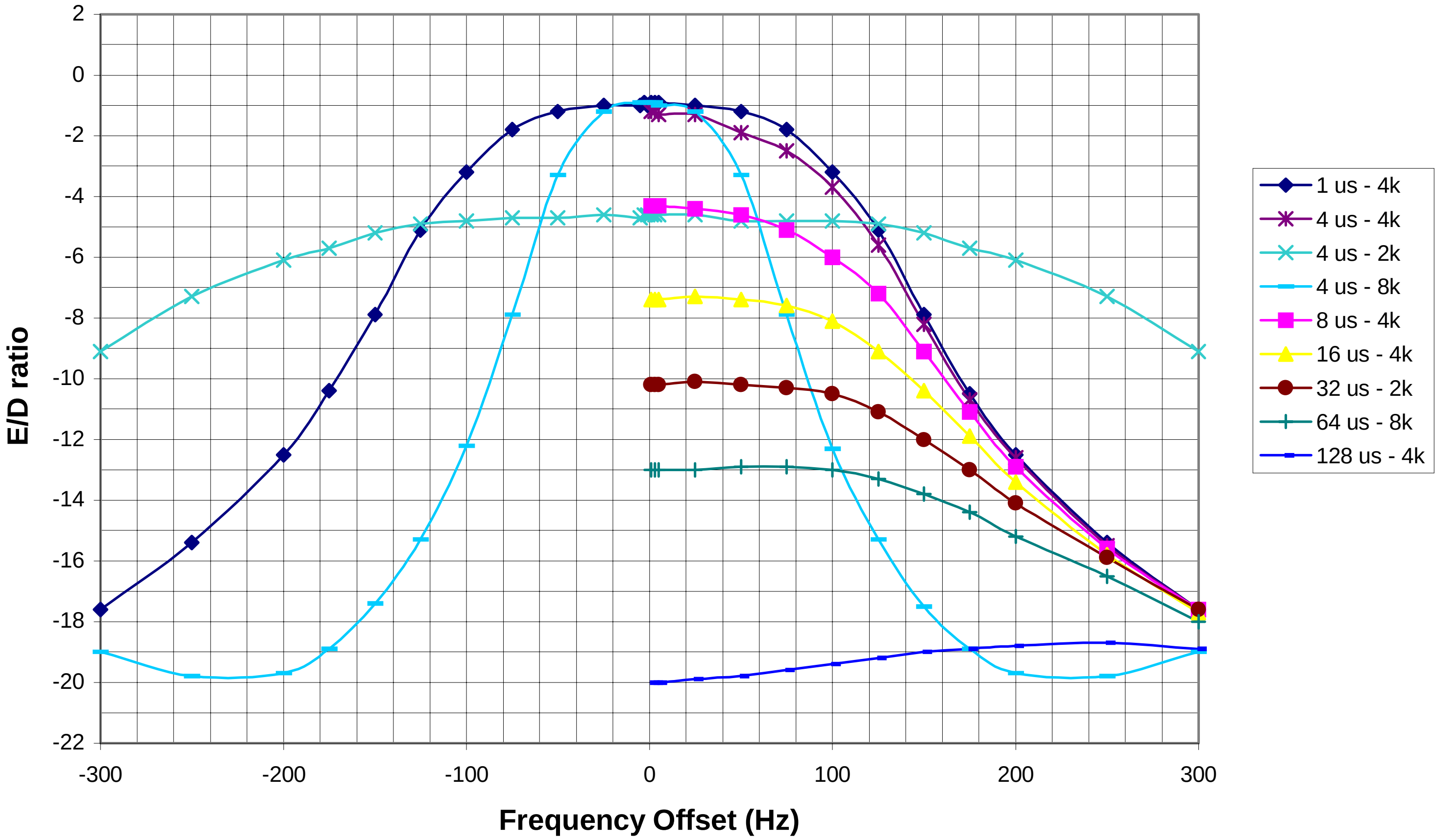


Figure 6.8.9 - Signal to echo ratio vs frequency offset
Comparison - Post Echo = 16 us

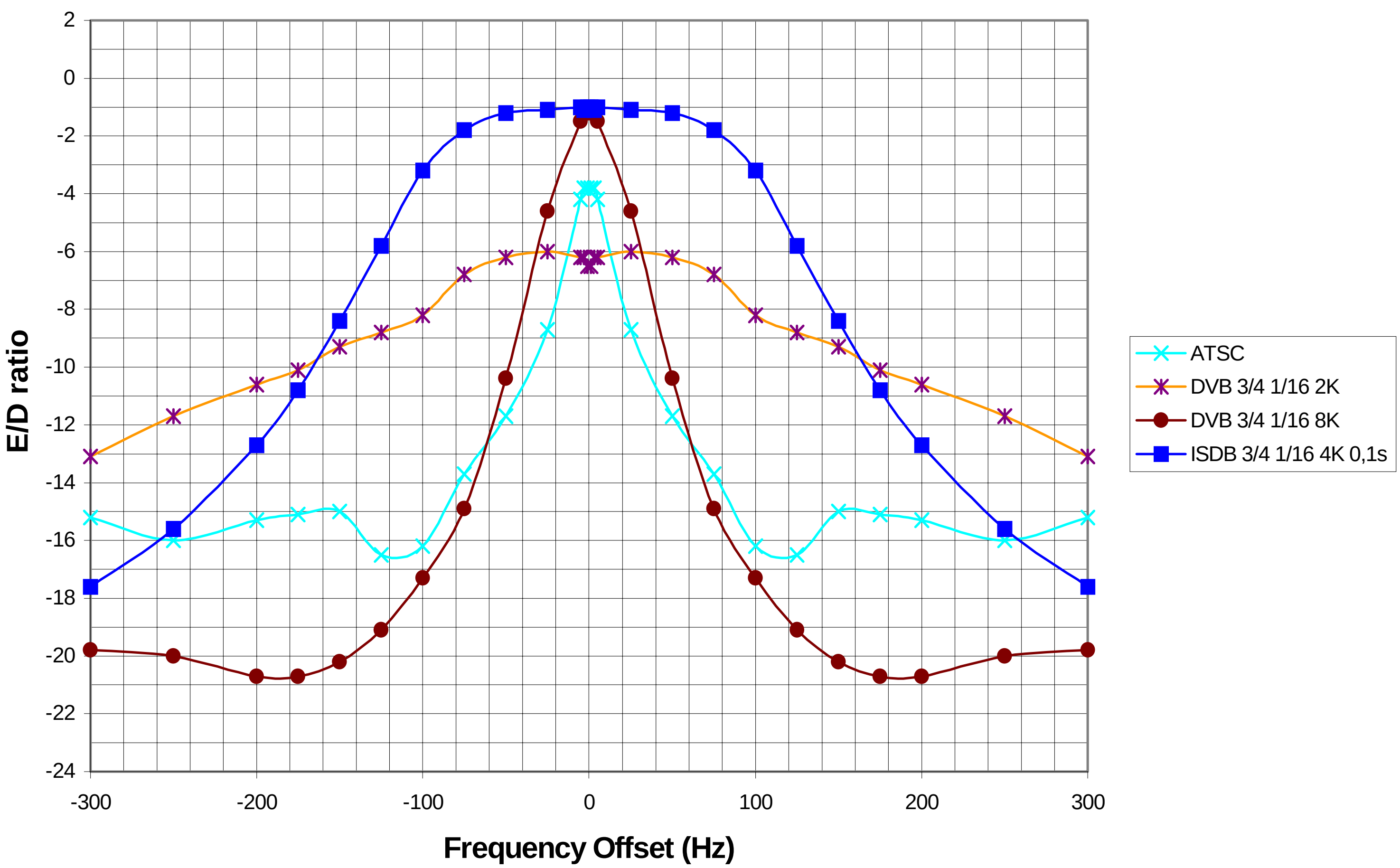
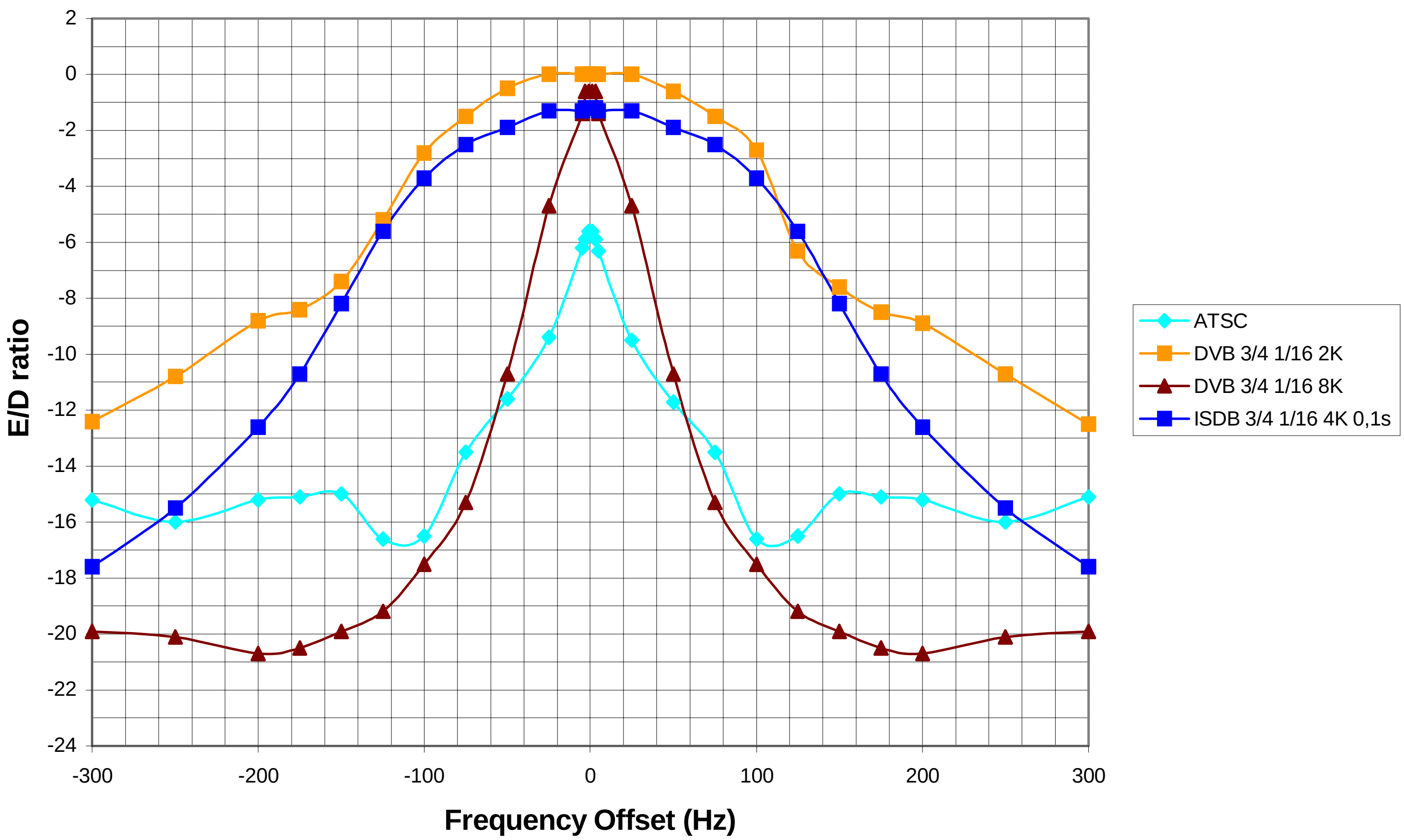


Figure 6.8.10 - Signal to echo ratio vs frequency offset
Comparison - Pre Echo=-2us



Chapter III – General Description of Field Tests

A) Coverage field trials for comparison in performance between the ATSC, DVB-T and ISDB-T systems

A1. Aim

This test aims to compare the performance between the ATSC, DVB-T and ISDB-T systems.
Therefore for this test a 5 kW (average power) digital transmitter tuned to channel 34 and operating with 2.5 kW average power was used. It operated with ATSC, DVB and ISDB modulators.

A 1 kW (peak power) PAL-M transmitter was also used operating in the same channel as the digital transmitter, serving as a reference to recognize possible problems with the received image in each test point.

To enhance the coverage evaluation, in all the test points field strength measurements with the following operating analogue channels were taken as well as the observation of their image quality:

- Low VHF: TV Cultura, channel 2, installed on the same site (see attachment 1).
- High VHF: TV Bandeirantes, channel 13, near site (see attachment 1).
- UHF: MTV, channel 32, near site, high power (see attachment 1).

A2. Choice of measurement points

In the field trial being carried out in Sao Paulo, the radiating system is installed on the TV Cultura Tower, channel 2, located in Sumare. A directive radiating pattern antenna has been used, comprising of a slot antenna, with its maximum radiation pattern turned to 117° ETN.

Measurements were planned to be taken at the intersection points between circles varying from 3 to 40 km and from 0° to 220° ETN, which is the aperture of the antenna radiation pattern, in steps of 15°. In each radial, a step of 3 km were planned to be used for $d \leq 15$ km and of 5 km for $15 < d \leq 40$ km.

The attached map illustrates the points where the measurements were effectively taken (attachment 2). During the tests, the number of points were reduced when verified recurrence of tests results or difficulties on accessing the points.

The measurements were carried out by the properly equipped reception test vehicle (see item A6.2).

The estimated signal strength in each test point were obtained from the propagation calculation methodology included in the Rules approved by the Ministry of Communications.

A3. Basic parameter characteristics:

- Field strength in dBμV/m
- Error margin in dB
- Noise power in the receiver bandwidth in dBm
- Signal-to-noise ratio (C/N) in dB

A4. General description

With the reception test vehicle's antenna directed to the highest signal level and the lowest multipath degradation, adjust the attenuator existing inside the reception test vehicle so that the receiver input power level is of –30 dBm (average for ATSC, DVB-T and ISDB-T receivers). Notice that if the -30 dBm value in the receiver input is not obtained, lower values can be used but never lower than -50 dBm to make the effect of the noise figures of the amplification and attenuation system and of the receiver as low as possible. Subsequently, record the electric field strength existing in the antenna position obtained through the indirect measurement made at the receiver input.

For the case of the PAL-M receiver, analyze the image quality: presence of white noise, interfering noise, ghosting, Doppler effect, impulsive noise etc, specifying them on the column "observations" of the result sheet.

As for the ATSC, DVB-T and ISDB-T receivers, add white noise until the image reaches the LOP (limit of perceptibility). Record the "added noise" in dB: this will define the "relative error margin".

Subjectively evaluate the PAL-M reception.

Also evaluate the reception condition of channels 2, 13 and 32.

A5. The equipment used

A5.1 - Transmitting station

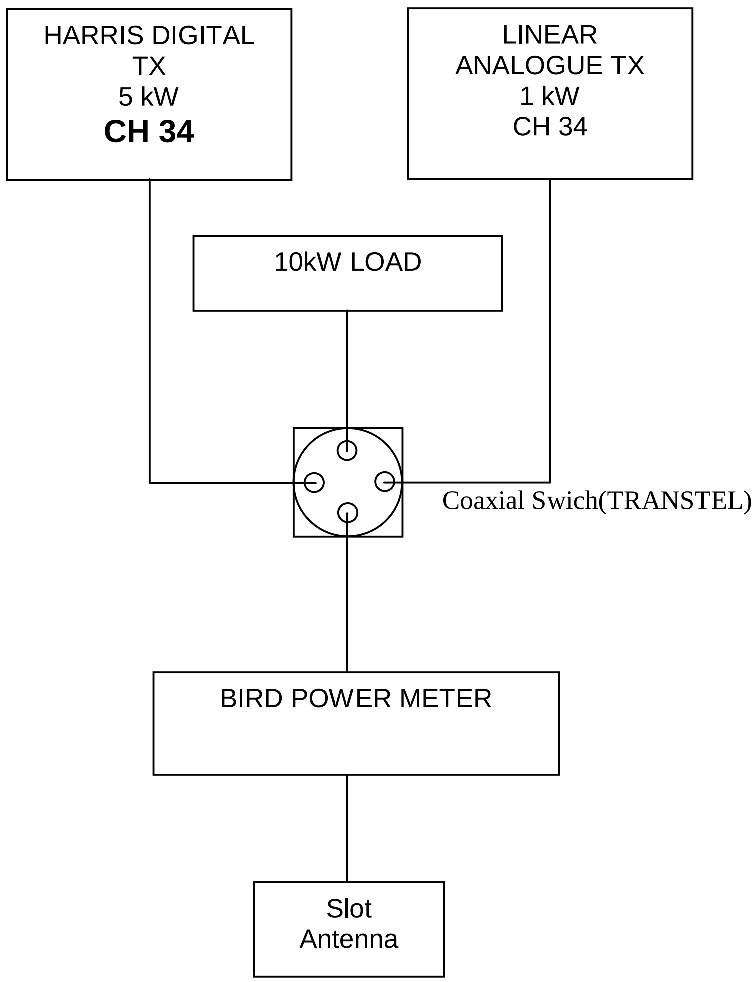
- 5 kW average power (operating with 2.5 kW) Harris digital transmitter, tuned to channel 34, with modulators for the three systems (ATSC, DVB-T and ISDB-T).
- 1kW (peak power) Linear analogue transmitter, tuned to channel 34, with PAL-M modulation
- Slot antenna (Transtel), standard Q, 220° coverage, model TTSLUQ. Radiation pattern as shown in attachments 4 (theoretical) and 5 (measured)
- 10 kW 50 Ohm load coupled to the coaxial switch
- Bird power meter
- Automatic coaxial switch
- 3 grounding-connection kits
- 130 m of 1' 5/8” cable with EIA connectors
- Cable ties
- MTS 210 stream player with Zone Plate image
- Network analyzer
- PAL-M color bar video signal generator PAL-M

A5.2 - Reception test vehicle

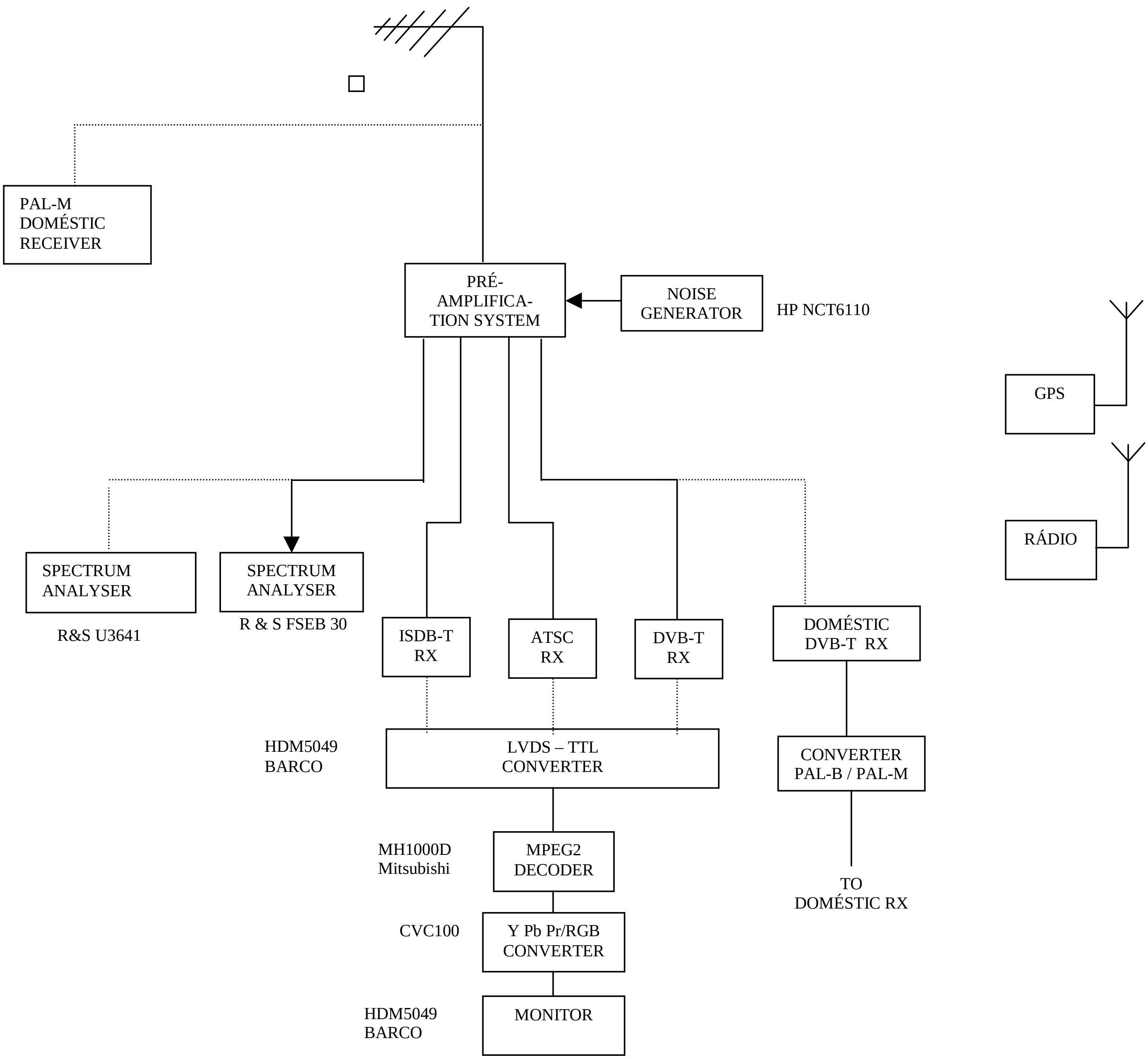
- Vehicle model Sprinter (Mercedes)
- R&S standard receiving antenna, model CBL 6111C
- Zenith system of amplifiers and attenuators
- HP NCT6110 noise generator
- HP 8447E amplifier
- R&S spectrum analyzer
- R&S U3641 spectrum analyzer
- MH1000D Mitsubishi MPEG2 decoder
- SPI (LVDS0 converter – TTL Nucomm GA Interface
- Philips PAL-M TV receiver
- 2:1 symmetric splitter
- NDS System 3000 DVB-T receiver
- Zenith ATSC receiver
- NEC ISDB-T receiver
- HDM 5049 Barco HDTV monitor
- Garmin GPS
- NEXTEL trunking system
- CVC100 YPbPr – RGB converter
- UHF domestic receiving antenna
- NOKIA DVB domestic receiver

A6. Measurement block diagrams

A6.1 – RF interconnection scheme for of digital signal comparison tests



A 6.2.– Reception test vehicle “lay out”



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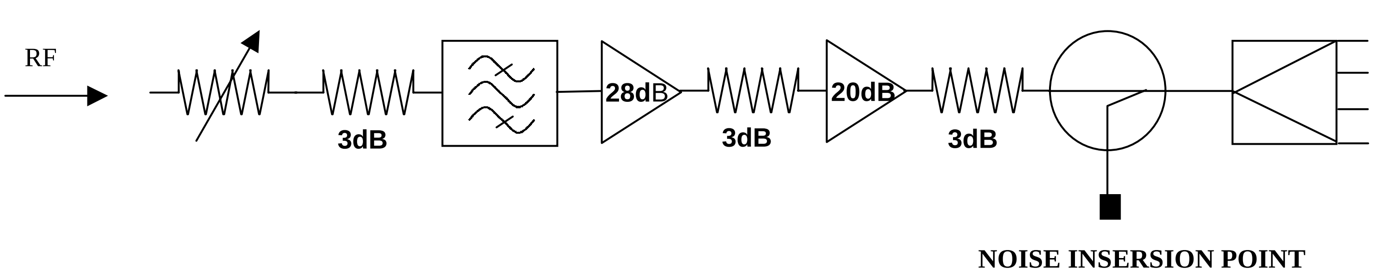
A6.2 a - Scheme of the ampflification & attenuation box



A7. Calibration, test and measurement procedures

A7.1 - Necessary procedures in the reception system prior to field trials.

Calculate and measure all gains and losses in the RF signal path (antennae, attenuators, cables, filters, etc). Particularly determine the allowed limits for the operation of Zenith amplifier and attenuator system, evaluating stability and levels that cause distortion by intermodulation (1 dB compression point).

A7.2 - Calibration to be carried out every morning (with vehicle nearby the transmitting station).

A7.2.1 - Measure the power at the transmitter outputs (analogue and digital in all systems).

A7.2.2 - For each system, vary the attenuators in the vehicle to obtain a –30 dBm level at the input of it respective receiver (reference value). Record the readings.

A7.2.3 - Measure the characteristics of the noise generated by the reception test vehicle in the appropriate bandwidth.

A7.2.4 - Save the spectrum analysis result of each system.

A7.3 - General procedures to be carried out in all the locations (points) prior to the measurements.

A7.3.1 - Raise the antenna 10m above the ground, avoiding any obstruction: trees, buildings, power cables, etc.

A7.3.2 - If the location is not satisfactory, move the vehicle to the nearest acceptable place.

A7.3.3 - Adjust the receiving antenna to the direction of the highest signal level and the lowest multipath degradation.

A7.3.4 - With the transmitters turned off and the attenuators of the attenuation and amplification system in such a position that –30 dBm is obtained at the receiver input, verify the interfering signals in the channel band.

A7.3.5 - Turn the transmitters on.

A7.4 – Test procedures adopted at each location.

Always when any signal level instability was noticed it was recorded the minimum, maximum and average figure and the **********

A7.3.6 - Vary the receiving antenna height from 10 to 8m and note if there is a significant signal variation. If there is significant signal variation, find another near location where this does not occur.

A7.3.7 - By using the GPS, determine and record the location geographical co-ordinates, as well as the date, description of location and weather conditions, plus any other relevant observation.

A7.3.8 - Vary 360° the direction of the receiving antenna, noting the situation of highest field strength.

A7.3.9 - If the direction of maximum field strength is not the same as the transmitting station direction, carry out the measurements for this new direction and record the probable reasons at the observation column.

A7.4 - Measurement procedures to be carried out at each location.

Every time an instability of the signal level is noticed, the min, max, and average values as well as the standard deviation corresponding to a 10 minutes interval should be recorded.

A7.4.1 - Measurements for PAL-M channel (34).

A7.4.1.1 - At the transmitting station, turn on the coaxial switch for transmitting the PAL-M signal on channel 34.

A7.4.1.2 - Carry out the subjective analysis of video and audio using two observers, noting in particular the presence of white noise, interfering noise, ghosting and Doppler effect. Describe the problem with detail when necessary. Record in the field test result sheet the grade concerning the subjective evaluation.

A7.4.1.3 – Measure the analogue signal level for video carrier peak power.

A7.4.1.4 – Repeat the above procedure for all analogue channels that are being evaluated.

A7.4.1.5 - At the transmitting station take the PAL-M channel off air.

A7.4.2 - Measurements for channel 34 – ATSC.

A7.4.2.1 - At the transmitting station, turn the digital transmitter coaxial switch on to transmit the digital signal, on channel 34. At the digital transmitter change the modulation to the ATSC system.

A7.4.2.2 - Adjust the amplifiers and attenuators so that the ATSC receiver input average power level is of –30 dBm. The power level can be measured by using the spectrum analyzer.

A7.4.2.3 - Record the amplifiers and attenuators readings (item A7.4.2.2) and calculate the field strength in dBuV/m and the signal level in dBm at the input of the cable connected to the antenna.

A7.4.2.4 - Save the signal spectrum using the spectrum analyzer, carrying out the analysis within a 20 MHz bandwidth with steps of 10 dB per division and observing the existence of interfering signals in the neighbouring of the channel.

A7.4.2.5 - Save the ATSC signal spectrum within a 6 MHz bandwidth with steps of 1 dB per division.

A7.4.2.6 - Add white noise in 0.1 dB steps until the threshold of perceptibility (TOP) is reached. Record the “added noise” (in dB) in the 6 MHz bandwidth. This number will be used to calculate the signal to noise ratio (C/N)dB at TOP in the location conditions.

A7.4.2.7 - At the transmitting station, take the ATSC channel off air.

A7.4.2.8 - Measure the system noise under the conditions of A7.4.2.7 using the spectrum analyzer. Record the average noise power within the channel bandwidth.

A7.4.2.9 - Calculate the signal-to-noise ratio (C/N) by subtracting the result of the item A7.4.2.8 of -30dBm. Record it.

A7.4.3 - Measurements for channel 34 – DVB-T

Repeat all the procedures above described (from item A7.4.2.1 to A7.4.2.9).

The tests should be carried out in the following DVB-T mode:

- Modulation: 64QAM
- Number of carriers: 2K
- Code Rate: ¾

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- Guard Interval: 1/16
- Resulting bit rate: 19.75 Mbps

If DVB-T system does not work with this mode change to a more robust mode:

- Modulation: 64QAM
- Number of carriers: 8K
- Code Rate: 2/3
- Guard Interval: 1/32
- Resulting bit rate: 18.09 Mbps

A7.4.4 – Measurements for channel 34 – ISDB – T:

Repeat all the procedures previously described (from item A7.4.2.1 to A7.4.2.9).

The tests should be carried out in the following ISDB-T mode:

- Modulation: 64QAM
- Number of carriers: 4K
- Code Rate: ¾
- Guard Interval: 1/16
- Interleaver: 0.1 s
- Resulting bit rate: 19.3 Mbps

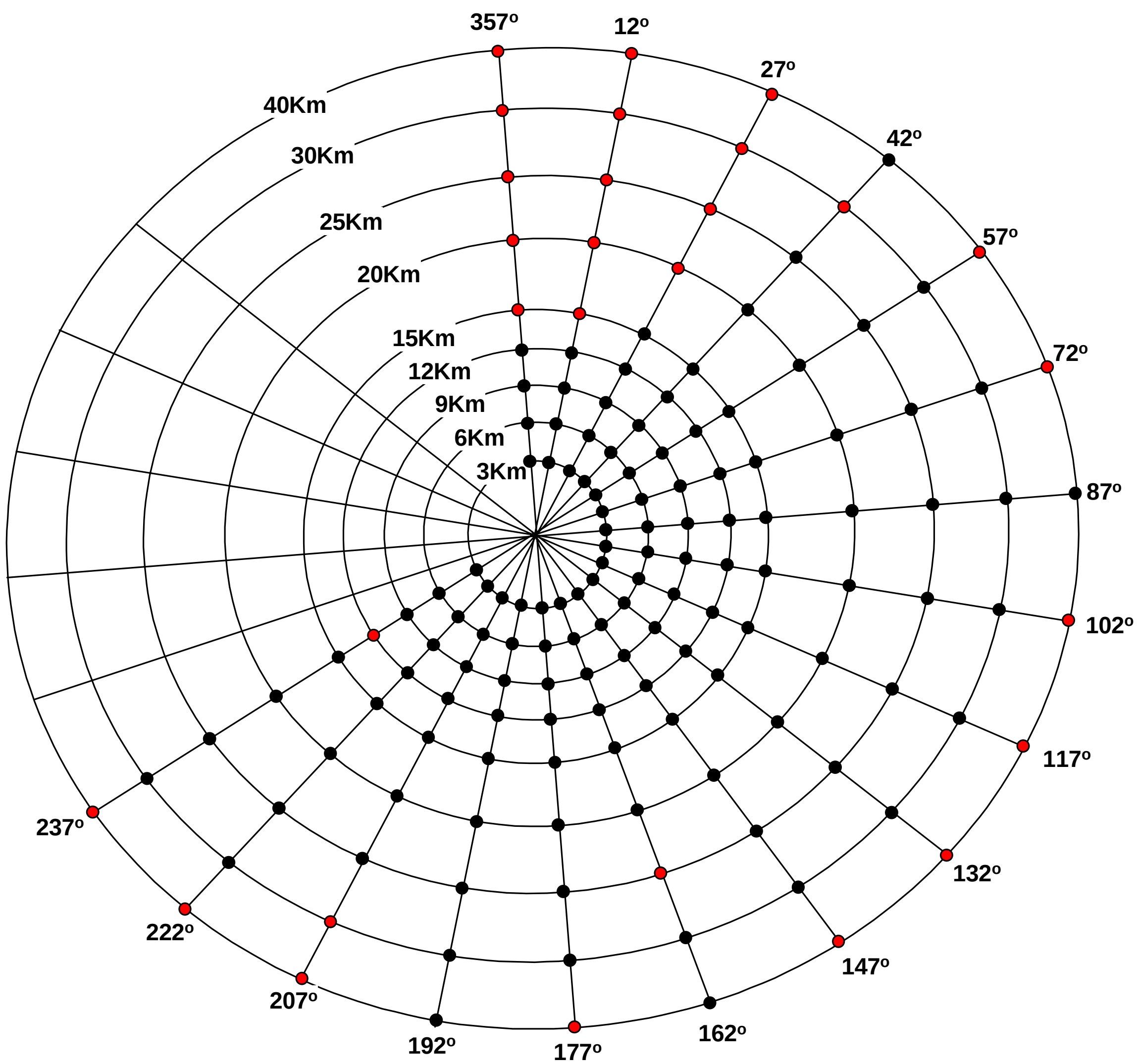
If ISDB-T system does not work with this mode change to a more robust mode:

- Modulation: 64QAM
- Number of carriers: 8K
- Code Rate: 2/3
- Guard Interval: 1/32
- Interleaver: 0.1 s
- Resulting bit rate: 17.7 Mbps

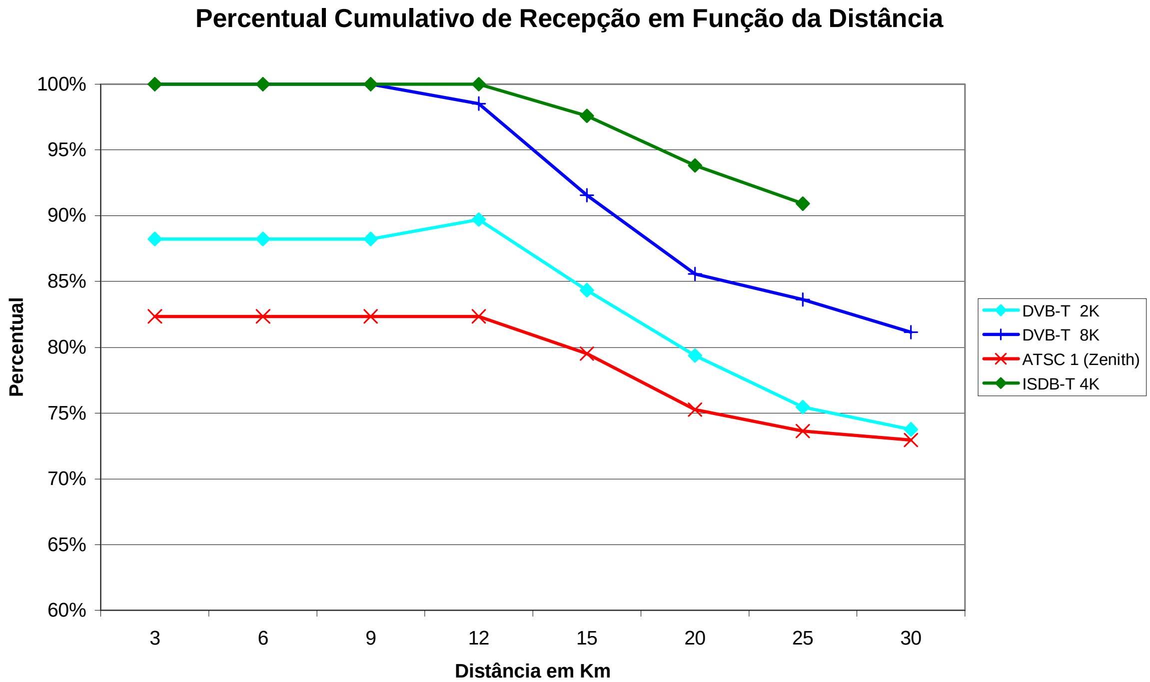
A8 - Tests results

The test result sheet is included in the attachment 6.

A8.1 – From the test point indicated in the item A2, 152 locations were plotted for performing the field tests. After the theoretical coverage calculation using a software and a data base of São Paulo terrain and adpting the already mentioned methodology, it was possible to delete 28 locations where the field strength was lower than 45 dBμV/m.



A8.2 – The figure below indicates the percentage of locations with reception success for each system versus the distance from TV Cultura transmitting antenna.



OBS: Distância – distance
Percentual – percentage

A8.3 – The real situation observed in the field trials at the 127 locations where tests were performed are shown in the table below:

Problem found	Percentage of Locations
Multipath	100%
Impulse Noise	23%
Doppler Effect	2%
Signal Fading	2%
Low Signal Level	15%

Chapter IV – General Considerations

The ATSC, DVB-T and ISDB-T systems have big differences in their development stages. These differences are especially significant when it comes to the implementation of receivers used in the tests.

The ATSC receivers, Zenith made, are units of professional receivers, specially prepared for laboratory tests. On the other hand, the DVB-T receivers are commercially available devices. The only difference is the changes that were made to make it operate with 6 MHz channels. The equipment made available by the ISDB-T has a develop delay. They are all prototypes without the same improvement of the other systems, when it comes to integration. As a consequence, the available receiver has a limited capability of processing and implements simple algorithms, with a wide space for evolution.

The combination of laboratory and field tests allowed to characterize the systems from a detailed analysis of each interference and, at the same time, it evaluate which are the most significant effects in real reception situations; the field evaluation showed that the most important effects are multipath and impulse noise, as explained in table 1, which shows the percentage of places where each interference was considered relevant.

Effect	**Percentage**
Multipath	100%
Impulse Noise	23%
Doppler	2%
Floating	2%
Low Level (30 a 51 dBµV/m)	15%

Table 1: Percentage of spots with interference in real conditions of evaluation

The American system, ATSC, uses 8VSB modulation and was evaluated in the only possible configuration. The European (DVB-T) and Japanese (ISDB-T) systems use COFDM modulation and were tested in several configurations, although all of them with a payload around 19 Mbps, the same used by the American system, so to allow a comparison with resembling bit rates. To both systems, the parameters used are described whenever it is needed.

Chapter V – Result analysis

V-1) Laboratory results

All results discussed bellow were presented in chapters **II** and **III** of this report. At this chapter it is emphasized the important points to differentiate the proposed modulations systems for digital terrestrial television systems.

V-1.1) Interference measures

This item result are directed related to the planning criteria

Only the co-channel interference results were considered relevant, because adjacent channel interference results are extremely dependent of the tuner and filter of the receivers that are in different development stages as commented on chapter **IV**.

Even waiting for further improvements of the systems, if we consider current implementations, channel allocation is possible with all the systems, even in big cities, which offer big planning challenges.

V-1.1.1) Interference of digital into PAL-M system interference (Proceeding 2.1)

Table 2 defines, in each case the protection ratio for digital systems interfered with by analog system, that is the minimum power difference between the desired analog signal and the digital one for good operation.

Channel	ATSC	DVB-T	ISDB-T
Co-channel	37 dB	38 dB	38 dB
Lower adjacent channel	-9 dB	-9 dB	-9 dB
Upper adjacent channel	-7 dB	-7 dB	-7 dB

Table 2: Protection ratios (dB) for PAL-M system interfered with by digital signal

Once all digital modulation schemes have flat spectrum, the protection ratios are similar. There were not observed significant differences between the standards, both for co-channel and adjacent channels protection ratios.

V-1.1.2) Interference of PAL-M into digital systems (Proceeding 2.2)

Protection ratios for digital systems interfered with by analogue television, are described on Table 3.

Channel	ATSC	DVB-T	ISDB-T
Co-channel	4 dB	7 dB	6 dB
Lower adjacent channel	-33 dB	-27 dB	-27 dB
Upper adjacent channel	-40 dB	-32 dB	-28 dB

Table 3: Protection ratios (dB) for PAL-M system interfered with by digital signal

ATSC and ISDB-T standard use a comb filter, designed to minimize the interference of audio and video carriers into the digital signal. This filter improves systems performance in terms of co-channel interference rejection but it degrades carrier-to-noise performance.

This analysis evidences that the observed differences in performance is much more related to the presence of the rejection filter and how it is implemented, than to the kind of the modulation.

The co-channel protection ratio for digital system interfered with by PAL-M system is not very relevant once the required separation between an analogue and a digital station is always determined by the co-channel interference of the digital into the analogue system.

In the case of adjacent interference, as commented on Item **V-1.1**, it is expected a decrease of the difference as the OFDM receivers improve.

V-1.1.3) Interference of Digital into Digital systems (Proceeding 2.3)

Protection ratios for different wanted digital terrestrial television systems interfered with by digital systems are shown on Table 4. Co-channel results are, as expected, very similar to carrier-to-noise threshold once all digital modulation has flat spectrum.

Channel	ATSC	DVB	ISDB
Co-channel	15 dB	20 dB	20 dB
Lower adjacent channel	-27 dB	-26 dB	-25 dB
Upper adjacent channel	-27 dB	-26 dB	-25 dB

Table 4: Protection ratios (dB) for wanted digital terrestrial television systems interfered with by digital system

For this kind of interference, ATSC standard is better than the tested set of parameters chosen to be testes for COFDM modulation. This result is relevant when considering the traditional approach for channel planing.

COFDM modulation was designed to allow alternative ways to cover a designed service area using a cluster of transmitters each one operating with lower power than it would be required in the case of a single transmitter.

This approach con yield better coverage, frequency economy and improve service availability, while maintaining satisfactory level of interference which is important in big cities. This is, however, a very complex and expensive approach.

The observed differences on adjacent channel interference were not considered relevant in this experiment.

V-1.1.4) Interference and noise (Proceeding 2.6 to 2.8)

Measures described on Items 2.6 through 2.8 relate interference level to the minimum carrier-to-noise necessary to have reception with a bit error rate bellow the threshold value. These results are important to the definition of the protection ratio values to be adopted in Brazil but they do not change the conclusions above.

V-1.2) Interference of an FM carrier and Impulse noise

V-1.2.1) Interference of an FM carrier into digital terrestrial television systems (Proceeding 2.4)

Figure 1 is the experimental result of the protection ratio for digital systems interfered with by FM carrier.

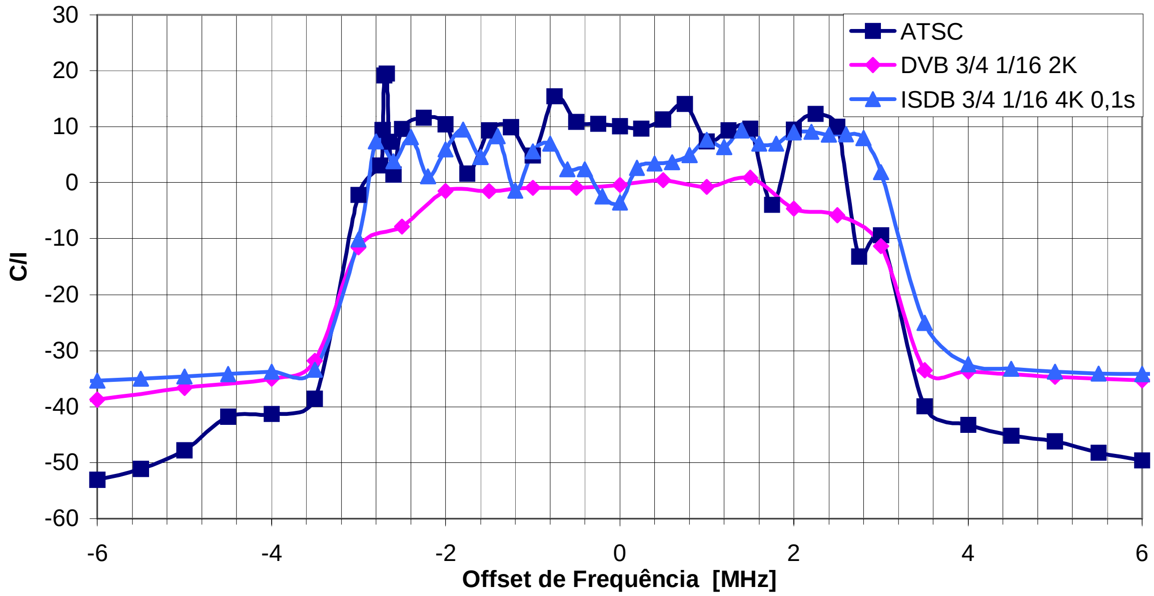


Figure 1: Protection ratio (dB) for digital systems interfered with by FM carrier

It indicates that COFDM modulation performs better for this kind of interference. In spite of its academic interest this measure was not considered very important as a FM dominated environment was not observed on field measurements.

V-1.2.2) Impulse noise measurements (Proceeding 2.5)

Mackenzie University proposed two kinds of experiment and they present similar results. Impulse noise is caused by auto ignition motors, industrial equipment, high voltage power transmission lines and home appliances. In laboratory this effect was simulates through a “simulator device”, which allows the control of the noise intensity. In practical circumstances this effect was considered relevant for about one quarter of the measured points. Simplified results are presented in Figure 2.

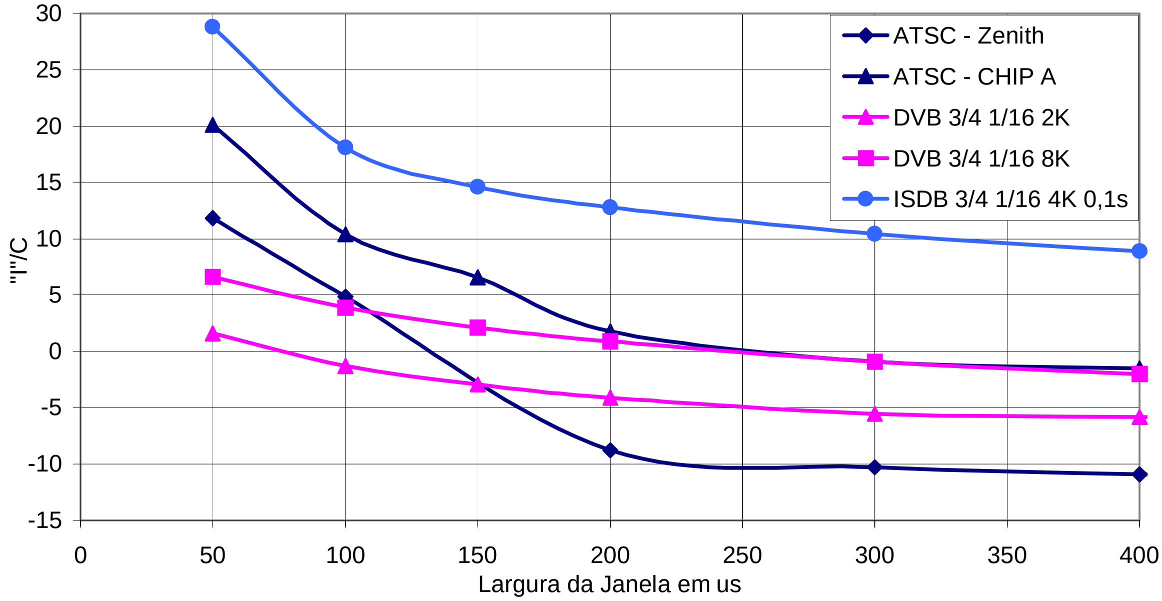


Figure 2: Width of the noise pulse versus the relation noise-to signals (dB)

The above curves show that ATSC new implementation (Chip A) has better performance than Zenith receiver does. Clearly, however, much better receiver immunity to white noise can be achieved with ISDB-T system.

For DVB terrestrial television system, the tested configuration with 8K carriers has better performance than the 2K configuration. In spite of this difference, DVB has the worse performance for impulse noise, result that was also seen in the field tests. It should be noticed the problem is not inherent of the COFDM modulation, once ISDB system presented very good performance by using time interleave.

All systems use some kinds of data interleave. In Japanese standard however, longer interleave is applied to the data. By changing transmission order, continuous portions of the signal are not corrupted and information can be recovered due to the redundancy of the system.

V-1.3) Multipath measurements

Brazilian multipath tests were very complete and conclusive. The available instruments allowed testing a great variety of different delays and frequency shifts. This was an exhaustive experiment because it was considered the most significant effect in real conditions

V-1.3.1) Interference of one multipath (Proceeding 3.1)

Curves of Figure 3 describe the behavior of digital terrestrial television systems in the presence of static multipath. If all the multipath that composes the signal at a certain reception point could be characterized by delay and intensity that are under these curves, than good chances are that the reception at that location is possible.

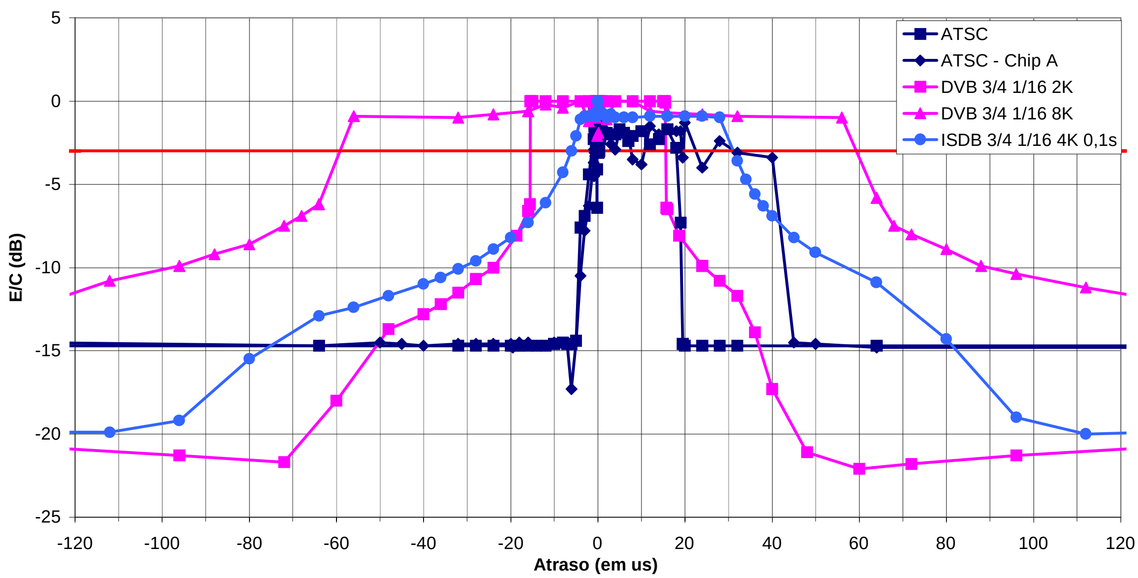


Figure 3: Echo-to-carrier ratio in dB & delay of the echo for threshold of visibility

At Figure 3, a delay of 20µs means that the path of the reflected signal was longer than the direct signal, so that it arrives the reception point 20µs after the main signal. Besides the delay difference, reflected signals can be more or less attenuated at the reflection points. The bigger the delay and the stronger the ghost, more difficult is the reception of the signal.

The performance of the proposed system in different situations of multipath is determined by the type of modulation used. COFDM modulation is better than 8VSB modulation for the different set of parameters tested. The difference is bigger for the set of parameters that uses 8K (eight thousand) carriers, because this set of parameters have good performance for longer ghosts.

For 8VSB modulation, the transition of the region in which strong echoes are accepted to the region in which echoes must be very attenuated is very abrupt.

This behavior is a characteristic of the 8VSB modulation and is determined by the size of the receiver equalizer.

The ISDB-T digital television system has worse performance than DVB-T systems for strong echoes because it was not possible to receive when the signal and the echo have the same amplitude. This performance is due to the simplification made in the available prototype receiver on the algorithm use to calculate the in phase and in quadrature algorithm.

V-1.3.2) Multipath measurements in presence of noise (Proceeding 3.2)

These experiment results allow determining the minimum carrier-to-noise relation in each simulation. Figure 4 show the performance comparison between the systems in a situation where the reflected signal is delayed by 2 μs in relation to the main signal.

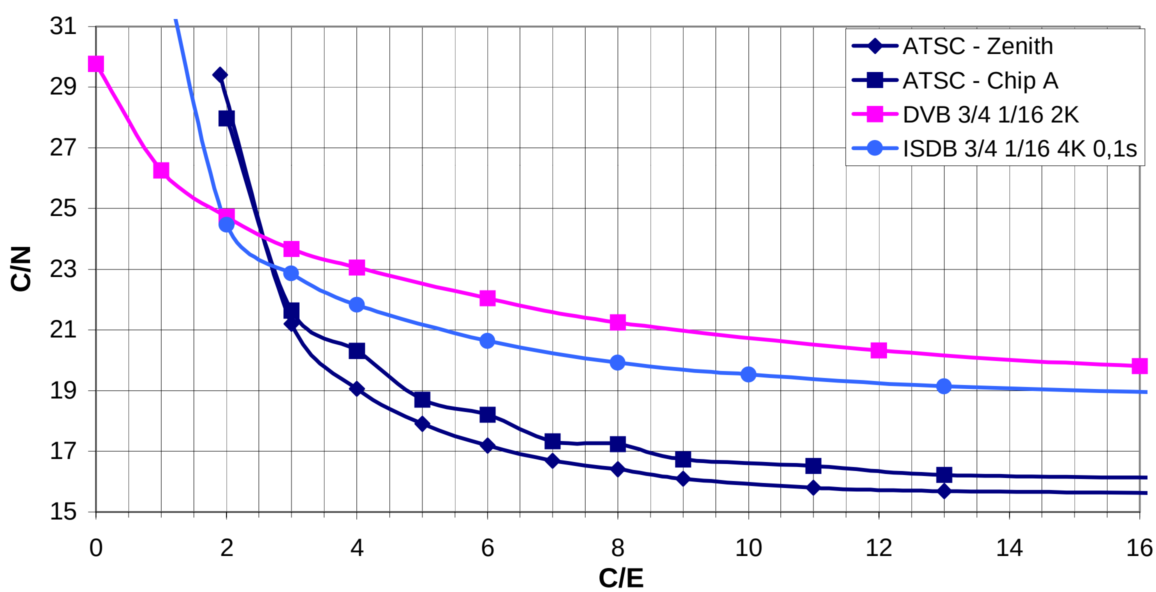


Figure 4: Carrier-to-noise relation & echo-to-noise relation in dB

In all digital television systems, increasing the amplitude of the ghost the minimum carrier-to-noise value also increases.

The DVB-T standard was the only system with acceptable performance in situations where the echo and the main signal have the same amplitude (C/E=0). The 8VSB modulation is not a good solution for handling strong echoes. Experimental curves show that the system does not work in the presence of ghosts less than 2 dB attenuated in relation to the main signal. (C/E around 2 dB).

The performance limitation in relation to the strength of the echo seem to be a characteristic of the 8VSB modulation not improved by newer implementation of the system. By using COFDM modulation, it is expected that future implementation of the ISDB-T system will achieve reliable reception with 0 dB echo.

For weak echoes, all systems have good performance and 8VSB modulation is better than COFDM for the set of parameters chosen. This advantage is related to the minimum carrier-to-noise for each system and will be discussed on Item **V-1.4.1** that analyses the carrier-to-noise ratio.

V-1.3.3) Different channel simulation (Proceeding 3.3)

In order to evaluate the proposed system in situation closer to the real conditions, some channel representing the combination of reflected signals were simulated. Channel A simulates the reception with an outdoor antenna in places where the reflected signals are very attenuated. Channel D represents reception with an indoor antenna that is considered difficult due to the presence of strong reflected signal. Channel C is an intermediary reception condition between channel A and D, where reflected signals have delay longer than the echoes of channel A and D. Channel E simulates an extremely severe multipath as it represents points where the middle points of reception in a single frequency network with three transmitters. Table 5 indicates whether systems functioned or not in each one of this reception conditions, and in affirmative case indicates the threshold carrier-to-noise ratio.

Channel	Type	ATSC	CHIP A	DVB	ISDB
Channel A	"outdoor"	16,0 dB	17,0 dB	19,7 dB	20,3 dB
Channel C	"intermediate"	Non func.	Non func.	23,2 dB	24,3 dB
Channel D	"indoor"	Non func.	Non func.	23,0 dB	25,3 dB
Channel E	SFN	Non func.	Non func.	32,4 dB	Not func.

Table 5: Simulation results for different channels

It was possible to receive the signal for all the proposed standard only for the easiest reception condition, channel A. For channel C and D, there is a clear difference between the systems, since only COFDM digital television systems functioned.

In the case of channel E, only DVB-T receivers have reliable reception. As pointed out before, the prototype receiver available uses simpler tools than DVB-T receivers to compensate for the spectrum degradations. It is expected to have similar performance in future implementations once using the same modulation scheme.

In the case of the 8VSB modulation, evolution on these channels reception was not observed, until now. Tested receivers of ATSC system, using integrated circuits developed on the second semester of 1999 and sophisticated equalization algorithms do not present performance improvements for the tested channels.

V-1.4) C/N Measurements

V-1.4.1) Carrier-to-noise ratio at the threshold (Measurements 4.1 and 4.4)

The results of the carrier-to-noise ratio of table 6 define the maximum amount of noise that each system can support without any other interference or impairment.

ATSC	CHIP A	DVB	ISDB
14,6 dB	15,1 dB	19,0 dB	18,6dB

Table 6: Carrier-to-noise ratio at the threshold

In this situation, the comparison between the ATSC and the configurations of DVB-T and ISDB-T shows that ATSC have an advantage of 4dB. In real conditions of multiple interference this difference is not that big.

In the case of COFDM modulation, the ability of the receiver to treat distortions caused by the white noise is directly related to the set of parameters and depends, significantly, of the implementation of the receiver.

The COFDM disadvantage in this measurement can impact on the coverage of distant regions of the transmitter, therefore how much bigger it is the distance for the radius of coverage area, bigger it is the relevance of the performance in distant points of the transmitter, defined for the C/N.

It is important to highlight; that the Brazilian characteristics for the real coverage lead to the conclusion that this parameter is not very relevant in our model of planning. The great majority of the broadcasters use transmitters of low power, and, in the great centers, even operating with high powers, the coverage is sufficient limited by the terrain characteristics.

V-1.4.2) Reception threshold (Measurements 4.2 and 4.3)

The table 7 is showing the minimum amount of signal power to have a reliable reception, without any interference or impairment.

ATSC	DVB	ISDB

-81,3 dBm	-80,8 dBm	-78,6 dBm

Table 7: Minimum amount of signal power level

This test highlights the technology employed on the manufacturing of the receiver and not on the system performance itself. It is a fact that the ISDB-T system achieved a bad result, and in our understanding that we tested an early stage prototype unit, and this was expected.

V-1.4.3) Relation between the carrier-to-noise ratio as a function of the signal level (Measurement 4.5)

The curves of Figure 5 indicate the relation between the carrier-to noise ratio and the signal power level to achieve an acceptable reception with some degree of reliability.

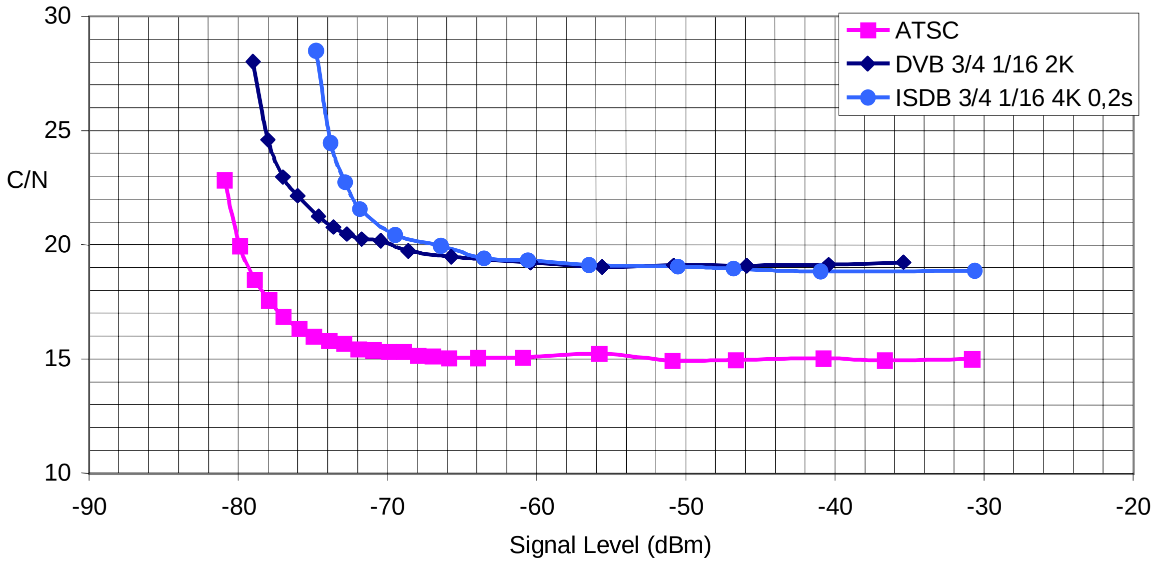


Figure 5: threshold value for carrier-to-noise ratio as a function of the signal level

This result is important because shows that at the limits of the coverage area the required C/N is, for all systems, significantly bigger than the value of threshold argued in the item V-1.4.1. This increase occurs, in all the cases, for levels of signal inferior than -64dBm

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V-1.5) Transmitter performance measurements

V-1.5.1) Peak-to average ratio

The results that shows the ratio between the transmitter peak power and the average power, used as reference in digital transmission are presented below, in Table 8.

ATSC	DVB	ISDB
6,66 dB	8,28 dB	8,54 dB

Table 8: Peak-to-average ratio

The data indicate that for transmit the same average power, a transmitter using COFDM modulation needs the peak power around 2dB higher than a transmitter using 8VSB modulation, i.e., the COFDM transmitter needs approximately 60% more power.

The transmitter performance results were considered as low relevance for choosing a system, because they don't affect directly the viewers. The comparison emphases was given for achieve the highest number of households, becoming with the broadcasters the responsibility of choosing equipment with quality and power necessary for guarantee its coverage area.

V-1.6) Doppler Measurements

V-1.6.1) Dynamic multipath (Procedure 6.0)

This experiment treat the cases where the reflections points are moving, i.e., reflections into people, cars, trains and airplanes. Figure 6 shows the graph where the echo signal is delayed 4µs from the main signal.

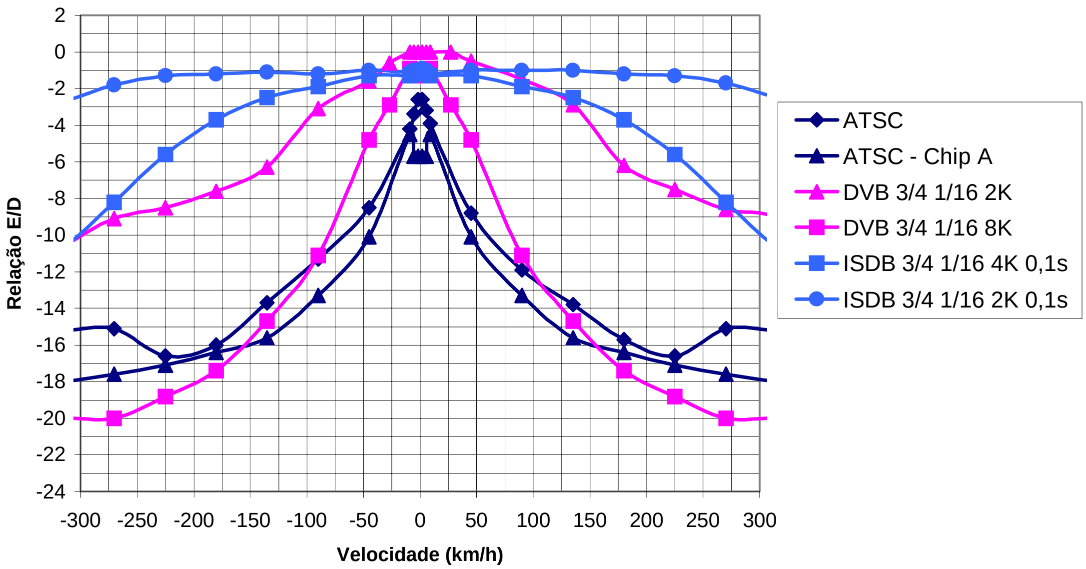

Figure 6: Echo-Signal ratio vs. speed

How fast moves the object where the signal is reflected, more difficult is the reception. The curves above shows that systems that uses COFDM modulation have better performance when compared with the system that uses 8VSB modulation. The COFDM systems support stronger echoes with higher speeds than supported by 8VSB system.

Into COFDM modulation, the receiver skill to handle the channel changes is related with the number of carriers, i.e., the 2K mode is better to follow the channel changes when compared with 8K mode.

V-2) Field Results

The results below are a resume from the database build during the tests. There are 127 coverage sites for ATSC and DVB included as well the results from all systems, including ISDB-T and the new implementations from ATSC into the most difficult sites.

V-2.1) Coverage measurements

Figure 7 shows the cumulative percentages from the sites with acceptable reception related with the distance from the transmitter.

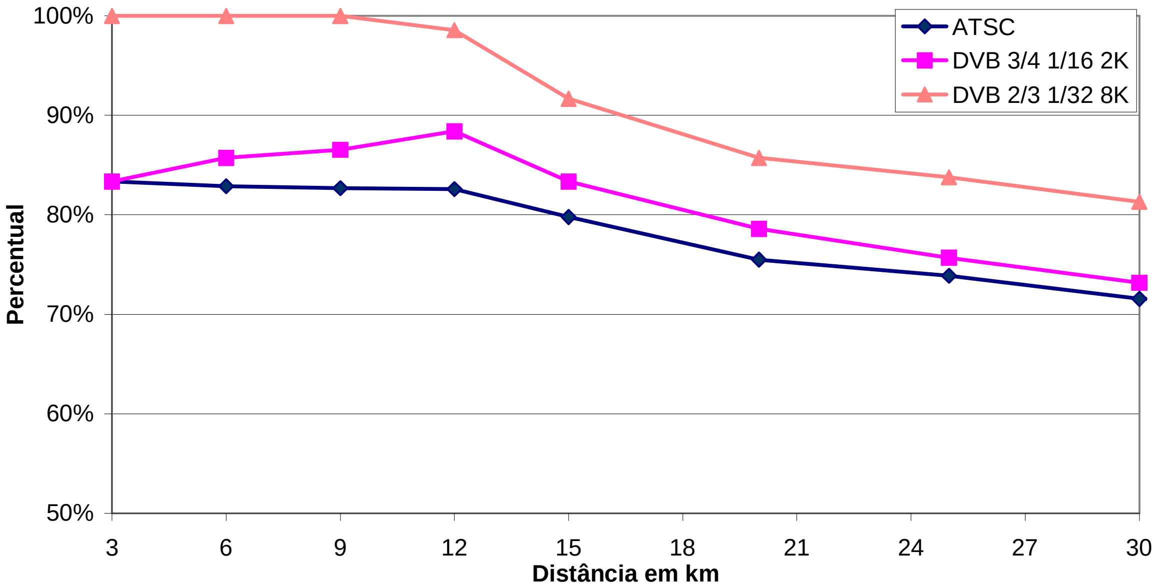

Figure 7: Acceptable reception cumulative percentage relating with transmitter distance

The best performance taking into account coverage efficiency was achieved with COFDM modulation. Only with this modulation was possible a good reception at all sites near the transmitter.

The area near the transmitter is characterized by a high concentration of buildings, with short multipaths but very strong. At this condition, an acceptable coverage with ATSC was not achieved.

When the sites with bigger distance from the transmitter are considered, the percentage of receiving success decrease for all systems tested. It is understood that the distance where the receiving success decrease is depends directly from the transmitter power. At the case of COFDM modulation, the 100% success area tends to increase if the transmitter power is increased.

At figure 8, only <u>six</u> sites are analyzed that were found high level of noise and multipath, and were all receivers from all systems were tested.

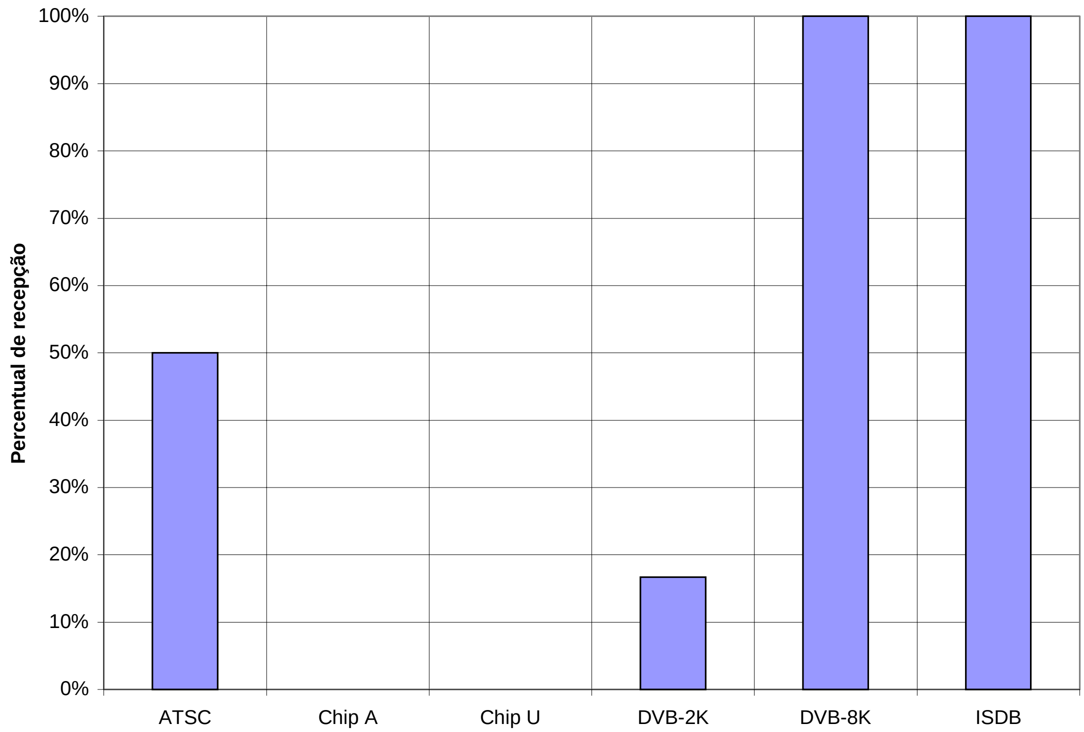

Figure 8: Percentage of success at critical sites

At these sites, it is also realized an advantage for the systems that uses COFDM modulation over the system with 8VSB modulation.

In the case of ATSC, should be pointed that beyond the Zenith receiver, were tested two others receivers (“Chip” A and “Chip” U) that are new implementations of the system. Although all efforts in the receivers improvement by using moderns equalization tools, this did not reflected an improvement of the success receiving percentage in real word situations.

It should be also pointed that in the case of ISDB-T only few sites were visited and its results were not totally compiled. Although that, all data obtained were very positive and the projected coverage efficiency was so good as the obtained by DVB-T.

The next steps of the tests include to get more data for ISDB-T, and to test one more ATSC and one more DVB receivers with new chip implementations.

Chapter VI – Conclusions

Considering:

- That the COFDM modulation presents a better performance in severe multipath situations verified in areas densely peopled;
- That the COFDM modulation allows the implementation of transmission in High Definition with adequate robustness;
- That there are solutions in the COFDM modulations that out perform the 8VSB modulation in the impulsive noise immunity;
- That only the COFDM modulation allowed a 100% reception of the spots within the 10 Km radius. This radius was a function of the used ERP; bigger ERPs will correspond to bigger radiuses with 100% reception;
- That the results of the lab tests suggest that only the COFDM modulation allows the reception in areas not reached by any system, through the use of Single Frequency Networks;
- That the 4 dB advantage in the signal-noise ratio of the 8VSB modulation did not turn out to cause better coverage;
- That the disadvantageous results of the relation between the peak power and the average power have a low relevance, once they are costly only for the broadcasters, not the population;
- That the noted disadvantage observed in the COFDM modulation to the protection relation for adjacent channels can be eliminated by introducing filters with better rejection characteristics in the receivers;
- That all the results of co-channel interference are not significant to the planning of any of the tested modulations;
- That when a point of reflection is moving, the COFDM modulation shows better performance enabling even mobile reception;
- That the 8VSB receivers developed during the 2nd semester of 1999 and made available to the tests, until now, in despite of the use of sophisticated equalizing techinique, did not show real improvements in practical situations;
- That the COFDM modulation presents flexibility in the solving of coverage problems;
- The objective of optimizing the reception, duplicating or improving the current analog systems coverage ;
- That it is indispensable the use of a modulation that maximize the free off air reception;

We conclude that the COFDM modulation, besides being technically superior, is more adequate to the Brazilian conditions than the 8VSB modulation and, therefore, we suggest to Anatel that it determines that the Digital Television system to be adopted in Brazil must use the COFDM modulation.

We can observe that the disadvantages shown by the COFDM modulation systems are solvable, even though it implies additional cost to the broadcasters. However, the mentioned disadvantages shown by the systems with 8VSB modulation picture the boundaries inherent to the modulation itself. Only the consumer, who will need reception systems – antenna and receiver – more sophisticated, in the same proportion that his location may require, shoulders the onus of the flaws in the 8VSB modulation. On the other hand, only the broadcaster who, in certain situations, will have to implement transmission systems more powerful or sophisticated shoulders the onus of the difficulties in the COFDM modulation, all solvable.

Among the possible systems that use the COFDM modulation, we believe that it is still necessary the accomplishment of further and complimentary tests, besides the market issue consideration, such as the evaluation of the impact that adopting on of the available systems will have on the national industry, and the timing of commercial availability of each system, so to make the final decision on the standard to be considered.

Therefore, we will use the additional period that Anatel has conceded, that will be until the end of April, so we can develop the activities, the experiments and the necessary studies to reach a final positioning about which Digital TV system we consider more adequate to be adopted in Brazil.

Chapter VII - Team

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Chapter VIII - Sponsoring

Enterprises that collaborated with the tests done so far:

Eletro Equip Telecomunicações Ltda
Harris Corporation
Linear Equipamentos Eletrônicos Ltda
Nec do Brasil S.A.
Nokia
Rohde & Schwarz
Tektronix Indústria e Comércio Ltda
Transtel Conti & Cia Ltda
Wandel & Goltermann
Zenith

Associations that collaborated with the tests done so far:

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