Abstract. The transmission of digital HDTV signals on satellite channels in the 20-30 GHz band is studied with the aim of designing an Italian domestic satellite, both for the exchange of programs among production centers and for direct broadcasting to end-users. Previous work on the definition of the system architecture and of the payloads is first briefly summarized. The transmission impairments due to the interfered environment are then analyzed in detail and simulation studies are reported. The results confirm the choices made for the link budgets during the system configuration design. Experimental tests carried out both with laboratory simulators and with the Olympus European satellite are finally described.

1. INTRODUCTION

The transmission of digital HDTV programs by means of broadband channels in the 20-30 GHz band is considered to be both an interesting and feasible target by the TV broadcasters in the near future. A research activity was performed inside the Progetto Finalizzato Telecomunicazioni, supported by CNR, with the aim of assessing the feasibility of an Italian domestic satellite system for the transmission of digital HDTV programs.

The details of the main system choices, of the network architecture and of the technological options were already described in previous papers [1, 2].

The aim of this paper is to present the final refinements to the overall design that were achieved in the last year of the study. These refinements fully confirm the preliminary design and give a complete picture of the system.

The description of the system is first summarized and the main choices briefly discussed. This leads to the presentation of the proposed network architecture with the multibeam coverage for the Telecommunication (TLC) service and the shaped global beam coverage for the Direct Broadcasting (DBS) service. The final link budgets are also presented.

A section is then devoted to the proposed final choices for the design of the space segment of the system, with a concise description of the forecasted payloads.

The core of the paper follows, concerning the study of the transmission impairments due to the interfering environment on the transmitted signal.

Assuming the proposed frequency plans for the allocation of the transmission channels, simulation results are presented in detail showing the complete performance of the transmission link and confirming the proposed link budgets.

Finally, some interesting field measurements performed by RAI are presented to validate the study.
2. SYSTEM DESCRIPTION

2.1. Network architecture

The satellite system was conceived for the offering in the late 90’s of two basic services, each one characterized by specific requirements and constraints:

- a point to point or point to multipoint service, to support the exchange of digital HDTV programs, among fixed and fixed or fixed and transportable stations (TLC service);
- a broadcasting service, for the distribution of the HDTV programs to both individual and communal reception (DBS service).

The system design was constrained by the conflicting requirements deriving from the utilization of the $K$ and $K_s$ frequency band and from the service requirements, such as:

- a net signal bit rate (not including the channel coding) of 70140 Mbit/s (140 Mbit/s for the exchange of programs among fixed stations in the TLC service, 70 Mbit/s for the transmission from transportable stations and for the DBS service);
- a high transmission quality ($BER$ lower than $10^{-9}$ after the decoders, corresponding to about 4.5 in the CCIR 5 grade scale: assuming a Reed-Solomon $(239, 255)$ internal code, this corresponds to a BER of about $2 \times 10^{-4}$) at the output of the convolutional decoder;
- a high link availability (more than 99.6% of the worst month);

<table>
<thead>
<tr>
<th>Type of Service</th>
<th>DBS</th>
<th>TLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link Parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To Single User</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To Multiple Users</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From Transp. Stations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From Fixed Stations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signal Bit Rate [Mbit/s]</td>
<td>70.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Coding Type [FEC]</td>
<td>1/2</td>
<td>1/2</td>
</tr>
<tr>
<td>Uplink Frequency [GHz]</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Downlink Frequency [GHz]</td>
<td>22.0</td>
<td>22.0</td>
</tr>
<tr>
<td>TX Antenna Diameter [m]</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>HPA RF Power [W]</td>
<td>350.0</td>
<td>350.0</td>
</tr>
<tr>
<td>E/S EIRP [dBW]</td>
<td>87.8</td>
<td>87.8</td>
</tr>
<tr>
<td>Free Space Loss [dB]</td>
<td>213.5</td>
<td>213.5</td>
</tr>
<tr>
<td>Atmospheric Loss [dB]</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Rain Loss [dB]</td>
<td>15.5</td>
<td>15.5</td>
</tr>
<tr>
<td>Antenna RX Peak Gain [dB]</td>
<td>50.0</td>
<td>50.0</td>
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<tr>
<td>Noise Temperature [K]</td>
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<td>11350</td>
</tr>
<tr>
<td>Satellite G/T [dB/K]</td>
<td>16.4</td>
<td>16.4</td>
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<tr>
<td>$E_b/N_0$ Uplink [dB/Hz]</td>
<td>24.9</td>
<td>24.9</td>
</tr>
<tr>
<td>Antenna TX Peak Gain [dB]</td>
<td>44.0</td>
<td>44.0</td>
</tr>
<tr>
<td>TWTA RF Power [W]</td>
<td>120.0</td>
<td>120.0</td>
</tr>
<tr>
<td>Satellite EIRP [dBW]</td>
<td>60.4</td>
<td>60.4</td>
</tr>
<tr>
<td>Free Space Loss [dB]</td>
<td>210.9</td>
<td>210.9</td>
</tr>
<tr>
<td>Atmospheric Loss [dB]</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Rain Loss [dB]</td>
<td>12.2</td>
<td>12.2</td>
</tr>
<tr>
<td>E/S Antenna Diameter [m]</td>
<td>1.2</td>
<td>3.0</td>
</tr>
<tr>
<td>E/S G/T [dB/K]</td>
<td>19.9</td>
<td>26.7</td>
</tr>
<tr>
<td>$E_b/N_0$ Downlink [dB/Hz]</td>
<td>6.3</td>
<td>13.2</td>
</tr>
<tr>
<td>System Margins [dB]</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Min. $E_b/N_0$ available [dB/Hz]</td>
<td>3.2</td>
<td>10.1</td>
</tr>
<tr>
<td>Net $E_b/N_0$ requirement [dB/Hz]</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Link Availability [% w.m.]</td>
<td>99.526</td>
<td>99.729</td>
</tr>
</tbody>
</table>
Transmission Issues for HDTV Satellite Systems

- a relatively high number of programs (8 for TLC, 5 for DBS), and the necessary flexibility to allow their simultaneous transmission.

The overall system dimensioning was the result of the comparison of several scenarios, where alternative architectural solutions (e.g. the satellite coverage) were analyzed along with the modulation and coding schemes that were considered, that is:

- QPSK modulation combined with a concatenation of a rate 1/2 convolutional code and of a Reed-Solomon (255, 239) code (scheme A1);
- QPSK modulation combined with a concatenation of a rate 3/4 convolutional code and of a Reed-Solomon (255, 239) code (scheme A2);
- 8-PSK modulation combined with a concatenation of a rate 2/3 trellis code (8 states) and of a Reed-Solomon (255, 239) code (scheme B).

These different choices impact significantly on basic system parameters, such as the frequency bandwidth, the frequency reuse, the protection levels from cross-polar interference and the satellite configuration.

In the final tradeoff among the configurations, the most suitable modulation techniques has been deemed to be the QPSK. The wide bandwidth requirement is balanced by a higher robustness to the cross-polar interferences, and by a lower requirement in terms of carrier-to-noise ratio.

The peculiarities of the TLC and DBS services addressed therefore the analysis of the network architecture toward two separate configurations, optimized for the specific requirements of each service. The link budgets considered in the system dimensioning are shown on Table 1.

A multibeam coverage of Italy has been deemed to be the best solution for the TLC service. The increase in the complexity of the space segment (if compared with a global coverage satellite) is balanced by the reduction in the size of the TX/RX terminals.

This solution fully meets the severe requirements for a "near studio quality". It also guarantees the technical viability of the on-board amplifiers (less than 20 W are required), and the viability of the transportable terminals (about 3.0 m antennas are sufficient, nearly the same size of the existing terminals adopted in the Olympus program).

The improvements mentioned above deriving from a multispot configuration were not applicable for the implementation of the DBS service. Apart from a higher satellite complexity, this solution is strongly constrained by the limited frequency bandwidth available for this service (the frequency band requirement would be doubled with respect to the global coverage). A wide reuse of the same frequency should be applied, with all the consequent problems related to the interference caused by the cross-polar signal.

A more traditional global coverage has been therefore preferred: a contoured beam was suggested, in order to maximize the utilization of the available satellite power (a maximum of about 60 W was assumed for the on-board TWTAs). With this solution the quality target are substantially met, if the antenna diameters envisaged for direct reception are in the range 0.91.2 m. Obviously, higher quality can be achieved with comunitary antennas, where larger dishes can be exploited.

The availability of higher power on board amplifier and/or the development of more sophisticated source coding algorithms (lower signal bit rate) lead toward a higher quality service with a smaller user dish.

The global and multibeam satellite coverages are shown in Fig. 1, in the hypothesis that the satellite is located at the orbital position 12.5° East.
2.2. Space segment design

Two separated payloads were conceived supporting the TLC and the DBS service respectively, both operating with transparent reconfigurable repeaters providing the required traffic routing flexibility.

The two identified payloads were allocated on different busses, considering also the further possibility of a partitioning of the two payloads on two identical sections to be allocated on two operating satellites.

The total mass and power consumption of each candidate payload are shown in Table 2.

The coverage of Italy for the TLC segment is obtained through a couple of three spots, each one generated by a dedicated antenna. The obtained multibeam antenna gain is large compared with the monobeam solution.

Two separate antennas are needed to simplify the feeding network design.

Each antenna includes three adjacent feeds that efficiently generate three spots widely separated for physical reasons. These spots on the earth surface are not adjacent but reciprocally spaced apart of about one beam. The spots generated by the other antenna complete the coverage.

Table 2 - Satellite mass and consumption for different payload configurations.

<table>
<thead>
<tr>
<th>Payload</th>
<th>kg</th>
<th>W</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC + DBS</td>
<td>400</td>
<td>3100</td>
<td>single large satellite</td>
</tr>
<tr>
<td>TLC</td>
<td>250</td>
<td>1850</td>
<td>TLC supported by a single satellite</td>
</tr>
<tr>
<td>DBS</td>
<td>250</td>
<td>1350</td>
<td>DBS supported by a single satellite</td>
</tr>
<tr>
<td>multi-service</td>
<td>280</td>
<td>2000</td>
<td>two multi-service satellites</td>
</tr>
</tbody>
</table>

The DBS segment is composed of a total number of eight transmission chains, including the redundancies allocated on two satellites, five of which are simultaneously active. The tunable receiving chains are connected to two 20 GHz receiving front ends (feeder link) independently switchable: reception is possible from spots covering Rome and Milan areas respectively.

The coverage of Italy for the DBS segment is obtained with a single TWTA and a contoured, shaped antenna beam. The preferred viable technological solution for the TWTA requiring a power of 120 W is to employ two TWT's operating in parallel with a 3/2 redundancy.

A dedicated DBS transmitting antenna might be a solution to maximize the "effective" power flux density on ground.

3. TRANSMISSION SYSTEM PERFORMANCE IN THE INTERFERED ENVIRONMENT

The transmission of HDTV signals in the 20 GHz frequency band is particularly demanding when the interference from adjacent channels and cross-polar channel is considered. Moreover, if DBS services are considered the signal to noise ratio can be very low due to the presence of fading phenomena and the small size of receiving antennas.

Results concerning the optimization and performance of the isolated channel were presented in [1, 2]. The aim of the work presented in this section is to verify if the degradation due to the use of real filters and the presence of interferents is correctly bounded by the link budgets presented in section 2. The performance evaluation of the transmission channel has been carried out...
Fig. 2 - Payload block diagram: TLC, DBS segments and service repeater.
Marco Ferrari, Valentino Castellani, Renato Lo Cigno, Giacinto Losquadro, Mirto Tabone

Fig. 3 - Model of the transmission channel used in the simulations.

using the telecommunication system simulator TOPSIM IV [3].

Fig. 3 shows the block diagram of the transmission channel model used in the simulations. It is a simplified model that does not take into account the noise and interference present in the up-link, but it was already shown that the effects of such impairments are negligible under reasonable operating conditions. The filters were modelled taking into account the feasibility constraints in the 20 GHz frequency band; their characteristics are summarized in Table 3. All filters, except the shaping filter, can be realized at radio frequency. The AM/AM and AM/PM characteristics of the TWT can be found in [1], while more information about the filters simulated can be found in [4].

Table 3 - Characteristics of the filters simulated in the transmission chain, all the filters have been defined through the Darlington method.

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission filter</td>
<td>elliptic filter with 5 poles</td>
</tr>
<tr>
<td>IMUX filter</td>
<td>pseudo elliptic equalized filter with 10 poles</td>
</tr>
<tr>
<td>OMUX filter</td>
<td>elliptic with 4 poles</td>
</tr>
<tr>
<td>Receiver filter</td>
<td>raised cosine filter with roll-off $\rho = 0.5$</td>
</tr>
</tbody>
</table>

The interferent signals were simulated in the worst case situation; the adjacent channels are at the same power level as the useful channel, while the co-channel has been simulated with a cross polar protection of 13.3 dB, a value resulting from measures performed by Telespazio under heavy rain. Such values should meet the requirement of being satisfied for the 99.6% of the worst month of the year.

From a transmissive point of view the coding technique used for error protection does not imply additional constraints, thus the transmission schemes proposed in section 2 reduce to a QPSK for scheme A. In Fig. 4 the frequency plan resulting from the use either of the QPSK or the 8PSK modulation system have been schematically reported. The frequency plans have been designed with the aim of allocating nine transmission channels, a number considered suitable for offering the broadcasting service and still having a certain number of backup channels in case of failures. If the transmission scheme B is chosen the gross bit rate is exactly 1/2 with respect to the transmission scheme A1 (this is due partly to the intrinsic bandwidth reduction due to the 8PSK modulation and partly to the 2/3 TCM code which is less redundant with respect to the rate 1/2 convolutional code). This situation leads to a waste of the available bandwidth, on the other hand the degradation due to interference is greatly reduced. From Fig. 4 it can be seen that the allocation of the channels upon the available band can be done in two different ways: the first one (labeled I) assigns exactly the same frequencies to the channels with opposite polarization, the second one (labeled S) assigns to channels with opposite polarization frequencies that are shifted by half the interchannel distance. This latter solution practically avoid the co-channel interference for the 8PSK modulation, its advantage is so evident that the solution I has not even been considered.

In the case of the QPSK modulation the advantage is no more evident, thus, although it is still expected to yield better results, both solutions were studied.

The situation outlined by the frequency plans drawn in Fig. 4 allows the sketching of an interesting evolving
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scenario: at first the transmission scheme A1 (technologically already available) is used, then with the evolution of the technology (e.g. a more powerful source encoding yielding a reduction of the net bit rate requirements for a given picture quality), the transmission can be switched to scheme B allowing the improvement of the offered service (i.e. a greater number of channels).

The work presented in [1] concerned the modeling of the transmission channel and the optimization of the same with ideal, raised cosine filters and no interference.

The following steps have been followed for the refinement and testing of the model:

1) the link parameters (input backoff (IBO) of the TWT amplifier and apportioning coefficient $\gamma$ of the raised cosine transfer function between transmitter side and receiver side) have been computed and optimized for the BER value required for offering a good service in the presence of interfering signals;

2) the parameters IBO and $\gamma$ computed in step 1 have been used to compute the BER versus $E_b/N_0$ on the down-link channel in the presence of the interferents;

3) starting from the ideal square root raised cosine transfer function masks for the design of real filters have been realized, then the impairments due to the use of real filters fitting those masks has been evaluated.

Figs. 5 and 6 summarize the results obtained in step 1. The optimum working point for the traveling wave tube is 0 dB of input backoff for the QPSK modulation and around 1 dB for the 8PSK modulation. The apportioning coefficient is 0.5 for both the modulation schemes, this corresponding to a shaping function equally distributed between the transmitter and the receiver side. The optimization procedure has been carried out for a BER of $2 \cdot 10^{-2}$ for the QPSK modulation and $1.3 \cdot 10^{-3}$ for the 8PSK modulation. These values have been chosen as upper limits that still allow the exploitation of the correcting capabilities of the error correcting codes used. It is interesting to notice the different performance of the QPSK modulation with the frequency plan I and S, the latter performing over 0.5 dB better than the first. This result is confirmed by the BER curves shown in Fig. 7.

Figs. 7 and 8 summarize the results obtained in steps 2 and 3. The four different curves present in the plots refer to different situations. The first one (curve 4) refers to a standard AWGN channel and has been reported for comparison purposes. The second one (curve 3) refers to a situation where the co-channel interference is absent, so that the interference comes only from the right and left channels that have the same polarization and power level of the useful one. The third one (curve 2) refers to the situation in which all the interfering channels are present. It must be noted that for the QPSK modulation the impairment due to the co-channel is prevailing with respect to the adjacent channels. This is due to the poor protection ratio (13.3 dB) that can be obtained in the 20 GHz band from the cross-polarization. This effect is not present for the 8PSK modulation due to the particular frequency plan.

The last curve (curve 1) refers to the complete satellite channel with the interferents and the real filters (Table 3). It can be noted that the impairments due to the intersymbol interference is almost negligible (less than 0.1 dB) with respect to the interchannel interference for
the QPSK modulation, while in the case of the 8PSK modulation the effect of intersymbol interference is still significant. In all the figures curves 2 and 3 have been obtained with a F.I.R. approximation of square root raised cosine filter both on the transmitter and the receiver side, while at the output of the satellite transponder the OMUX filter described in Table 3 has been used.

All the results presented in this work have been obtained assuming an ideal recovery of the carrier and the clock. The problem of recovering the carrier and the clock with low signal to noise ratio and heavy interference has been ignored because it is beyond the scope of this work. The problem is however of the utmost importance because the use of concatenated codes with very high coding gains allow the transmission of reliable information under very difficult operating conditions, but this can be achieved only if the carrier and the clock are correctly recovered. The performance of the traditional recovery sub-systems is generally not suited for these applications, so that new schemes should be envisaged. As a logical prosecution of the work presented here new recovery system based on maximum likelihood estimation and suitable for digital implementation are being studied.

4. EXPERIMENTAL TESTS

Some significant experimental tests were carried out at the RAI Research Center in order to validate the more relevant choices that guided the study presented in the previous sections.

These experiments were run first in the laboratory, on a hardware satellite simulator, and successively using the 30/20 GHz payload of the Olympus satellite. The transmissions via Olympus were carried out in tight cooperation with ESA, that provided for the access to the satellite, and with Telespazio, that provided for the transportable earth station. The access to the Olympus 30/20 GHz communication payload offered a unique opportunity to test digital TV/HDTV systems with a down-link frequency in the vicinity of the 21.4 to 22 GHz band, that was allocated to wide-RF band HDTV by the recent WARC'92 Conference in Torremolinos (Spain).

The aim of these experiments was twofold:

- to check the performance of the modulation and coding schemes for the transmission of HDTV signals at a rate of 70 Mbit/s;
- to assess the signal transmission from satellite in the 30/20 GHz bandwidth.

Four modems have been tested on the hardware satellite simulator and via the Olympus satellite link ($R_u =$ useful bit-rate):

- un-coded QPSK at $R_u = 70$ Mbit/s
- QPSK with convolutional coding rate 3/4, at $R_u = 34$ and 45 Mbit/s
- QPSK with convolutional coding rate 2/3, concate-
nated with a Reed-Solomon (255, 239) block code shortened to (152, 136), at $R_u = 70$ Mb/s.

The last choice, in particular, is very close to the transmission scheme A1 of section 2. The transmission tests were conducted with two types of signals: the first one with pseudo-random signals to measure the BER performance, the second one devoted to the transmission of live TV (at 34 Mbit/s) and HDTV (at 45 and 70 Mbit/s) signals. The TV/HDTV codecs, developed by Teletrra Spa under the Eureka 256 Project [6], are equipped with a Reed-Solomon (255, 239) code, ensuring error-free pictures for an input BER between $1 \cdot 10^{-5}$ to $5 \cdot 10^{-4}$ (depending on the interleaving depth adopted). The video signal was associated with 5 sound channels at 2 Mbit/s (CCITT Rec.G.732, 384 kbit/s per channel).

4.1. Measurements over a hardware satellite simulator

The satellite simulator was composed of IF/RF frequency up-converters (UPC), a 50 W TWTA at 12 GHz, a 12/20 GHz UPC, a complete 20 GHz receiver. Considering that the TWTA AM/AM and AM/PM characteristics do not significantly depend on the frequency band (e.g., 20 or 12 GHz), this satellite simulator can be considered a good approximation of a real 20 GHz satellite chain.

Fig. 9 shows the performance of the modems in IF-loop and over the satellite simulator. Compared with the theoretical performance, the modem $E_b/N_0$ degradation in IF loop is within 0.7 to 1.3 dB.

4.2. Measurements over the 20 GHz satellite link

The 30/20 GHz payload of Olympus is associated with two independent spot-beam antennas, which can be pointed, on demand, in the directions of the transmitting and receiving earth stations (situated in Turin, Italy, during the HDTV experiments). The typical parameters of the satellite link are summarized as follows:

- satellite receiver G/T (on beam axis): 14 dB/K
- saturated EIRP (after September '91): 54.9 dBW

When the up-link EIRP is 70 dBW, the available C/N (in 34 MHz) is of about 18.4 dB, assuming an atmospheric attenuation of 1.5 dB on the up-link and 1.2 dB on the down-link.

Due to operational constraint on the satellite, it was not possible to operate in the wide-band channel mode (i.e., channel 2), which could support 140 Mbit/s HDTV transmissions. Thus the transmissions were carried-out mainly on channel 1 (frequencies 28.0721 8.925 GHz), having a 3 dB bandwidth of about 54 MHz. The frequency response of the satellite (channel 1) is reported in 10. Therefore it was only possible to achieve good transmission performance with symbol-rates lower than 35 Mbaud (i.e., un-coded QPSK at 70 Mbit/s, and QPSK with convolutional coding, rate 3/4, at 34 Mbit/s and 45 Mbit/s). An additional experiment at a higher symbol-rate (about 59 Mbaud) allowed to investigate the effects of the satellite filter distortions due to bandwidth limitations.

The TDS-7 transportable earth station, used during the experiments as transmitter and receiver, was provided and operated by Telespazio. It makes use of two TWTA amplifiers combined in phase, each with 80 W nominal power, giving a total 74 dBW EIRP at saturation. The antenna has a diameter of 2.7 m, and the receiver G/T is of 26.3 dB/K in clear sky.

The station RF-loop bandwidth at 3 dB is of about 110 MHz, with a group delay lower than 24 ns in the band; therefore it can be considered wide-band for the digital signals used in the tests.

The AM/PM distortion of the total transmit chain is lower than 7 deg/dB.
During the transmission period the weather was cloudy, but it was not raining. The estimated C/N in 34 MHz was of about 18.4 dB for a transmit EIRP of 70 dBW.

Fig. 11 gives the BER versus Eb/N0 performance of the modems by satellite (up-link EIRP=70 dBW), obtained by adding Gaussian noise at the receiving site in IF in order to increase the BER.

The given values of Eb/N0 include the effective noise contribution on the satellite path and the added noise. The IF-loop curves are given as a reference. As the satellite TWTA operating point is about 2 dB from saturation (output back-off), the non-linear distortion on QPSK is low. Excluding the QPSK rate 2/3 system at 70 Mbit/s, the bandwidth limitations on the chain are moderate and the overall Eb/N0 degradations are in the range 0.6 to 0.8 dB at BER = 1·10^-5. This confirms the results of the computer simulations and of the laboratory tests over the satellite simulator.

As regards the QPSK rate 2/3 system at 59 Mbaud, a severe bandwidth limitation is introduced by the 54 MHz satellite channel. Therefore the Eb/N0 degradation on the satellite link is quite large (about 4 dB at BER = 1·10^-5). Nevertheless this system still offers a coding gain of about 3.8 dB with respect to un-coded QPSK at the same useful bit-rate.

Fig. 12 shows the BER performance of the modems as a function of the up-link station EIRP. The following minimum EIRP (corresponding to BER = 1·10^-5 have been identified:

coding scheme   | gross bit rate | minimum EIRP
---------------|----------------|----------------
uncoded        | 70 Mbit/s      | 63 dBW         
conv. 2/3      | 70 Mbit/s      | 59 dBW         
+ RS(152, 136) | 45 Mbit/s      | 55.5 dBW       
conv. 3/4      | 34 Mbit/s      | 54.5 dBW       

In all cases the margin on the up-link EIRP is larger than 10 dB compared with the maximum station EIRP capability.

During the transmissions of live TV/HDTV signals, it was possible to confirm that error-free pictures can be achieved for BER < 1·10^-5 (with interleaving 2), confirming the results of laboratory tests.

The above experimental results demonstrate the validity of the theoretical studies carried out on digital HDTV broadcasting in the 20 GHz frequency range. The transmission of error-free HDTV signals at 20 GHz via Olympus was fully successful, ensuring large C/N margins also under propagation conditions affected by clouds.

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