REPORT ITU-R BO.2007

CONSIDERATIONS FOR THE INTRODUCTION OF BSS (HDTV) SYSTEMS*

(1995)

1 Introduction

WARC-92 made an allocation in the bands 21.4 - 22.0 GHz in Regions 1 and 3 and 17.3 - 17.8 GHz in Region 2 to the broadcasting-satellite service on a primary basis from 1 April 2007. It has adopted, by Resolution No. 525, a set of interim procedures to allow HDTV (BSS) to be introduced in Regions 1 and 3 from 1 April 1992.

Resolution No. 525 also stipulates that the located frequency band shall be used for High-Definition Television (HDTV) in the BSS. It stipulates further that, before a future conference has taken decisions on definitive procedures, the use of the allocated band shall be based on Resolution No. 33 (WARC-79) and Article 34, and that after 1 April 2007 the introduction of HDTV systems in this band must be regulated in a flexible and equitable manner until such time as a future competent world radio conference has adopted definitive provisions for this purpose in accordance with Resolution No. 507 (WARC-79).

The interim procedures utilize sections of Resolution No. 33 which apply to the broadcasting-satellite service in bands where plans are not in force but limits the requirements for coordination with the assignments of other countries to systems which exceed certain trigger values.

This Report lists a number of characteristics to be considered in the development of HDTV-BSS systems under these procedures. Although the interim procedures of Resolution No. 525 (WARC-92) apply only to the introduction of BSS (HDTV) in the 21.4 - 22 GHz band in Regions I and 3, the material in 5, 6 and 7, and in the Annexes to this Report may also be of interest for system planning in the 17.3 - 17.8 GHz bind in Region 2. Likewise, this material may be of interest in connection with the possible accommodation in the 12 GHz band of HDTV-BSS systems, particularly for the tropical countries of Regions 1 and 3 as envisioned in Resolution No. 524 (WARC-92).

2 Regulatory provisions

Resolution No. 525 established an interim set of regulatory provisions to give flexible and equitable access to the geostationary orbit and the designated spectrum before a competent radiocommunication conference takes definitive decisions on a replacement procedure. ‘Me Resolution makes a distinction between “operational” and “experimental” systems and to systems introduced before and after 1 April 2007. Table I indicates the applicable procedures.

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* This Report provides technical information relevant to the application of the interim procedures contained in Resolution No. 525 (WARC-92).

TABLE 1

General scheme of applicable procedures to implement BSS (HDTV) systems*

Date of use of HDTV band	Conditions		Applicable RR provisions	
Before 1 April 2007	Experimental systems		Article 34: Res. No. 33 Sect. A: Res. No. 33 Sect. B: Res. No. 33 Sect. C:	Experimental stations Coordination BSS space stations and terrestrial stations Coordination BSS space stations and space systems of other Administrations Notification and registration of frequencies
	Operational systems	PFD > a	Res. No. 33 Sect. A: Res. No. 33 Sect. B: Res. No. 33 Sect. C:	Coordination BSS space stations and terrestrial stations Coodination BSS space stations and space systems of other Administrations Notification and registration of frequencies
		PFD < a	Res. No. 33 Sect. B: Res. No. 33 Sect. C:	Coordination BSS space stations and space systems of other Administrations Notification and registration of frequencies
After 1 April 2007	New procedures adopted by future WARC		Application of such a new procedure	
	No new procedures adopted		Res. No. 33 Sect. B: Res. No. 33 Sect. C:	Coordination BSS space stations and space systems of other Administrations Notification and registration of frequencies

* Source: Resolution No. 525 (WARC-92).

a: Limits defined in § 4 of this Report.

3 Status of existing services

The band 21.4-22.0 GHz is also allocated to the fixed and mobile services on a primary basis. Paragraph 1 of the Annex to Resolution No. 525 indicates that:

"It will be understood that prior to I April 2007, all existing services in the band 21.4-22.0 GHz in Regions I and 3 operating in accordance with the Table of Frequency Allocation shall be entitled to continue to operate. After that date they may continue to operate, but they shall neither cause harmful interference to BSS (HDTV) systems nor be entitled to claim protection from such systems."

This requirement may result in f-fixed services needing to be relocated from the 21.4-22.0 GHz band to other nearby bands. Radiocommunication WP I 0- I I S has requested SG 9 to look into this topic [Doc. 10-11S/TEMP/5].

4 Trigger points for coordination

The trigger points whereby the power flux-density at the Earth's surface produced by emissions from a space station on the territory of any other country are:

- -115 dB(W/m2) in any 1 MHz band for angles of arrival between 0^o and 5^o above the horizontal plane; or

- -105 dB(W/m2) in any 1 MHz bind for angles of arrival between 25° and 90° above the horizontal plane; or
- values to be derived by linear interpolation between these limits for angles of arrival between 5° and 25° above the horizontal plane.

Radiocommunication WP 10- 11S reviewed these values which are to provide protection to the fixed service and apply only until 1 April 2007, in accordance with Resolution 525. Beyond this date, higher pfd levels may be introduced, subject to further studies on service availability requirements.

5 Service requirements

Further study is needed on the detailed development of service requirements for HDTV (BSS). A set of provisional requirements is listed below:

5.1 Overall system objectives

a) An agreed standard for satellite broadcasting of digital HDTV (see also 9).

b) The transmission standard should be applicable to other relevant media with the minimum conversion complexity.

c) The emitted signal shall be received by small (45-90 cm) individual antenna installation. It should also be suitable to feed cable bead-ends. Compatibility with B-ISDN is desired.

5.2 Service and coverage requirements

a) HDTV is intended for fixed reception with highest quality possible within HDTV format (virtual studio quality).

b) Service availability for a percentage of the time of the worst-month (service continuity for digital systems is normally determined by the drop-out point) to be determined by further study (see also 6).

c) Subjectively acceptable failure characteristics. In the 21 GHz range, this might require attenuation mitigation techniques such as layered modulation and channel coding as well as adaptive satellite e.i.r.p. control, providing standard definition and/or limited definition TV quality only in case of deep fadings.

Important note - Sound should not fail before the picture.

d) The choice of a technically suitable modulation technique to achieve (to the extent possible) high spectrum-efficiency, low transmit power and low protection ratios in order to maximize frequency reuse and minimize sharing constraints with the same and other services.

e) Possibility for national, multinational and subnational coverage.

f) Provisions for scrambling with the aim of spectrum shaping for energy dispersal.

g) Provisions for conditional access.

5.3 Multiplex-related requirements

a) All service elements related to one complete programme service have to be combined using adequate multiplexing techniques.

Service elements will include sound, picture and data and, optionally, baseband error protection.

b) Fixed gross bit rate at the output of the multiplexer.

c) Flexible mulfiplex configuration with dynamic reconfiguration. (This includes frequent transmission of mulfiplex configuration information.)

d) Common multiplex and service information (SI) for the various delivery systems.

5.4 Receiver requirements

a) User friendliness.

b) Acceptable receiver cost in mass production.

c) Maximum of commonality in signal processing for different delivery media, such as satellite, terrestrial and cable transmission.

d) Capability of receiving full quality digital HDTV signals delivered by satellite, terrestrial and cable networks (optionally in combination with existing TV signals).

6 Service availability

The availability of the HDTV-BSS needs to be given urgent further study. Some Administrations are proposing 99.6 to 99.7% of the worst-month for service continuity. It is noted that since-the HDTV system will probably be digital, the system will experience rapid degradation and not the gradual degradation experienced in ,dialogue systems. Careful selection of the coding and modulation may improve e service availability. Annex I and the Annex 3 give possible approaches to this topic.

Studies have been performed by Italy on advanced error protection strategies for digital TV/HDTV satellite provisioning. These strategies make use of an “inner” convolutional/trellis code associated with the digital modem and -in “outer” block code associated to the video codec to minimize the BER. In receivers operating at high bit rates the use of “parallel Viterbi” chips may be necessary and this can cause a coding gain degradation. Italy is studying [Doc. 10-11S/97 and TG 11/2] techniques to avoid this degradation.

Adaptive satellite e.i.r.p. control using multi-beam satellite antenna can provide another useful means to improve service availability especially for countries which have high density rainfalls. Annex 2 gives a concept of this approach.

It is expected that HDTV-BSS at 17 and 21 GHz has to cope with large attenuation in most countries. Service availability criteria should be discussed in the context of expected attenuation values and corresponding mitigation strategies.

Further study is needed on the topic of service availability and new mitigation technologies.

7 Scenarios for a future usage of the 21 GHz band

As mentioned in the introduction, the allocation of the 21 GHz band to BSS has only recently been made at the WARC-92.

As a consequence of this fact it is difficult at the present time to present consolidated scenarios for the future usage of this band, also taking into account that the allocation of the band will be only fully effective by April 2007.

Both Europe and Japan are now working in various research projects (e.g. HD-SAT in Europe) to overcome the technical challenges of exploiting the 21 GHz bind in order to prepare for the taking into operation of the studio-quality (wide-RF band) HDTV and ISDB broadcasting-satellite services in this band. Japan plans to launch in 1997 an experimental satellite COMETS (Communication and Broadcasting Engineering Test Satellite), including a 21 GHz band mission, to develop new broadcasting systems including ISDB (Integrated Services Digital Broadcasting). The bandwidth of the COMETS 21 GHz transponders will be 120 MHz (maximum). The output power will be 200 W and the number of beams will be 2 (assumed to cover the whole of Japan by 6 beams). New high-data rate broadcasting services supporting ultra high-definition TV and three-dimensional representation are also a long-term development goal in Japan.

The ITU-R has established a comprehensive Report on HDTV satellite broadcasting in this band (Report ITU-R BO. 1075-1) and is working on flexible planning concepts for this service.

While in the near future Europe will introduce digital multi-programme satellite TV ("multivision"), digital HDTV is a longer term concept, which may require an early access to the 21 GHz frequency band only if studio-like picture quality is anticipated. In any case the new band may not only help to ensure the future of satellite broadcasting but also that of the consumer television industry.

As a conclusion, it presently seems too early to evaluate the use and the regulatory matters of this band. The completion of the various projects now under way (e.g. the RACE HD-SAT and COMETS projects) will certainly help in setting up more suitable scenarios for the usage and planning of the 21 GHz band.

8 Standardization process

It is necessary to define the service and the associated key parameters in order to obtain the maximum efficiency when using the new frequency allocation.

It is known that the GSO is a limited resource. It is also known that the best way to obtain the maximum efficiency in the use of the orbit-spectrum resource is by proper implementation of the systems with a certain level of uniformity in their key parameters.

The implementation of wideband HDTV systems will be promoted when service objectives have been agreed by broadcast organizations, major BSS operators in industry.

To do that, it will be necessary to assess all the items that contribute to a complete characterization of the BSS (HDTV) systems such as:

Service objectives:

- service quality;
- service reliability.

System characteristics:

- propagation factors;
- source coding of W-HDTV signals;
- modulation and channel coding;
- receiving system characteristics;
- satellite and earth station technology.

Spectrum management:

- procedures for flexible usage of this band (up and downlink);
- total bandwidth required by each service;
- protection ratios;
- sharing with fixed and mobile services.

The results of the research projects currently carried out in Europe and Japan for the opening up of the 21 GHz band for wideband HDTV and multi-service ISDB satellite broadcasting will provide the basis for determining the aforementioned technical parameters.

9 Special applications

Special applications may require transmission standards which are different from those commonly used. For special events, satellite news gathering (SNG) in the FSS may be employed. Furthermore, there may be times when it is desirable for the signal to be sent straight to the BSS satellite instead of via a studio.

A number of SNG terminals do not operate at bit rates of 140 Mbit/s but use lower rates such as 68 or 34 Mbit/s or lower. Further study is needed on how these special applications may be accommodated in the HDTV-BSS environment. Working Party 4/SNG is currently examining these aspects.

10 Feeder links

Although a worldwide allocation for feeder links was sought at WARC-92, it was not achieved. The 17.3-18.1 GHz band is available for HDTV-BSS feeder links. This band is shared with other services including feeder links for the WARC-77 and RARC-83 Plans. Sharing conditions impose constraints on the flexible use of this band for HDTV-BSS feeder links. The band 18.1-18.4 GHz may be used for feeder links although it is not available in certain countries. In Regions 2 and 3, the band 24.75-25.25 GHz is also available. The existing FSS bind 27.5-30.0 GHz could be used worldwide but sharing is then required with FSS systems.

References

All issues mentioned are treated within the research work (see for example [1], [2] and [3]).

[1] TSUZUKU, A., FUKUCHI, *et al* [6-9 September, 1993] - Advanced satellite broadcasting experiment using Japan’s R&D satellite COMETS. *Proc. 23rd European Microwave Conference (EUM’93)*, Madrid, Spain, 110-112).

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[6] MERTENS, H. - Spectrum and planning aspects for digital HDTV satellite broadcasting in [4].

ANNEX 1

Possible coding and modulation approaches to improve service availability for digital HDTV satellite broadcasting

1 Introduction

WARC-92 allocated the frequency band 21.4-22.0 GHz to BSS (HDTV) in Regions 1 and 3 and the band 17.3 - 17.8 GHz in Region 2. Due to severe atmospheric attenuation levels in these frequency bands and in the 12 GHz BSS band for tropical countries, conventional digital techniques exhibiting abrupt breakdown failure characteristics may not be able to provide the required service availability without exceeding pfd limits under clear-sky conditions.

In this Annex, new coding/modulation approaches are considered to improve service availability of digital HDTV satellite-broadcasting services.

The advanced approaches outlined in this Annex achieve a graceful degradation of HDTV service during high rain fades; this behaviour is very similar to that of analogue systems which is well accepted by television viewers. Most of the time, e.g. for up to 99% of the worst-month, the service provides nominal HDTV quality, while during heavy rain fades, the receiver provides standard broadcast TV quality and/or limited definition TV quality

2 Examples of the layered modulation approach

2.1 Example 1

This example is based on an RF time mulfiplex combining various types of modulation [Palicot and Veillard, Sept. 1993].

The conceptual coding/modulation approaches are built around a frame (see Fig. 1) consisting of two parts:

Part 1 (R 1): HDTV component with high bit-rate signal of duration T_1;

Part 2 (R2): Conventional TV component with low bit-rate signal of duration T_2.

The low bit-rate R_2 signal is associated with a channel coding and modulation which are more robust in presence of noise than the channel coding and the modulation associated with the high bit-rate signal.

During severe atmospheric attenuations, the receiver automatically switches from the HDTV component to the conventional TV component. The switching criterion can be related to the received power or to the bit-error ratio of the HDTV component. For a given satellite transmitted power, this approach allows to extend the service continuity and hence to reduce the service outage time.

At the transmission side (Fig. 2), the HDTV signal is down-sampled and a compatible 625-line picture is obtained which is applied to coder 2. The residual component (difference between HDTV input and locally decoded output of coder 2) is coded by coder 1. This scheme allows to reduce the transmitted data rate or to increase the portion of the data rate allocated to the picture component in the multiplex.

At the reception site (Fig. 3), up-sampling (H:2/1, V:2/1) is carried out for the output of decoder 2 and the resulting information combined with the output of decoder 1 reconstructs the whole HDTV picture.

In order to compare the approaches outlined above with a reference system[* **] , it is assumed that the bit rate after HDTV coding is the same for a convention coder and for a compatible coder.

Figure 4 shows the failure characteristic of a compatible example compared to the reference system [Palicot and Veillard, 1993]. This figure exhibits hysterisis when switching between two service qualities to prevent excessively frequent switching.

2.2 Example 2

This example shows a layered modulation approach with three layers [Tsuzuku, *et al.,* 1993]. In other words, this example can realize graceful degradation with three grades.

As regards source coding, HDTV information is divided into three digital data streams according to the principle shown in Example 1. For example, the data streams are a VCR quality component, a difference component between conventional TV and VCR quality, and a difference component between HDTV and conventional TV quality. These three data streams are transmitted by the following hierarchical modulation method.

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[*] In Europe and in the United States,studies on the graceful degradation concept based on layered modulation are also undertaken for terrestrial emission of HDTV signals in order to adapt the service to different receive conditions (e.g. fixed and portable receivers). In the case of HDTV-BSS the concept of layered modulation provides for increased service continuity during high precipitation fades rather than for receiving optionally TV signals of lower resolution.

[**] The reference system is a system that uses a single bit rate.

The principle of this hierarchical modulation is controlling the Euclidean distance of the symbol. The constellation of the nominal 8-PSK is shown in Fig. 5(a). However, the immunity from the noise can be changed by taking a different distance between each symbol. An example of the constellation of the hierarchical 8-PSK is shown in Fig. 5(b). The 8-PSK symbol can transfer 3 bits, and each bit has different immunity from the noise by different Euclidean distance.

The BER (Bit-Error Ratio) characteristics of the hierarchical modulation shown in Fig. 5(b) is derived theoretically. The results are shown in Fig. 6. The BER of the first bit is the same as that of QPSK, the second bit is almost the same as that of the normal 8-PSK, and the third bit is nearly equal to that of 16-PSK. If the required BER is 10-4 (before error correction), the frequency utilization efficiency vs. *CIN* ratio is shown in Fig. 7. Using this modulation, when the *CIN* ratio is more than 22.6 dB, we can transfer the data 1.5 times as much as the QPSK.

2.3 Example 3

A further example of a layered modulation approach with three layers is given in 3 and 4 of Annex 3.

3 Fading characteristics due to heavy rain

Digital systems have rapid f-failure characteristics, so profiles of fading due to heavy rain affect the service availability of the system.

Examples of *CIN* fading due to heavy rain at 22 GHz are shown in Fig. 8. These profiles are estimated using a *CIN* drop profile measured at 12 GHz in Tokyo with the Japanese BS-3 broadcasting satellite and the method described in Report ITU-R PN.721-3. The rapid and deep fading characteristics in the 21 GHz band appear in the figures.

The lines for service interruption in the figures are calculated from the data described in Example 1 in § 2.1. As a transmission parameter, we assume 70 dBW satellite e.i.r.p., a 45 cm diameter reception antenna and 2.0 dB noise figure. Service outage time as estimated from the figure is summarized in Table 2.

For the viewers of HDTV, for example, even a relatively short interruption of service can severely disturb an attractive and exciting scene. Therefore, although it is important to evaluate the service continuity due to the rain attenuation with cumulative time percentage, detailed rain fade profiles are much more important when considering service availability. Digital broadcasting should bring excellent performance, far better than current FM television broadcasting.

It should be noted that the effectiveness of layered modulation depends largely on the available link budget margin for the high-quality service (HQ). Layered modulation can significantly improve the service availability, accepting a lower quality level of service during high precipitation periods, if the HQ link budget margin is relatively small (e.g. 3-4 dB), i.e. for limited satellite transmit power and/or small home receive antennas. If the HQ link budget margin is rather large, say 10-15 dB, because high satellite e.i.r.p. and/or large home receive antennas are used, the improvement in service continuity by the second (and, if applicable, the third layer) is relatively small, because rain attenuation increases exponentially for small cumulative percentages of time.

4 Summary

The described methods are examples of how the service continuity could be increased by using a concept of layered modulation in conjunction with layered picture coding and layered channel coding. Other variants of this principal approach are presently under investigation. It can already be deduced, however, that by means of this technique the service continuity could be extended to, or even exceed, 99.9% of the worst-month in areas of moderate climate without the need for increasing the satellite transmit power, the service quality under severe attenuation conditions being reduced from high definition to normal or limited definition television. In countries characterized by high density (tropical) rainstorms, additional measures such as adaptive satellite e.i.r.p. control method (see Annex 2) might be required to reach such a high service continuity. Nominal high-quality sound service should be preserved even under severe fades and the sound should only fail after the failure of picture.

The concepts outlined in this Annex warrant further study. For example:

- Effects of detailed compensation by the layered modulation approach using the practical rainfall profile.
- Parameters for efficient service availability and the threshold CIN value for each layer.
- Effects of frequent strong rainfall in typhoons, etc. and of heavy continuous rain.
- Complexity of the demodulator and the decrease of efficiency of spectrum usage due to layered transmission.
- Development of stable demodulator in a low CIN environment, especially for synchronization.

FIGURE 1

Time multiplex of high and low bit-rate components

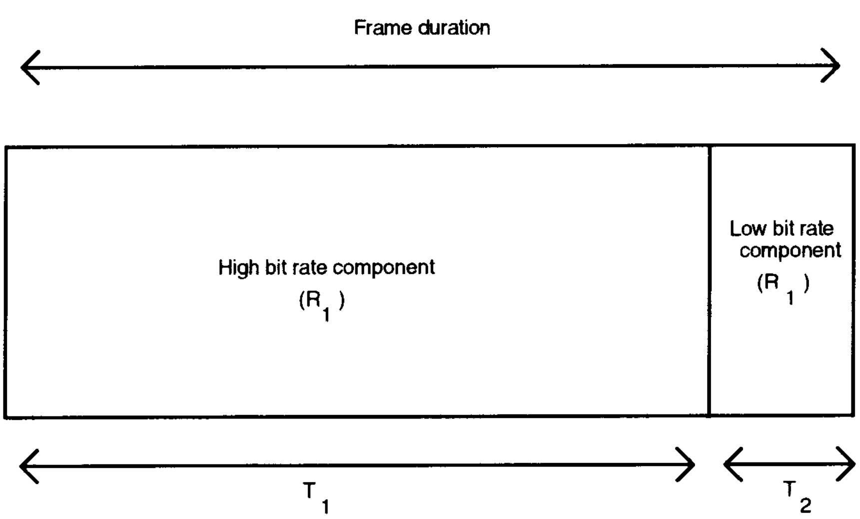


FIGURE 2

Example of compatible coding and modulation scheme

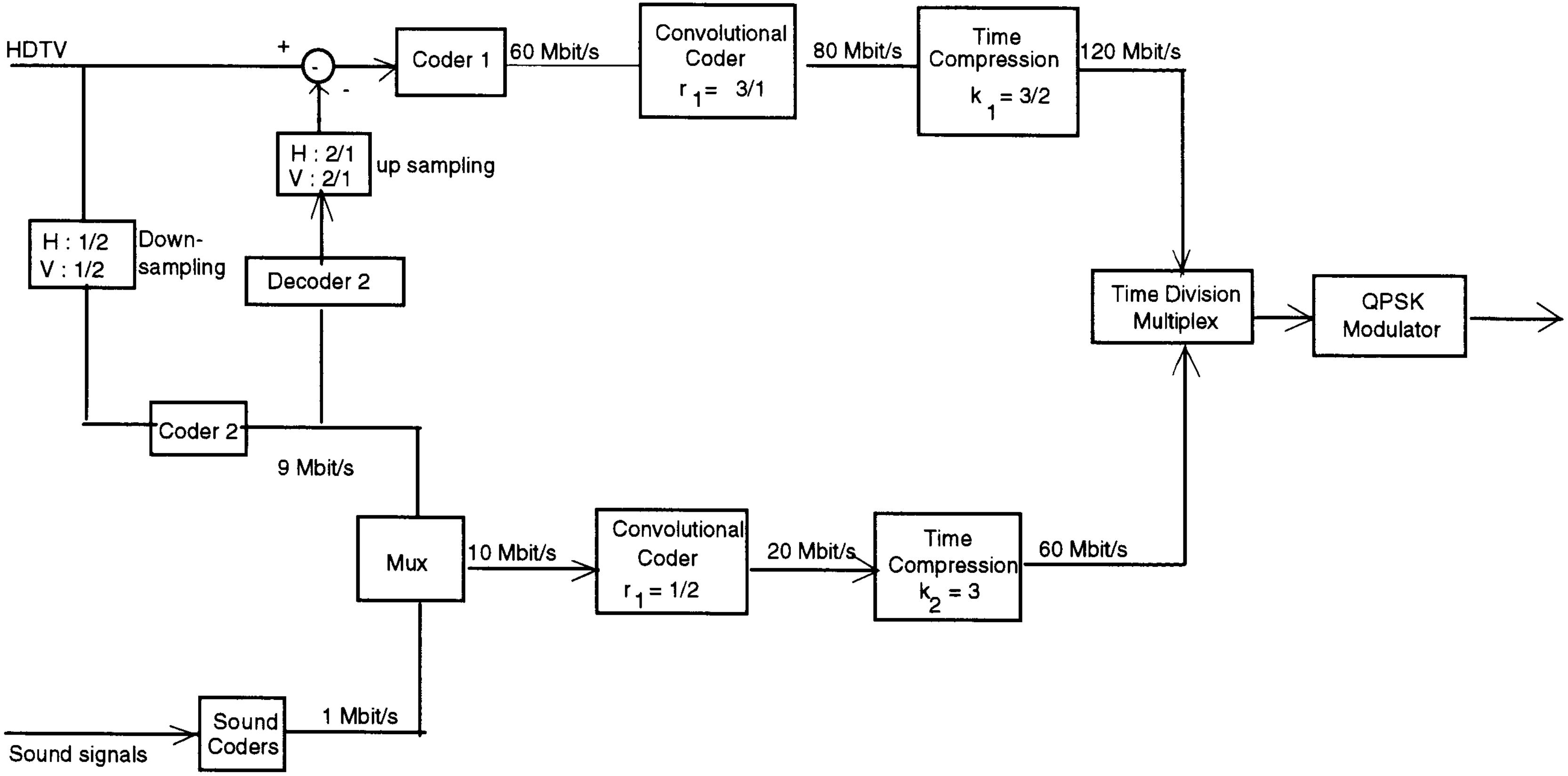


FIGURE 3

Example of compatible decoding and demodulation scheme

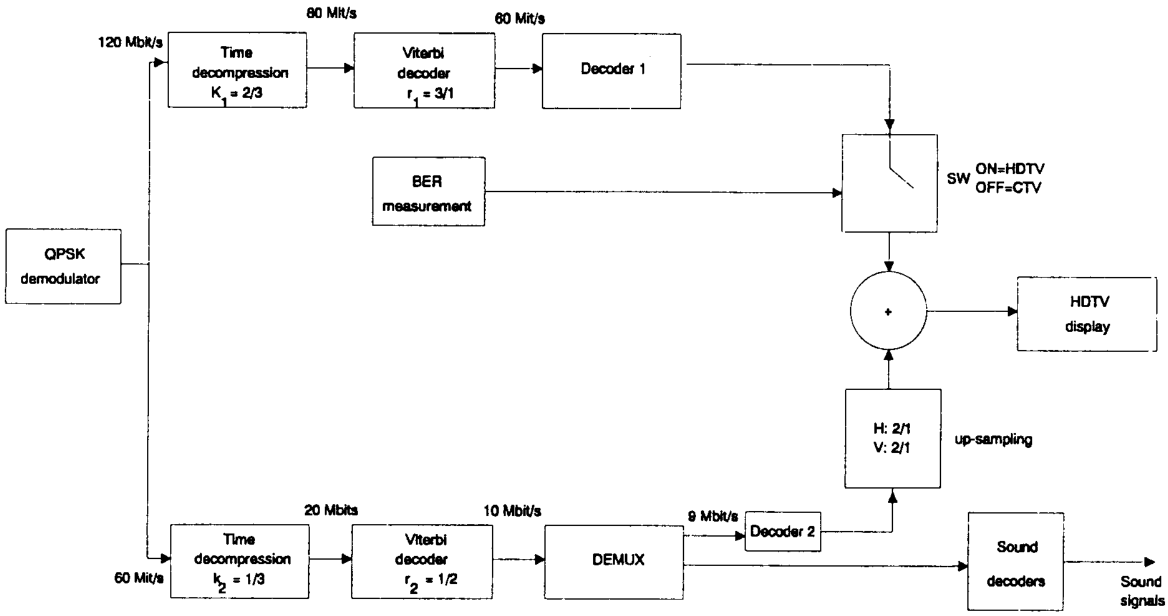
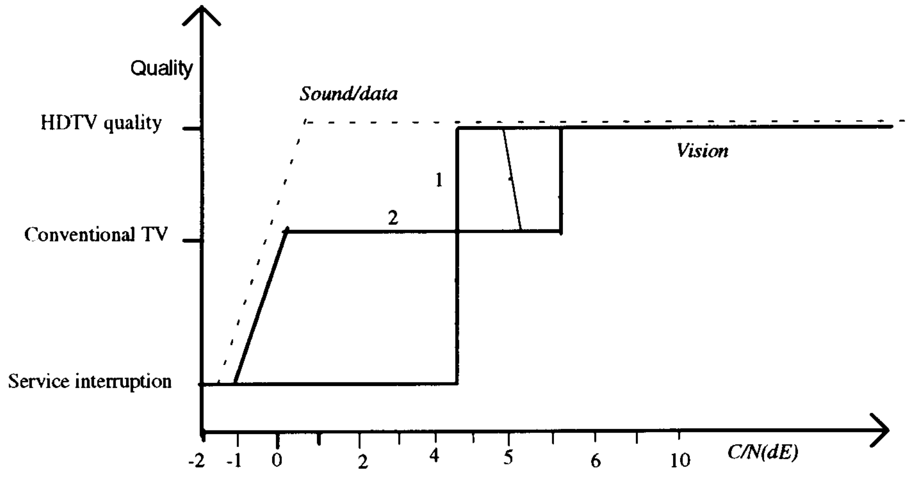


FIGURE 4

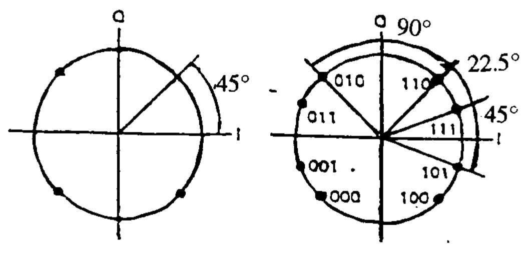
Picture/sound quality versus *C/N*: Comparison of failure characteristics between the compatible coding example and the reference system



1: Reference system (single bit rate)
2 : Compatible coding example

FIGURE 5

Principle of graceful degradation by hierarchical 8-PSK modulation



(a) 8-PSK (b) Hierarchical 8-PSK

FIGURE 6

Bit error rate characteristics of hierarchical 8-PSK

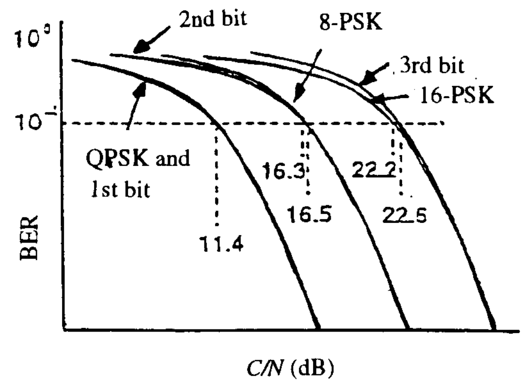


FIGURE 7

Frequency utilization of hierarchical 8-PSK

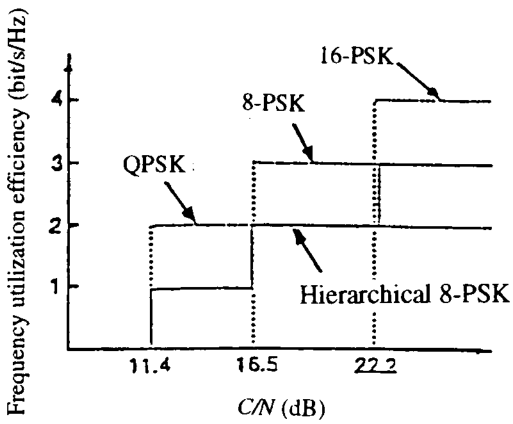
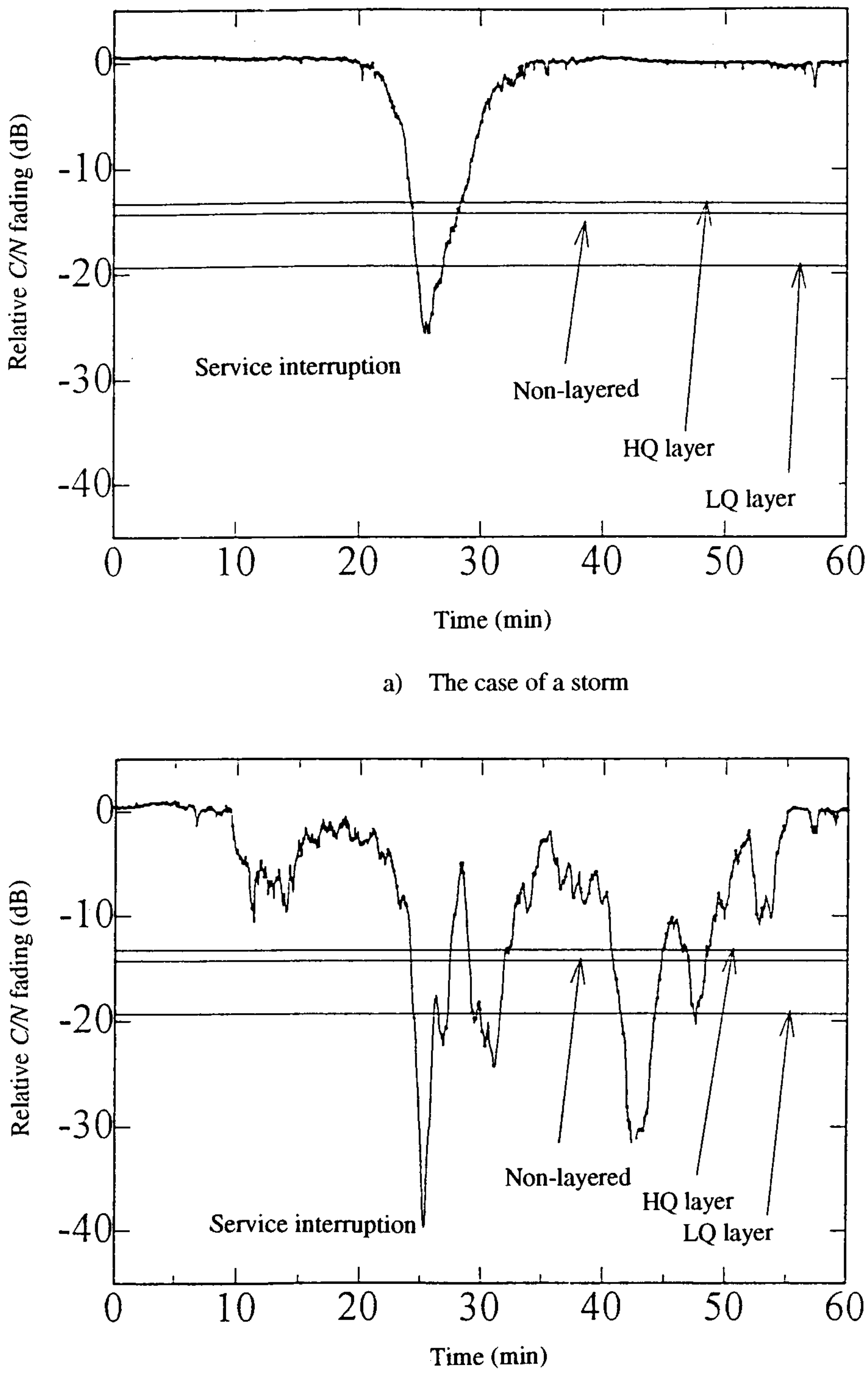


FIGURE 8

Examples of C/N fading due to rain at 22 GHz



a) The case of a storm

b) The case of a typhoon

TABLE 2

Service outage time by layered and non-layered transmission based on the examples in Fig. 8a) and b)

Example	Scheme	Service outage time (min)	Outage ratio to non-layered system (%)
a) - Storm	Non-layered	3.6	-
	Layered (HQ layer)	4.0	111
	Layered (LQ layer)	2.0	56
b) - Typhoon	Non-Layered	11.4	-
	Layered (HQ layer)	12.5	110
	Layered (LQ layer)	7.1	62

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ANNEX 2

An adaptive satellite e.i.r.p. control method for the 21 GHz band satellite broadcasting

1 Introduction

At 21 GHz, it seems difficult to install DBS services based on conventional transponder concept which is characterized by a single TWT per channel and for the whole service area. In order to cope with the rather high rain attenuations in the band, too big a power margin would have to be included in the link budget.

By dividing the service area into spot beams, lower power TWTs can be used. In addition, concepts to allow control of the transmit power individually for each spot beam permitting thus to compensate for locally concentrated atmospheric attenuations.

This Annex describes the technical aspects of an adaptive satellite e.i.r.p. control method for the 21 GHz band satellite broadcasting service.

2 Principle of the method

The service area is covered by a shaped beam consisting of, for example, six beams as shown in Fig. 9. Satellite transmitting power for each beam can be changed independently within the limit of total power. Then the power margin of this satellite is regarded as a common resource among the beams. The power margin is distributed to beams adaptively according to the rain intensities in the beams.

3 Example of the method

Example system parameters and link budget are shown in Tables 3 and 4, respectively. When sky is clear, the system uniformly covers the whole service area and compensates the gaseous attenuation of up to 3 dB. When it rains in some local areas, the e.i.r.p. toward these areas is continuously increased up to the maximum possible value. For the present example, a total of 10 dB of atmospheric attenuation can thus be compensated for (3 dB by the built-in margin for gases absorption and 7 dB by the variation of satellite transmission power. See Table 4).

A nominal block diagram of this variable e.i.r.p. transponder system is given in Fig. 10.

The increase in e.i.r.p. is made by an increase of the output power of TWTAs and a parallel operation Of two TWTAs. As shown in Fig. 10, for any given spot beam a group of TWTAs is directly connected to a feed horn through the multiplexer, and no BFN (beam fanning network) is placed. Therefore, the loss is low, and the large power does not concentrate on a point.

The rainfall’s spatial characteristics should be considered when introducing the adaptive e.i.r.p. control method. According to the actual observation of rainfall, the areas where heavy rainfall happens tend to be smaller than the beam size of broadcasting satellites. Rainfall areas may be widely distributed not only in a beam but also across some e beams.

Figure 11 shows examples of spatial correlation coefficients of rainfall in England [Fukuchi, 1988]. It shows that there is almost no correlation of rainfall in an area distant from a measuring site. Accordingly, the e.i.r.p. control method is effective only in the vicinity of the measuring site. To achieve efficient mitigation of heavy rain attenuation in the band and improve control, observatories should be located in populated areas. Otherwise, the use of data from densely concentrated measuring sites is required for thorough improvement of the efficiency of the adaptive e.i.r.p. control method.

4 Summary

This Annex presents an adaptively variable e.i.r.p. transponder system for a 21 GRZ band nationwide satellite broadcasting service. This approach has a potential to ensure high quality pictures with high service continuity by increasing the transmit power to areas effected from high density rain fades.

By using multiple TWTAs of rather limited power and the concept of spot beam antenna, a reliable transponder system can be built which is realizable, with respect to electric power sources and heat dissipation [Shogen *et al.*, 1992, 1993], with a satellite bus available at present.

The following subjects are left for future study:

1) Multibeam antenna.
2) Lightened TWT with variable power capability.
3) Techniques for combining RF power.
4) Combination with graceful degradation technique.
5) Not only service time availability but also spatial availability.
6) Performance of the e.i.r.p. control method in heavy local rainfall, like thunderstorms.
7) Establishment of optimum measuring sites and the detailed operation strategy of the e.i.r.p. control.

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FIGURE 9

Footprint of 6 beams

(example for Japan)

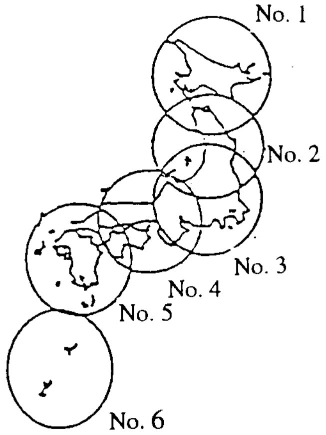


FIGURE 10

A block diagram of the variable e.i.r.p. transponder system

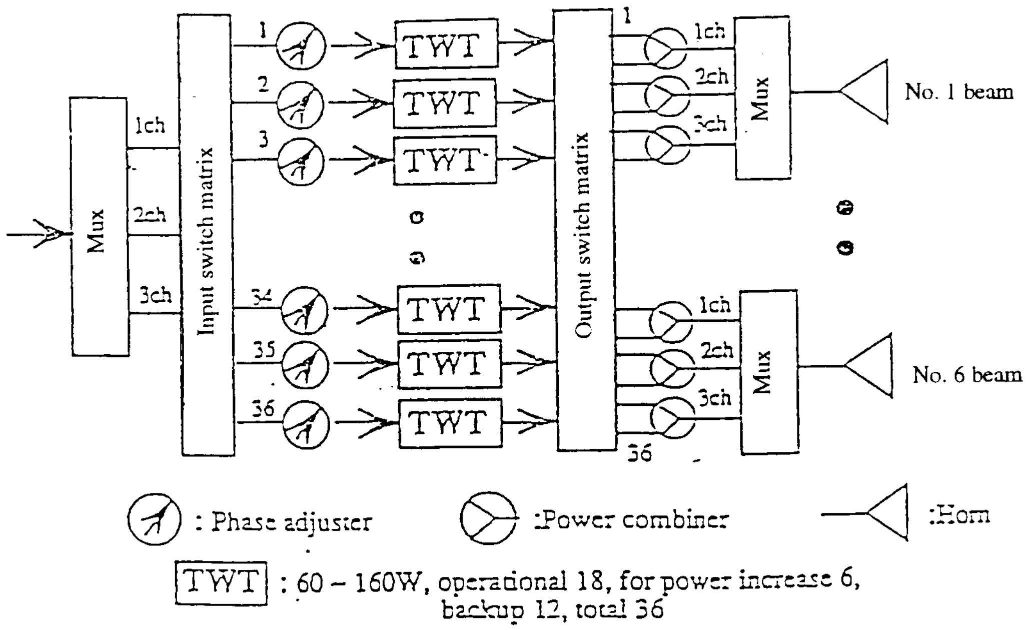


FIGURE 11

Separation distance dependence of the correlation coefficients between rainfall rates at two locations
(Symbol: measured line: approximated)
Integration time (5 min)

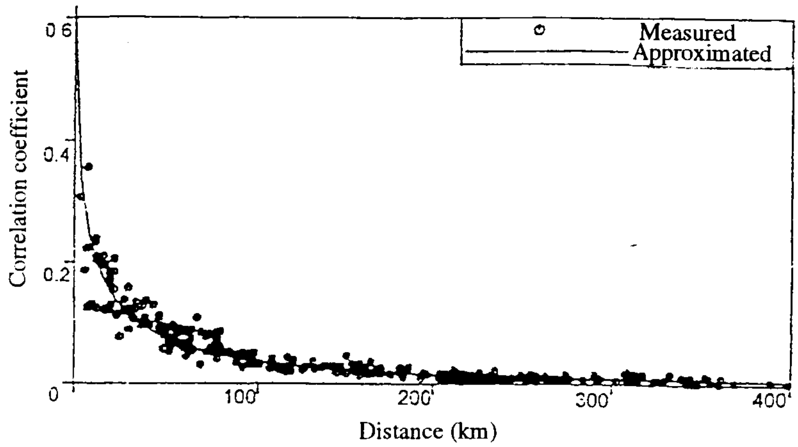


TABLE 3

Assumed 21 GHz band DBS system parameters

Frequency	21.4 ~ 22 GHz
Receiving antenna at home	45 cm in diameter
NF of converter at home	1.5 dB
Available service time	99% of the worst-month
Required total *C/N* ratio(1)	10 dB
Usable bit rate	78.336 Mbit/s(2)
Modulation	QPSK with ¾ convolutional code
Bit rate(3)	104.448 Mbit/s
Nyquist bandwidth	52.224 MHz
No. of channels/satellite(4)	3
Required bit error rate	10^{-8}

(1) E_b/N_0 = 5.2 dB, demodulator degradation = 2 dB, interference = 1 dB.

(2) Picture 70 Mbit/s, sound 2 Mbit/s, data 1.421 Mbit/s, FEC 4.915 Mbit/s (FEC:RS(255,239)).

(3) An integral multiple of the basic bit rate of 2.048 Mbit/s.

(4) From the limitation of electric power and heat treatment.

TABLE 4

Example of link budget at Tokyo

Satellite parameters		Clear sky	Rain
Frequency of carrier	(GHz)	22.0	
Transmitter power	(W)	60	320
Transmitting antenna gain	(dBi)	47	
Feeder loss	(dB)	-4	
e.i.r.p.	(dBW)	60.78	68.05
Propagation factors			
Free space loss	(dB)	-210.87	
Gaseous attenuation	(dB)	-3.14	
Rain attenuation	(dB)	0	-6.73
Receiving system			
Antenna diameter	(cm)	45	
Antenna efficiency	(%)	70	
Pointing error loss	(dB)	-1.0	
Antenna noise temperature	(^{o}K)	144.12	233.21
Noise figure of converter	(dB)	1.5	
Environmental temperature	(^{o}C)	24.9	
Equivalent noise temperature	(^{o}K)	122.89	
Noise (Nyquist) bandwidth	(MHz)	52.224	
Downlink *C/N*	(dB)	11.69	10.98
Feeder link *C/N*	(dB)	30	
Total *C/N*	(dB)	11.63	10.93

ANNEX 3

Bandwidth efficient coding and modulation schemes for wideband HDTV applications supported by satellite and cable networks

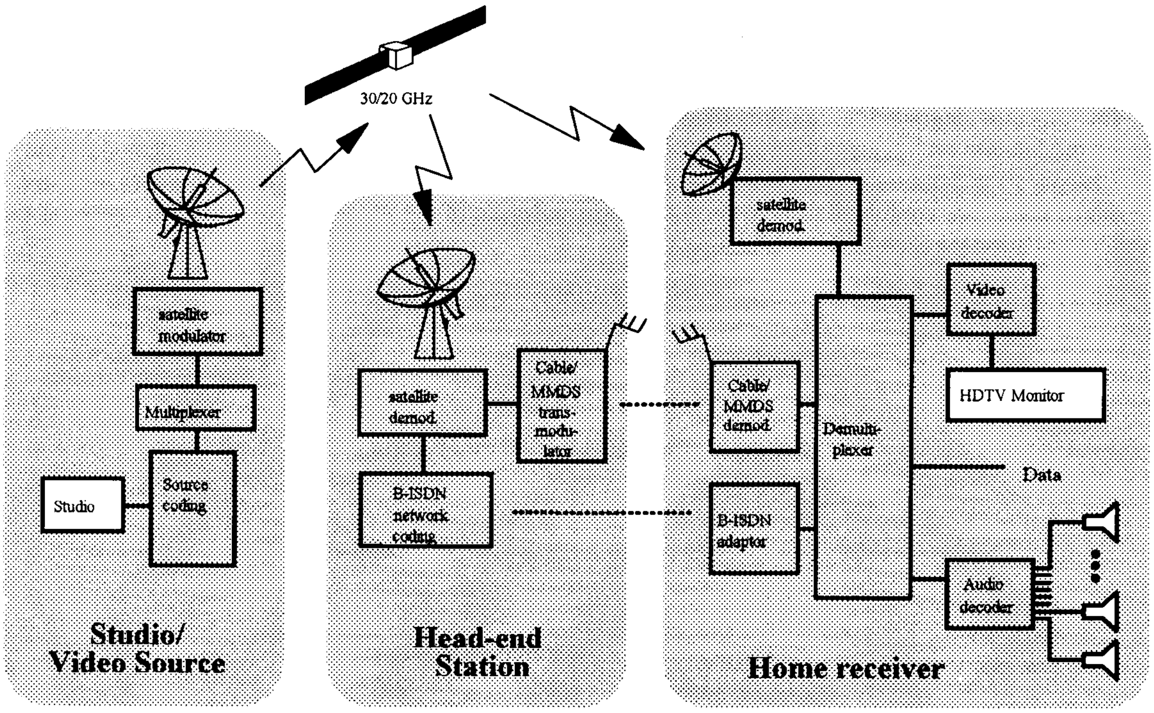
1 Introduction

HD-SAT [1] is an ongoing research project begun in 1992, jointly funded by the participating partners and the European Commission (DG XIN) as part of the RACE 11 programme. HD-SAT bas as its objective to study, develop and demonstrate the feasibility of a complete broadcasting chain based on 30/20 GHz satellite transmission to potentially provide to the television end-user’s home virtual studio quality HDTV, along with multilingual/multichannel sound. The HD-SAT “system”, includes the studio to satellite uplink, the direct-to-home (DTH) satellite reception, as well as secondary distribution via terrestrial networks including cable and MMDS

(Multipoint Microwave Distribution System), as well as the currently developing Integrated Broadband Communication Networks (IBCN). Fig. 12 below gives the overall architecture of the HD-SAT system.

FIGURE 12

Overall HD-SAT system architecture



A proposal for “Bandwidth efficient coding and modulation schemes for wideband HDTV applications -supported by satellite and cable networks” is given below, and contains the main following items:

- a summary of the basic HD-SAT service characterization;
- an introduction to graceful degradation in the Ka-band for service continuity;
- an example of a three-layer system;
- an introduction to the interworking aspects considered in the Project, and more particularly the “common receiver concept” and the “interoperability with cable networks”.

2 Service characterization

Service requirements and characterizations within the HD-SAT project have been determined with user requirement studies including a comprehensive survey which was sent to European satellite operators, terrestrial broadcasters and cable network operators.

A summary of the basic HD-SAT service characterization is given below:

- service availability of 99.6% (of worst-month);

- highest quality possible within HDTV format *(virtual studio quality);*
- European coverage;
- small (60 - 90 cm) direct-to-home receiver antenna;
- full quality service to the end-user via cable and MMDS networks.

3 Service continuity - graceful degradation in the Ka-band

The use of the 20 GHz frequency band for satellite transmission must cope in an efficient way with the adverse propagation conditions in these bands, which are characterized by deep rain fades and atmospheric depolarization. A key issue is the service continuity, for which new solutions are implemented which involve layered channel modulation to allow for a "graceful degradation" under deteriorating atmospheric conditions.

Contrary to the gradual degradation observed in analogue systems, for digital TV it is possible to go from virtually error-free reception to complete loss of picture decoder operation over a range of less than 1 dB of *CIN* degradation (the brick-wall effect). By providing for the means of receiving lower quality pictures under deteriorating reception conditions, digital graceful degradation can allow for an increased service continuity.

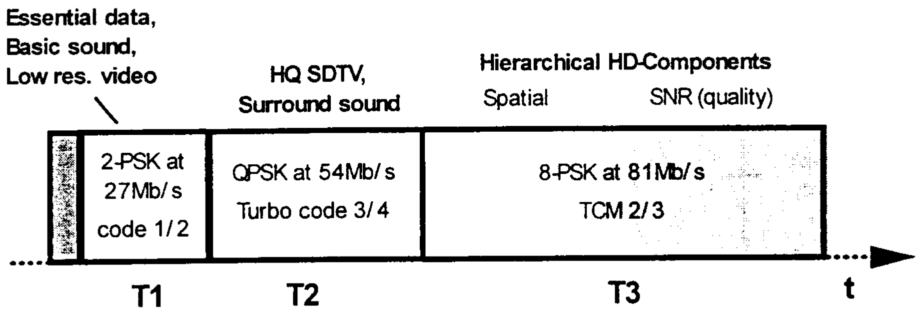
The goal for a successful satellite modulation scheme is, using minimum satellite power and a small home receiver antenna size, to achieve service continuity for 99.6% of the worst-month within Europe.

The graceful degradation satellite modem for HD-SAT has been conceived using the concept of time-multiplex of modulation techniques offering a hierarchy of *CIN* values required for successful demodulation. In this way, as the propagation conditions deteriorate, the modulation layers requiring the higher *CIN* values ire "lost", while the more robust layers are con6nued to be received. Synchronization of the modem is simplified by keeping the same symbol rate (27 MBd/s) for each of the modulation layers.

Figure 13 illustrates the modulation "frame" for a three-layer implementation.

FIGURE 13

Example of hierarchical channel coding



T1: Turbo code 1/2.

T2: Turbo code 3/4 or "convolutional code and Reed-Solomon".

When choosing, for example, the ratio T1:T:2:T3 = 1:3:6, the corresponding bit rates will be 2.7 Mbit/s for T1, 16.2 Mbit/s for T2 and 48.6 Mbit/s for T3, giving the total gross bit rate of 67.5 Mbit/s.

8-PSK modulation combined with Trellis convolution coding is selected as an appropriate scheme for the highest spectral efficiency (but least “robust”) of the HD-SAT modulation hierarchy. Lower level schemes include QPSK with Turbo code or a classical scheme of convolutional code with concatenated Reed-Solomon, for an intermediate level of service, and 2-PSK for the low-level service fallback mode.

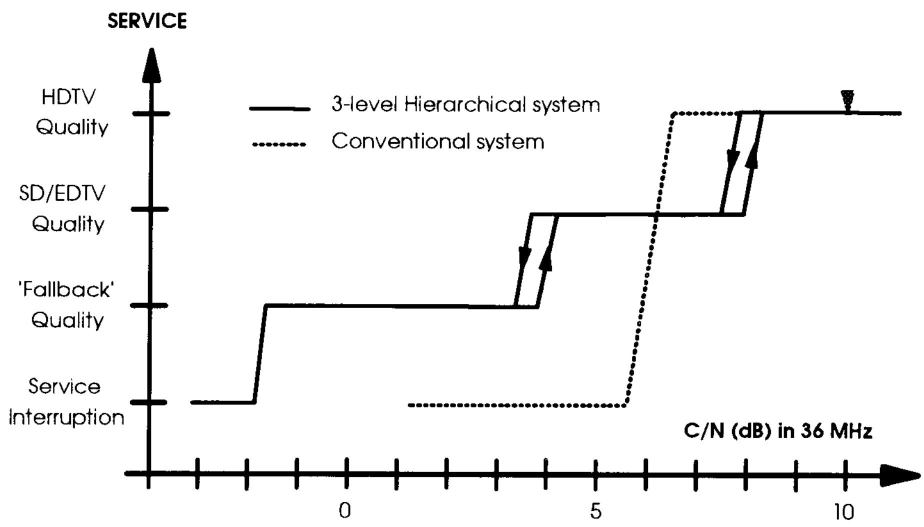
Turbo coding uses iterative processes in a hardware efficient implementation of code concatenation. lt is particularly effective when applied to relatively low code rates. Results of turbo coding applied to QPSK within HD-SAT show a significant coding gain, a high degree of independence to roll-off combined with good transmission efficiency (by removing the need for an FEC outer code) within a non-linear satellite channel. Under these conditions the performance of the channel coding closely approaches the Shannon limit.

A modulation scheme allowing for approximately 12 dB of attenuation between the nominal clear sky operating point for HDTV and complete loss of service is proposed as a viable solution. Of this 12 dB, 9 dB is provided by the graceful degradation operation itself, with the remaining 3 dB coming from the operating point of a “nominal” home receiver antenna.

A graph of HD-SAT service versus received *CIN* is given as Fig. 14 to illustrate the graceful degradation operation and performance.

FIGURE 14

Hierarchical channel coding *C/N* performance



4 Picture coding (MPEG-2) and attribution of the modulation layers

The HD-SAT system uses MPEG-2 coding (high profile at high level) and multiplexing, which amongst other functionalities offers the two following key features:

- spatial and SNR scalability;
- downward compatibility.

The codec definition and the function of the satellite graceful degradation modem use intimately related. The allocaton of the appropriate components of the Codec to the modulation layer will define the HD-SAT services under graceful degradation.

The three-layer system below is chosen primarily for its comprehensive range of service availabilities over both moderate and severely degraded propagation conditions, as well as for its potential for interworking with other systems and media.

TABLE 5

Performances of layers

1st layer	Essential data, sound and limited definition image	e.g. 1.5 Mbit/s
2nd layer	“Good”quality SDTV sound and image and additional data	e.g. 10 Mbit/s
3rd layer	First sublayer: Spatial hierarchical data complement to achieve HDTV quality	e.g. 15 Mbit/s
	Second sublayer: Additional SNR scalable information complement to reach virtual studio quality HDTV	e.g. 20 Mbit/s

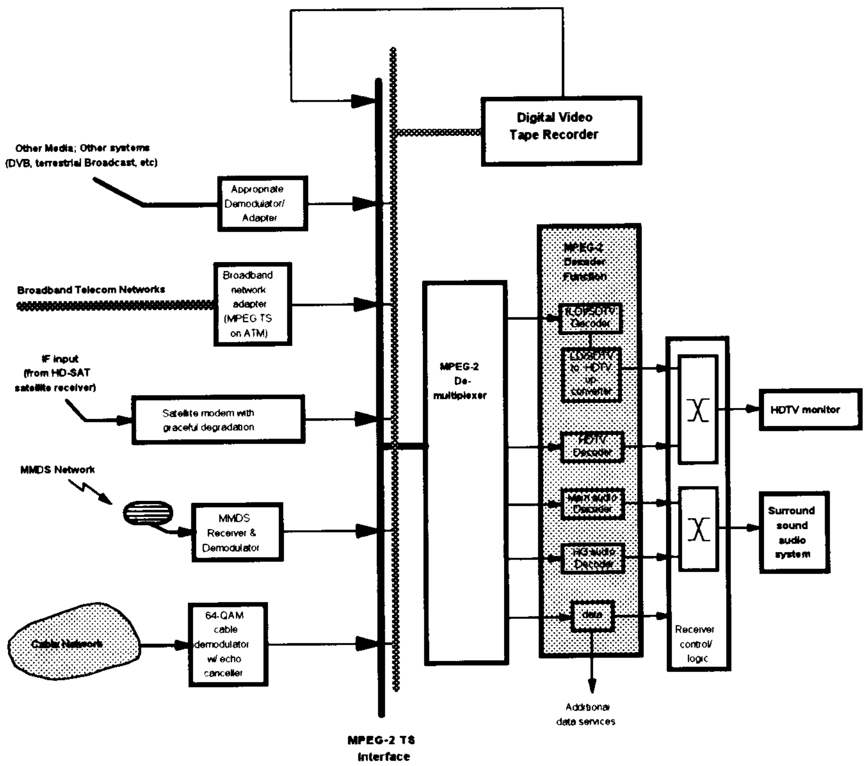
5 Interworking aspects

5.1 Common receiver concept

Interworking between media and television formats could be made economically feasible by the concept of the *Common Receiver* (see Fig. 15) which allows an end-user to receive programmes and services over a variety of media using a common demultiplexer, source decoder and display. For etch media to be exploited, this common receiver uses the appropriate channel adapter/decoder which provides the common MPEG-2 transport stream format to the input of the multiplexer.

FIGURE 15

HD-SAT common receiver architecture



5.2 Interoperability with cable networks

The channel characteristics of a coaxial television cable network are very different from those of a satellite transponder. In particular, there is no need nor place for graceful degradation within the cable channel.

At the cable head-end, an adaptation of the HD-SAT MPEG-2 transport stream is required to optimize the use of the cable bandwidth. The base HD-SAT MPEG-2 transport stream necessarily contains some additional components for the service continuity fallback service which are not used in media implementation without graceful degradation.

For these purposes an MPEG-2 *transmultiplexer* is placed between the satellite demodulator and the cable modulator. The MPEG-2 transmultiplexer is effectively an MPEG-2 "switch" which accepts one (or several) MPEG-2 transport stream(s) on the inputs and delivers one (or several) MPEG-2 transport stream(s) on the output. The transmultiplexer is programmable to allow re-arrangement of the components and programmes which in this application means a filtering out of the unneeded components.

The cable bead-end station is configured in such a way that operation under graceful degradation modes is not used. In increasing the antenna size by a factor of about four relative to the direct-to-home receiver, the HDTV service -continuity is the same or better than the overall service continuity for the direct-to-home receiver implementing graceful degradation. The resultant antenna size for the cable head-end would be on the order of 2.5 m. It is further noted that the additional increase in service availability which would be gained in using the graceful degradation modes under these larger antenna conditions is negligible.

Looking for maximum commonality with the system proposed by DVB, HD-SAT is developing 64-QAM transmission for cable, offering a capacity of 45 Mbit/s of channel data rate within 8 MHz.

Reference

[11] The HD-SAT consortium is comprised by 12 European partners forming a complete team which includes Broadcasters, Research Institutions and Industry: Alcatel Espace - F (Coordinating partner), Alcatel Italia - 1, Alenia Spazio - 1, Cable Management International Services (CMIS) - IRL, Centre Commute D'Etudes de Télédiffusion et Télécommunications (CCETT) - F, Institut für Rundfunktechnik (IRT) - D, Radio Televisions Italia (RAI) - 1, Télédiffusion de France (TDF) - F, Thomson CSF - F, University of Salford UK, British Broadcasting Corporation (BBC) - UK, and the European Broadcasting Union (sponsoring partner).

Additional sponsorship support to HD-SAT includes: Deutsche Bundespost Telekom (D), The European Space Agency, Telespuio (1), Radiotelevision Eireann (IRL).