RECOMMENDATION ITU-R BO.788-1*

Coding rate for virtually transparent studio quality HDTV emissions in the broadcasting-satellite service

(Questions ITU-R 92/11 and ITU-R 100/11)

(1992-1994)

The ITU Radiocommunication Assembly,

considering

a) that wide-RF band HDTV should provide virtually transparent studio quality;

b) that digital studio quality HDTV signals require about 1 Gbit/s for an interlaced picture and about 2 Gbit/s for a progressively scanned picture;

c) that practical satellite emissions will require a substantial reduction of these bit rates given the demands on the radio-frequency spectrum and other technical and economic aspects;

d) that bit-rate reduction can be achieved by source coding which could, at its best, provide virtually transparent picture quality free of any remaining perceptible coding artifacts;

e) that several bit-rate reduction techniques are continuously being investigated by various administrations in the three ITU Regions;

f) that satellite broadcasting of HDTV signals should aim at being compatible with hierarchical levels of the digital network, e.g. 140 Mbit/s;

g) that the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92) has allocated the bands 21.4-22 GHz in Regions 1 and 3 and 17.3-17.8 GHz in Region 2 to the broadcasting-satellite service (BSS), for HDTV,

recommends

1 that at present

– when a virtually transparent picture quality is desired for reception of BSS HDTV emissions, the coding of the vision signal requires around 110 Mbit/s;

– another 10 to 30 Mbit/s would be required for programme sound, ancillary data, framing, synchronization and baseband error correction;

2 that members of the Radiocommunication Sector involved in the development of bit-rate reduction techniques be encouraged to continue their efforts with the aim of meeting the same picture quality with bit rates lower than 140 Mbit/s.

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* Radiocommunication Study Group 6 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44.

ANNEX 1

Quality objectives for the digital picture coding of virtually transparent studio quality HDTV

1 Introduction

This Recommendation states that, at present, a data rate of about 110 Mbit/s would suffice in order to provide for digital HDTV a picture quality which is virtually transparent to that of the current studio signal.

In addition, the Recommendation calls for continued efforts in the development of bit-rate reduction techniques to meet the same picture quality with lower bit rates.

The aim of this Annex is to provide supporting technical information.

2 Intrinsic picture quality

Various methods have been developed to compress the studio data rate of about 1 Gbit/s (interlaced picture) down to values which can reasonably be transmitted in BSS or other radiocommunication channels. Examples of methods are:

– hybrid discrete cosine transform (DCT),

– sub-band coding, and

– vector quantization.

Hybrid DCT has currently become the most widely used algorithm. All these methods make use of motion compensation in combination with variable length code (VLC) coding and/or other coding techniques.

2.1 General remarks on coding artifacts

Bit-rate reduction processes rely on eliminating, to a greater or lesser extent, redundant and/or irrelevant information of the vision (or sound) studio signal. In doing this, inevitably coding artifacts are introduced. The challenge for the system designer is to determine the coding algorithm such that these artifacts remain virtually imperceptible under the defined viewing conditions. However, for some very critical images containing a high content of moving parts this might not be achieved and some visible artifacts will appear in the decoded picture; for example, reduction in resolution of fine details, diagonal information and especially dynamic motion portrayal. For high-quality transmissions a sufficiently high bit rate needs to be made available in order to achieve in practice an unimpaired picture under nominal receiving conditions for a high percentage of the picture content expected to occur in broadcasting applications.

In general, for any bit-rate reduction process, one could state that the higher the available transmission bit rate, the lower the probability of perceptible artifacts (defects) in the picture due to the vision coding process. Quite generally, one could also state that with increasing complexity of the picture coding algorithm the data rate necessary to maintain the desired subjective picture quality can be reduced.

In order to transmit an HDTV broadcast signal, the quality of which is subjectively virtually transparent to that of the studio or production signal, most experts today agree that some 110-120 Mbit/s would be sufficient for the coding of the vision signal. The vast majority of pictures (including highly critical motion portrayal) would be free of perceptible coding artifacts. It should be noted that for any bit-rate reduced vision system, images could be found or determined which would overload the information capacity of the system. For example, a picture which is composed of white Gaussian noise will be reproduced more or less incorrectly because of the complete lack of correlation in the picture content.

2.2 Target for wide-RF band HDTV satellite broadcasting

The service quality for the wide-RF band HDTV satellite broadcasting service should be targeted to:

– be virtually transparent to the HDTV studio production system. This implies virtually no perceptible reduction of the spatio/temporal resolution or additional artifacts to the HDTV image as viewed from a distance of three times the picture height;

– convey a quality that can be perceived by the viewer as subjectively equivalent to that of the HDTV image and sound as produced in the studio.

It is to be noted that, to date, no formal assessment method has been adopted to express the quality of digitally coded, bit-rate reduced HDTV (and normal definition TV) pictures. There is no real definition of the term "virtually transparent studio quality". An attempt was made to apply the ITU-R method which was developed for analogue TV signals (currently under study by Radiocommunication Study Group 6). This method determines by subjective assessments the mean difference between the scores of the test and the reference conditions, using the double-stimulus continuous quality scale in accordance with the conditions of Recommendation ITU-R BT.500. For distribution purposes a mean difference of 12% is often applied for conventional analogue systems.

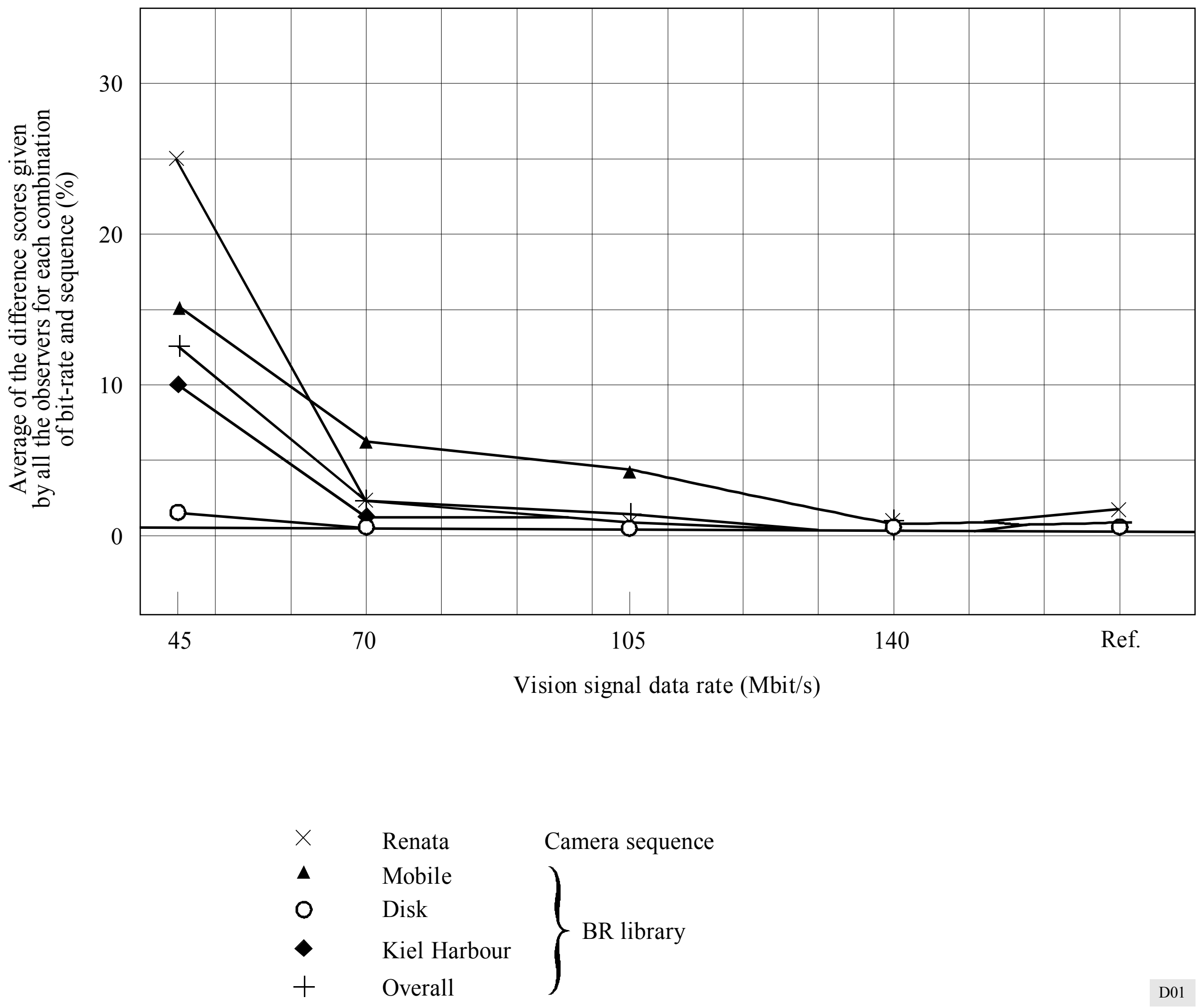
It remains doubtful whether this value also holds for virtually transparent quality which requires, as defined above, a video signal subjectively free of perceptible artifacts. In addition, quality rating may not be the most representative method to describe the performance of picture coding systems using bit-rate reduction, where, for a given algorithm, coding artifacts depend on the actual content of a video sequence and on the maximum available data rate, and where artifacts may be systematic. Radiocommunication Study Group 6 is planning to evaluate the quality of HDTV systems as a function of the programme content criticality and its probability of occurrence. This will also define the "picture content failure characteristic" of a system and will provide a more useful measure of a system than a simple quality rating. The wide-RF band HDTV systems are assumed to be capable of transmitting any image produced by a camera or image generation device which would be representative of typical programme material.

An example measurement undertaken by RAI to determine the performance of the EUREKA-256 HDTV codec is presented here in order to illustrate the need for a proper definition of the term "virtually transparent studio quality".

Figure 1 gives the results of some limited formal assessment tests (see Appendix 1 for the details on the measurement conditions). For five different video sequences the Figure reads the mean difference of scores between the decoded and the uncoded (studio) pictures as a function of the data rate available for the vision signal. At 140 Mbit/s, no sequence gives rise to visible artifacts. When coded with 105 Mbit/s artifacts start to appear but stay within a few per cent of mean scores. These results thus seem to support the value of about 110 Mbit/s stated as being necessary in this Recommendation. On the other hand, if the usual 12% criterion as a limit of quality for distribution purposes were applied, about 60 Mbit/s would suffice.

FIGURE 1

Results of picture quality measurements on the example HDTV codec
Tests using the HDTV studio format 1 920/2:1/50
Viewing distance: 3H for HDTV



2.3 The need for headroom

The quality available from consumer HDTV studio equipment will improve in time with better equipment characteristics. Equally, the resolution available from HDTV displays is likely to increase with time. The quality expectation of the public is also likely to rise in time. The performance claimed above for the HDTV-BSS will thus have to evolve accordingly. In addition, new services might be introduced in the future such as stereoscopy and some form of holography. Therefore, a certain amount of headroom will be needed to take account of all these possible developments. This headroom can be assumed to be in the potential improvement of the source coding algorithms. These better algorithms should not only be thought of as a way to reduce the bit rate required for a given quality, but also should be used to increase the quality of reproduction as necessitated by improvements in studio, displays and higher expectation of the viewing audience.

The quality performance defined above will be needed in the future for the wide-RF band HDTV-BSS in order to allow it to provide a quality similar to what is expected to be delivered by the other HDTV delivery media such as optical fibre networks (e.g. B-ISDN) and recorded media (e.g. disks and cassettes). The wide-RF band HDTV-BSS has the potential to provide the same quality of service to all viewers anywhere in relatively large service areas. Availability of a suitable frequency band for this service would allow for orderly implementation of such service, and should allow it to match the quality of other delivery media.

2.4 Overview on various current studies

Computer simulation which was carried out in Japan, the United States of America and Europe on both hybrid DCT and vector quantization consistently confirms that, for a rate of about 120 Mbit/s (video only), an excellent picture quality can be achieved without noticeable degradation.

At a rate of 60 Mbit/s (video only) the computer simulations indicated that hybrid DCT methods with motion compensation would achieve good picture quality for most of the images except for a slight degradation with specific test pictures.

Hardware test transmission carried out in Europe seem to confirm these computer studies (see also § 2.2). Various large research projects have been launched in Europe in order to continue the studies on digital HDTV broadcasting. Whereas for satellite broadcasting emphasis is on quality requirements as defined by this Recommendation (RACE 2075, HD-SAT), coding schemes for terrestrial broadcasting of digital HDTV should provide for the best quality (not necessarily matching that of the studio) which is possible under the bandwidth constraints of terrestrial TV channels (RACE 2082, DTTB).

Subjective tests are being conducted in the United States of America and Canada on four digital compression hardware systems operating at data rates of 20-25 Mbit/s (vision signal data rates nominally 17 Mbit/s) intended for terrestrial broadcasting of digital HDTV. Non-expert viewer judgements reported excellent picture quality over a wide range of still pictures and motion sequences using the double-stimulus continuous quality scale in accordance with conditions of Recommendation ITU-R BT.500. Mean differences between the scores for the test and the studio reference signal (1125/2:1/60 Hz) ranged between 2% and 14%.

Taking the above studies into consideration, evaluation procedures including proper video sources for digitally coded HDTV pictures and sequences should be studied and a standardized procedure should be authorized for unique subjective evaluation.

3 Conclusions on source coding for vision

There is a very close relationship between the required picture quality and the necessary bit rate for vision coding. Computer simulations, hardware evaluation and field tests done so far have revealed that about 110 Mbit/s (video only) would fulfil the requirements for highest possible quality (transparent studio quality). This bit rate would also provide, once compression techniques progress further, some headroom to cope with future improved (progressive) studio signals and/or enhanced display techniques.

Whether bit rates well below this figure would also meet highest quality requirements has not been shown yet. Work in progress indicates that coding techniques would eventually lead to video baseband bit rates in the order of 45-70 Mbit/s while meeting the described quality requirements. If strict transparency to the studio quality is not required, that is to say, for certain very critical pictures if one accepts some perceptible coding artifacts these and even lower rates can certainly be achieved.

Any refinements in coding techniques leading to lower bit-rate requirements will result in a corresponding decrease of RF channel width and hence in a corresponding increase of the capacity of a given BSS band.

APPENDIX 1

Details on the measurement conditions for the example codec

System:	EU256
Algorithm:	Hybrid DCT with motion compensation and entropy (VLC) coding
Source material:	Five digitally produced 4:2:2 sequences scaled to HDTV 1920/2:1/50
Viewing:	High quality 4:2:2 monitors at 3H of the virtual HDTV picture
Method:	Subjective assessments according to the double-stimulus continuous-quality scale method described in Recommendation ITU-R BT.500
Observers:	Non-expert viewers

APPENDIX 2

List of abbreviations

B-ISDN:	broadband integrated services digital network
DCT:	discrete cosine transform
DTTB:	digital terrestrial television broadcasting
EUREKA:	European Research Programme
RACE:	research and development on advanced telecommunication technologies in Europe
RAI:	Radio Televisione Italiana
VLC:	variable length code