HD–DIVINE, a Scandinavian terrestrial HDTV project

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In the summer of 1992 a digital terrestrial HDTV broadcasting system was demonstrated as a result of a collaborative Scandinavian study. The system included a motion compensated hybrid DCT video codec, a 512–carrier OFDM 16 QAM modem and four ISO/IEC Layer II sound codecs. The complete system was implemented in hardware. Since then further refinements of the vision codec and final assembly of the modem have resulted in a fully operational demonstration system and in January field trials have started. The current implementation uses the 1250/50/2:1 studio standard and fills an 8 MHz UHF channel. A second implementation, ready in March 1993, will allow reconfiguration from 1 HDTV input signal to 4 input signals conforming to CCIR Recommendation 601.

1. Introduction

What are the driving forces for a change in the television broadcasting standards? There has been a structural shift in the European broadcasting industry from public service oriented terrestrial networks to strong influences from new commercial satellite/cable distributed channels. This has resulted in more channels being available to the individual household and, in the view of some spectators, more choice. Obviously the driving factors are a combination of people's interest in the new services and the possibilities for the new media moguls to make a profit.

Digital video compression technology brings the possibility to further increase the number of available channels. This has led some European pay–TV channels to study near–video–on–demand services using powerful data–rate compression. Some actors think that 16:9 alone will create the demand that will move us into the digital era. In HD–DIVINE we think that HDTV is an inevitable "must" for the shift to be successful. One problem with HDTV is that it requires high resolution displays with a screen size of approximately 70 inches diagonal to give full justice to the picture. It seems that such displays can only be realized today with projection techniques with the inherent limitations in viewing conditions. Flat screen wall panels are far away in the future.

2. Why digital?

Digital is not a goal in itself. However, tendencies in television production technology and telecommunications point in this direction. The environment for the broadcasting signals in the future will be digital. If the broadcasting signal itself becomes digital, then new possibilities for new media ser-

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vices open up, using for instance the B–ISDN networks for connected services. Further, the choice of production standard will be of less importance, since (within certain limits) the system as well as the receiving terminal can be made adaptive. Another advantage of the digital approach is that the service provider keeps full control of the technical quality level throughout the signal chain. What is sent out is what is received. The inherent flexibility in a clever digital system can offer opportunities for new varieties of broadcasting such as interactive multimedia services. Of course, conditional access can be made much more reliable and elaborate. The possibility of squeezing more programmes into a given transponder or terrestrial network will reduce distribution costs.

Clearly there is not much in this shift in technology that is of interest to the broad public. It is the service providers, the network operators and niche users that will benefit from digital technology as such, at least in the short term.

3. Why HDTV?

The HD–DIVINE project pushes hard for HDTV quality. Bearing in mind the bleak outlook for flat screen displays this might seem as a touch of escapism. However, if a change in the broadcasting standard is to bring added value to the television public, HDTV is the most important new feature. The move from today's standards to new ones must bring with it a picture quality with resolution, sharpness, richness of colours and screen size that will be qualified as "amazing" by the viewers. A new broadcasting standard will be with us for the next 40–50 years and within this time frame we can expect significant improvements in display technology. The very fact that HDTV signals will be widely available will probably stimulate the progress. It might be that demands imposed by projection displays will not after all be so detrimental. The larger screen sizes needed for HDTV will in any case require a change in viewing habits away from the kitchen and back into the living room.

The next generation of television broadcasting standards should allow for flexibility. They shall provide the means to distribute prestigious productions for the living room as well as low–cost programmes for the kitchen or any other place where the main activity is something other than watching television.

4. Why terrestrial?

There is no doubt that the centre of gravity in television broadcasting in Europe is moving away from terrestrial networks into satellites and cable networks. The terrestrial frequencies are limited in number and in many European countries there is no further space for additional services. Major investments are placed in cable networks and satellite distribution technology. This makes the distribution cost of a new channel over satellite/cable much smaller than what would have been the case for terrestrial distribution but it still reaches a large and increasing audience. In the not–too–distant future, the differences of coverage will be practically eliminated. With this in mind what could justify terrestrial services?

The idea in Europe is that terrestrial networks should be used for services intended for mobile reception or at least allow for portable, "plug–less" receivers. You can not move around easily with a screen of 70 inches so HDTV in this context seems a little superfluous. Another way is to investigate the possibilities both to cut the costs to a level competitive with satellite/cable *and* to find technical solutions for increasing the capacity in the terrestrial networks.

It might be that we must work on the basis of different requirements for satellite and terrestrial services. The working assumption for HD–DIVINE, however, is that the same requirements should be chosen, independently of the distribution media. The terrestrial environment was chosen as a "show case" because it proved to be the hardest nut to crack.

5. The HD–DIVINE system

HD–DIVINE is a project that developed a demonstration system to prove the feasibility of HDTV in terrestrial channels. The system, as it stands today, will not be proposed as a standard, either in Europe or anywhere else. It has, as its main building blocks, a video codec and an OFDM modem.

Since the first demonstration at the International Broadcasting Convention (IBC) in July 1992, a demonstration system of a modern teletext service has been developed. It was felt that this area of television has not been fully covered in the discussion of the next generation of television broadcasting standards. This Broadcast Multimedia system was presented at the NAB'93 Multimedia World Conference. A second codec was also developed with minor changes compared to the first. The most important additional feature is the possibility spliting the service into 4 parallel television services each with 4:2:2 subjective video quality and stereo sound. The future plans include a further updated MPEG 2 based video coding algorithm, a more elaborate service multiplex, a Broadcast Multimedia function and further studies of the basic modulation parameters for the terrestrial modem in connection with field trials.

5.1. The video coding algorithm

The net data rate for the video in the HD–DIVINE system is roughly 24 Mbit/s. With a sampling rate of 54 MHz for the luminance and 13.5 MHz for each of the chrominance components and 8 bits/pixel the overall source data rate is around 650 Mbit/s. Thus the compression ratio is of the order of 1:30.

The vision codec is implemented as four parallel standard–resolution codecs with the HDTV screen divided in four vertical stripes for each of the codecs. Using a statistical multiplex the outputs of the four codecs are assembled into a single data stream. The interface of each of the codecs conforms to CCIR Recommendation 601, allowing for the reconfiguration of the system for the distribution of four standard–definition programmes.

Each of the four codecs ues a discrete–cosine transform (DCT) with a block size of 8x8 combined with adaptive quantization. DPCM with motion compensation is used between frames. Huffman coding is used as a variable–length code. There is a movement vector for every 4x2 pixel block. The maximum magnitude of the movement vectors is ± 32 pixels (horizontal) and ± 16 pixels (vertical) with half–pixel accuracy. Estimation and compensation is done on a field basis and is done only between fields of the same parity. The field of motion vectors is processed in the same way as the image data i.e. in a hybrid–DCT loop but without motion compensation. This reduces the bit–rate required for the motion vector field.

It is not always possible to reduce the amount of data in a video sequence as much as is done in HD–DIVINE without introducing visible distortion. To smooth this effect, adaptive spatial prefiltering is implemented. This has another very significant effect on image quality. In effect, the filters used are very efficient in removing noise. Noise is not only unpleasant to look at, it also costs bits to code. The postfilter further reduces quantizing noise introduced in the coding loop.

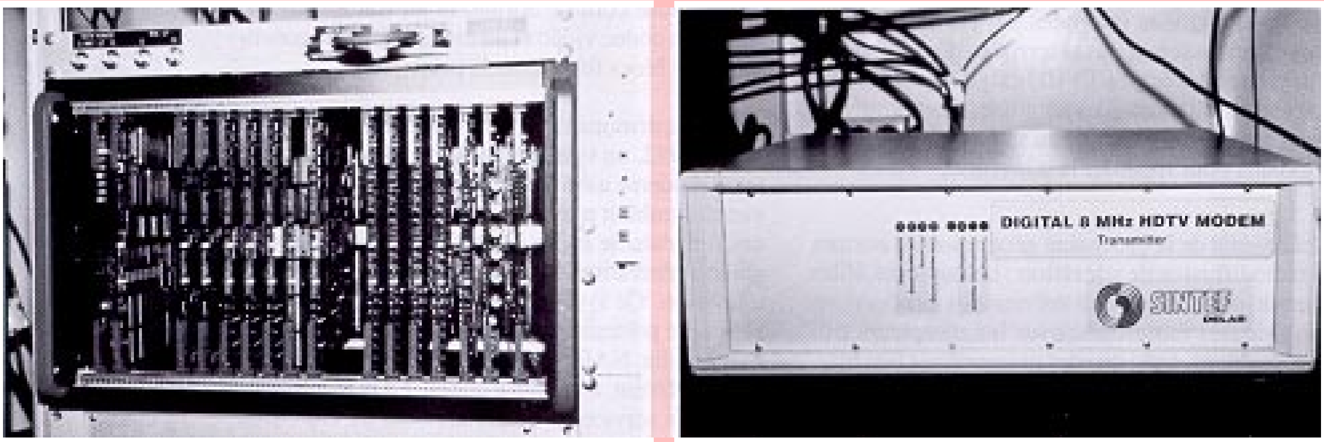
The physical dimensions of the hardware implementation are quite small, bearing in mind that it is a prototype system and therefore full integration is not utilized; the vision decoder has just 16 boards, each measuring 9x11 inches.

5.2. The OFDM modem

The technique used in the HD–DIVINE modem is not new. Several laboratories are studying COFDM, including National Transcommunications (NTL) in the United Kingdom and the CCETT in France, and it is currently used in digital audio broadcasting (DAB).

OFDM is a multi–carrier system. The spectrum is shaped to provide robust co–channel interference properties for co–existing PAL transmissions by cutting out the carriers which coincide with the PAL vision and sound carriers. Further carriers are left out at the edges of the spectrum to improve the adjacent–channel interference properties. In HD–DIVINE, 448 out of a total of 512 carriers are used.

The spectrum of each adjacent carrier overlaps that of its neighbours. This results in a rectangular



HD–DIVINE

24 Mbit/s HDTV video decoder *(left)*

27 Mbit/s OFDM modulator *(right)*

overall spectrum and an efficient use of the available bandwidth. Demodulation of the carriers is possible if they are mutually orthogonal during the symbol time. This is valid if the frequency spacing between successive carriers is $\Delta f = 1/T_S$. The symbol time T_S in HD–DIVINE is 64 µs. To improve the immunity against inter–symbol interference, the symbol time is extended by a period of ΔT. This guard interval is set to 2 µs in HD–DIVINE. Dynamic equalization is used for each carrier to compensate for the channel. The method used requires that the receiver is stationary.

Each single carrier is modulated using 16 QAM with a resulting total bit rate of $4x448x1/(Ts + \Delta T) \pm 27$ Mbit/s. The error correction code is a Reed–Solomon code (208,224) which leaves a net bit–rate of $27x208/224 \pm 25$ Mbit/s.

The hardware implementation of the modem is also physically size; the modulator has only one board, measuring 11x25 inches plus two smaller ones.

6. Network planning

So far, only preliminary network planning studies have been carried out within the project. The basic assumption is that directional receiving antennas are used. The calculated requirement for a C/N ratio of 20 dB or less will be checked during field trials starting in January 1993. With techniques for integrated coding and modulation (e.g. trellis-coded modulation) the required C/N ratio will be even lower. The single frequency network (SFN) is an interesting concept. In particular, the idea of regional tailoring using a number of low–power transmitters in regional SFNs is attractive for a public service broadcaster with the need to split up the nation–wide network part–time.

Laboratory tests are being carried out on the modem, and the protection ratios for co– and adjacent channel interference are being measured. Full–scale field experiments are planned for February 1993.

7. Conclusions

The feasibility of digital terrestrial HDTV broadcasting has been demonstrated in real–time over–the–air transmissions using the HD–DIVINE hardware. The working assumption for HD–DIVINE is that the same primary parameters should be used for a new television broadcasting system, regardless of the specific broadcasting media. This means that the most difficult problem of HDTV in terrestrial channels must be solved. The key word associated with the digital approach is *flexibility*. The future studies will concentrate on how to implement flexibility in the HD–DIVINE system, and to what degree.

Bibliography

[1] Working Group on Digital Terrestrial Television Broadcasting (WGDTB): **Report to the European Launching Group on the Prospects for Digital Terrestrial Television,** November 1992

[2] Appelquist, P., Franceschi, O.: **Development of a terrestrial digital HDTV system – The HD–DIVINE project**
EBU Technical Review No. 253, Autumn 1992.

[3] Bernard, P.: **STERNE: the CCETT proposal for digital television broadcasting**
IBC Technical Papers, IEE Conference Publication 358, 1992.

[4] Mason, A.G., Lodge, N.K.: **Digital terrestrial television development in the SPECTRE project**
IBC Technical Papers, IEE Conference Publication 358, 1992.

[5] Stare, E.: **Development of a prototype system for digital terrestrial HDTV**
TELE English edition, 1/92.

[6] Mason, A.G., Drury, G.M., Lodge, N.K.**: Digital television to the home – When will it Come?**
IBC Technical Papers, IEC Conference Publication 327, 1990.

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