

# European activities on digital television broadcasting – From company to cooperative projects

B. Marti (CCETT)

P. Bernard (CCETT)

N. Lodge (ITC)

R. Schäfer (Heinrich–Hertz–Institut)

## 1. Introduction

Stimulated by recent advances in image compression techniques (for example those achieved within MPEG), and by developments in the United States (FCC competition for digital terrestrial television standardization), digital television broadcasting has become an important topic in Europe both at the political and at the technical level. Early in 1991, several companies started activities dealing with terrestrial broadcasting, with a series of projects taking shape: SPECTRE, from the IBA in the UK (now ITC and NTL), STERNE at the CCETT in France, DIAMONDS at Thomson–LER, also in France, HDTV–T in Germany and HD–DIVINE in the Scandinavian countries. All these projects have a lot in common – and each has its specific features. They all aim at terrestrial broadcasting of digitally–coded video signals using spread–spectrum techniques of the type known as OFDM or COFDM ((coded) orthogonal frequency–division multiplexing). However, the projects do not all have the same objectives: some aim at the short–term introduction of HDTV, others (SPECTRE, STERNE) aim at proving the technical feasibility of various scenarios for the introduction of digital television.

This contribution focusses mainly on the channel aspects of some European digital television projects, the source coding aspects being dealt with mainly in the framework of a larger standardization effort within MPEG.

The channel–related studies in Europe take account of a particularly difficult situation as regards frequency planning, and are aiming at single frequency networking as a means of achieving maximum economy of frequencies. Continuing the approach adopted for Digital Audio Broadcasting, COFDM is the favoured system Europe and is the basis of the digital terrestrial television broadcasting (dTTb) project funded by the European Commission.

The first results are very encouraging, although the feasibility of portable reception – a specific feature of terrestrial broadcasting that cable and satellite systems cannot offer – remains to be fully established.

\* Paper delivered by the authors at NAB HDTV World, Las Vegas, April 1993.



This article will present SPECTRE and STERNE in some detail, and also introduce the HDTV-T project.

The main risk in the present situation is the high probability of the emergence of a new form of duality, not unlike the PAL/SECAM duality. Among the countries involved in local projects, no two have similar situations in terms of frequency planning and spectrum occupation, in terms of regulations, in terms of the status of their operators. Although the technical basis in all these countries is very similar, this situation may lead to diverging specifications in as much as a standard for a digital system must be much more detailed than that of an analogue system.

To deal with this potential problem, a cooperative project known as dTTb – digital terrestrial television broadcasting – has been initiated in order to gather together the available resources in the field of digital broadcasting techniques and move towards a single target – a European standard. A description of this cooperative project will form the third part of this article.

## 2. OFDM/COFDM

All three projects described in the following *Sections* use spread spectrum techniques known as OFDM or COFDM. It will be helpful to summarise the main principles of these systems here.

The idea that orthogonal frequency division multiplexing (OFDM) would resist the interfering power which is concentrated mainly in the carriers of analogue television signals sharing the same band was first presented by the Independent Broadcasting Authority (IBA) at the International Broadcasting Convention IBC'90.

The main difference between OFDM as used in SPECTRE or HDTV-T, and COFDM as derived from Digital Audio Broadcasting, relates to the initial "C" of the second method.

In OFDM systems, the source data stream is dispatched to a set of orthogonal, overlapping, narrow-band carriers; these are normally generated with a Fourier transform. Each carrier is modulated at a relatively low speed using a specific form of modulation which, at least in theory, may be different for different carriers in the set. For example, it might be thought appropriate to modulate the carriers which are close to an interfering co-channel PAL vision (or sound) carrier with robust QPSK, while other carriers, less exposed to inter-

ference, could use a more efficient modulation such as 64QAM. The choice between these possibilities permits a flexible trade-off between spectrum efficiency (e.g. all 64QAM) and bit-error performance (all QPSK, for example). To maintain the orthogonality condition at the receiver input, despite the influence of multipath propagation, a guard interval is inserted between every successive symbol on each carrier.

The use of a convolutional code linked to a Viterbi decoding scheme using maximum a posteriori likelihood decisions, ensures error-free decoding of a set of signals transmitted on these carriers. An information interleaving device working in the time-frequency domain is linked to the convolutional coding procedure, so that maximum statistical independence is obtained between the elementary signals and the fading of the Rayleigh channel, at the input to the channel decoder. This allows both frequency and time diversity. Thus, whenever a negative echo results in the loss of one of the carriers it is possible (knowing that, statistically, there should be at the same time a positive echo on other carriers) to recover the "lost" information by exploiting the diversity and the efficient channel coding scheme.

The introduction of trellis coding methods, which are based on the association of a trellis code with a modulation scheme having a large number of states, provides the required efficiency. In contrast to non-coded modulations, trellis coding allows quite significant spectrum efficiency without any marked loss in performance caused by noise or interference. With this addition of coding of the information, associated with frequency and time interleaving, OFDM becomes COFDM.

In the case of aggressive channels, such as the Rayleigh channel which is characteristic of mobile communications, reception with a bit-error ratio (BER) of  $10^{-4}$  can be obtained with a spectral efficiency of 1 bit/Hz, at a carrier-to-noise ratio (C/N) of 6.1 dB. A spectral efficiency of 5 bit/Hz has been obtained with C/N = 25 dB. In a channel having additive white Gaussian noise, as is the case for fixed reception with a roof-top antenna, the same results require C/N ratio values of 3.5 dB and 20 dB respectively.

The COFDM signal has superior anti-multipath and anti-interference properties which make it particularly attractive for the digital transmission of wideband signals in the UHF band. The virtual insensitivity to multipath propagation is due to the fact that the data is transmitted in parallel on a large number of orthogonal carriers. This increases the

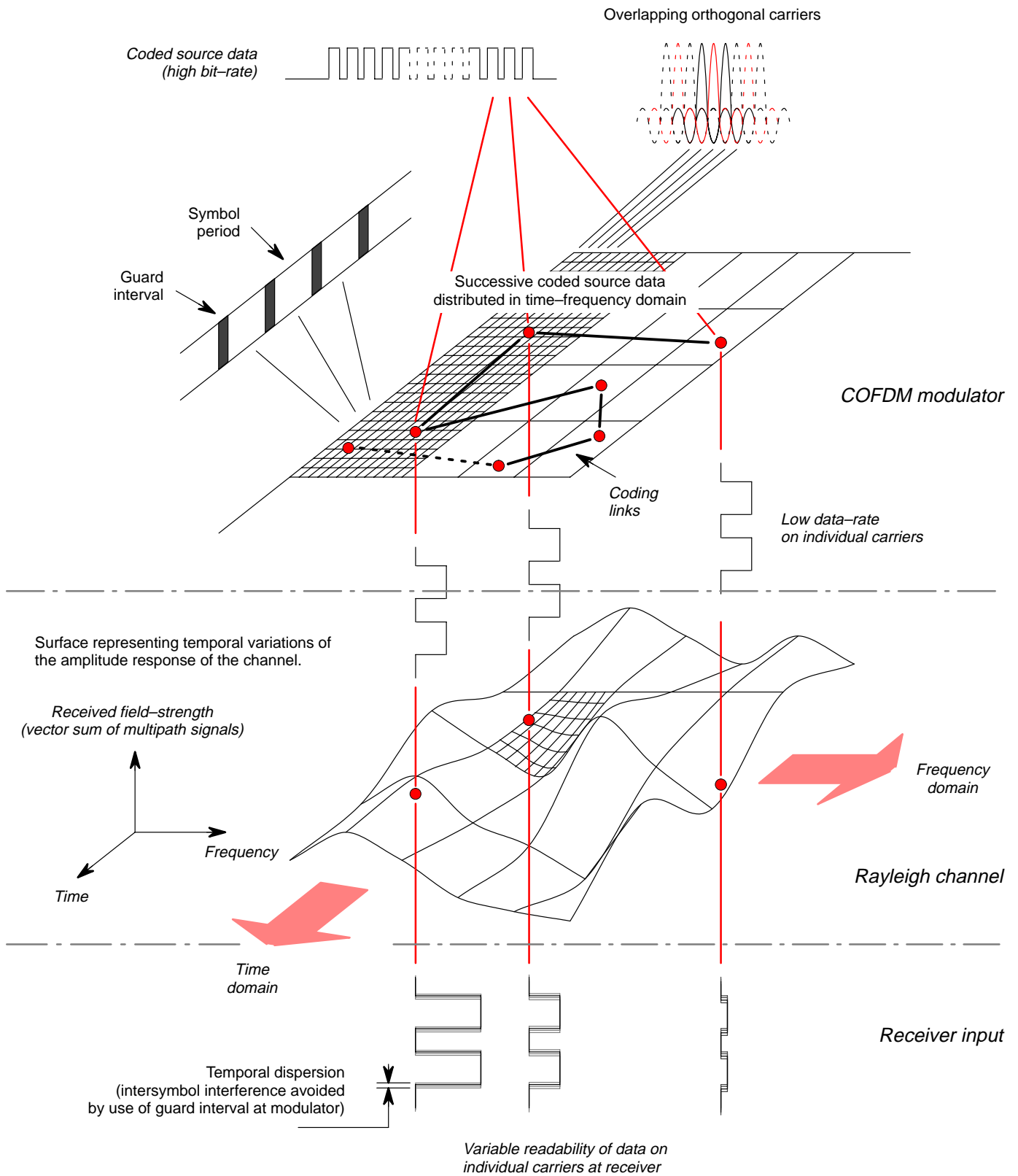
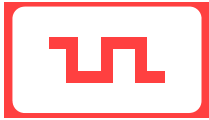
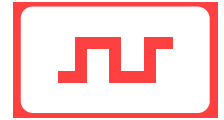


Figure 1  
Principles of COFDM  
in a Rayleigh  
channel.



duration of each symbol to that it is long compared to the multipath delay spread.

The relative insensitivity of COFDM to multipath propagation can be exploited by the deliberate generation of artificial echoes provided by gap-filling transmitters. This is the concept of the single frequency network (SFN) and its utilization at regional/local level, or even nationally, significantly reduces the problems of frequency planning.

A code of the convolutional type is applied to the incoming data in order to provide the OFDM modulator with a set of de-correlated bits to be applied to the various carriers of the multiplex, and to the various time-slots of the data-stream on each carrier. The code which is applied may present various levels of intrinsic efficiency, the variant chosen for DAB being a 1/2 rate code. The consequence of using a code is that, whenever a carrier is corrupted by noise or echoes, the information it bears can be reconstructed from information borne by other carriers, or at a different sampling time.

*Fig. 1* shows the principle of COFDM. A number of orthogonal carriers generated with a fast Fourier transform are modulated using a multi-level scheme by incoming data at a given sampling rate, leaving room for a guard interval. This interval serves to absorb long echoes. Insensitivity to echoes is achieved by virtue of the fact that each carrier is modulated at a relatively low speed, thus minimising the risk of inter-symbol interference. *Fig. 1* also shows how incoming an information element is spread out in frequency and in time, to ensure two types of diversity. The channel response shown is that of a Rayleigh channel, characteristic of time-varying multipath propagation of the kind found in mobile communications. Portable and fixed reception may have other characteristics, yet to be established. Each carrier could, in principle, bear a different modulation scheme: QPSK, 4 ... 64QAM. Many types of convolutional or trellis coding are also possible, and without coordination each local or national project could lead to different, incompatible, choices.

### 3. SPECTRE

#### 3.1 . The concept

The SPECTRE (Special Purpose Extra Channels for Terrestrial Radiocommunication Enhancements) system is an application of the OFDM concept, with an implementation which is flexible

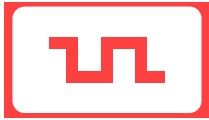
enough to allow variations on the given scheme and various measurements to be performed. It also makes use of an advanced form of source coding (motion-compensated discrete cosine transform: MC-DCT) for the experiments, although most of the channel error measurements have been made using pseudo-random binary sequences (PRBS).

The video coder provides a data-stream of 13 Mbit/s including an internal protection using a Reed-Solomon (255,239) burst-error correction code. The video codec is designed to operate over a range of bit-rates and is up-gradeable to permit the processing of higher-definition signals having a bit-rate of the order of 24 Mbit/s.

#### 3.2. OFDM modulator

The OFDM hardware is designed to be a flexible laboratory tool. It is structured in a rather unusual manner in that it uses a large number of digital signal processing (DSP) chips working in parallel to constitute a powerful computing engine. The modem uses software running in real time to execute the fast Fourier transform (FFT) function which modulates and assembles some 400 carriers into the orthogonal frequency division multiplex.

The modem can be programmed to perform a variety of digital modulation schemes. At present, QPSK, 8-PSK and 16-QAM have been implemented. The demodulator performs coherent carrier recovery on all 400 carriers and also determines the FFT block synchronization and automatic frequency control (AFC) from within the data. In fact, all the synchronization information is found by correlative techniques within the normal transmitted information, so no special synchronization signals are necessary. The modulator mixes the signal to the required UHF channel and presents this signal to the high-power amplifier (HPA) consisting of two linear 200 W valve amplifiers operating in parallel to produce 400 W. This is backed-off by 6 dB to accommodate the large dynamic amplitude range of the OFDM signal. OFDM, like noise, has an approximately Gaussian amplitude distribution. This means that it has a high peak-to-mean power ratio, so the HPA needs to be operated at a much lower level than its normal rating for PAL signals. The chosen back-off level will depend on the HPA design, and a solid-state amplifier is likely to behave differently from a valve amplifier. The reason for using a valve amplifier was simply that this equipment had recently been removed from a relay station site and was available to the project at the right time. The specific requirement was that the HPA be linear, to give the best performance, and that sufficient pow-



er be available at the site should an increase in power be necessary during the trials.

### ■ 3.3. *Field trials*

The first trials were performed using two existing transmitting sites: Stockland Hill and Beacon Hill. The first is configured as the wanted signal, the second as the interferer. The wanted signal is a transmission of the OFDM modulated compressed video signal, whilst the interfering signal is an OFDM signal fed from a PRBS generator. It is not necessary to provide a video signal source at the interfering site because the properties of coded video are noise-like and can be simulated using the random bit-stream from a PRBS generator. The effective radiated power (erp) of the SPECTRE transmission is 250 W. This is 30 dB below the power of the existing PAL transmissions (250 kW at Stockland Hill). The Beacon Hill site is similar to Stockland Hill, except that the antenna height is lower (50 m) and the erp of the SPECTRE transmission erp is only 100 W.

Stockland Hill is a good site for these experiments, for a number of reasons:

- it includes a sea path which enables tropospheric co-channel interference from the French SECAM system to be studied;
- co-channel interference from the PAL transmitter at Rowridge (United Kingdom) will also be present;
- the site offers a range of “taboo” channels, so various experiments can be carried out;
- the number of rebroadcast transmitters in the area provides an excellent environment in which to study interference from OFDM.

The receiving equipment is contained in a Renault Espace, modified as a survey vehicle. The vehicle is fitted with a compressor to raise its telescopic mast to 10 m, and a generator is supported on a platform at the rear to power the receiving equipment which is mounted in special racks inside. The OFDM demodulator and video decoder are constructed in identical form to the transmission equipment. The survey vehicle measures quality around the field trial service area using a log-periodic antenna and results are logged by a lap-top computer for analysis at the laboratory.

A relay site which receives Stockland Hill transmissions off-air could be used for longer-term monitoring studies. Indeed, at a later time it might also be possible to use this site for the installation of a SPECTRE relay station. Since the SPECTRE

transmissions from the main station could use up all the theoretical redundancy in the frequency plan in some localities, there may be no additional channels available for the planning of SPECTRE relays. However, since OFDM has good anti-multipath properties, the relays could be on the same frequency as the main transmissions, using active deflection techniques. The relay would then consist only of a UHF amplifier, without any frequency transposition. Careful site shielding would be needed to prevent oscillation problems, but interference between the main station and the relay transmission should not cause a problem because one signal looks like an active multipath reflection of the other.

### ■ 3.4. *Laboratory measurements*

Before it had become possible to make measurements from off-air transmissions, several laboratory tests had been carried out to determine the noise and interference properties of the QPSK-OFDM version of the system. The spectrum has “holes” at the PAL vision and sound carrier positions, and also a small “hole” at the PAL subcarrier. This is found to help when the PAL pictures contain highly-saturated colours. Each OFDM carrier is spaced 15 625 Hz from its neighbour. The measurements included the degree of co-channel interference from PAL signals, and adjacent-channel interference. OFDM signals would be transmitted from the same geographical locations as existing PAL-I services, but in “taboo” channels at -30 dB power level relative to them. It is therefore essential that the adjacent-channel and image-channel protection ratios are better than -30 dB.

Field trials have recently been carried out in the area of Exeter, which lies in a valley with a shadowed area. These measurements have shown that, in this configuration, the coverage of an OFDM signal is comparable with that of a co-sited PAL-I transmission.

## ■ 4. *STERNE*

### ■ 4.1. *Introduction*

The CCETT has played an important rôle in recent years in the definition of standards for television contribution coding, as well as in the EUREKA 147 DAB project where the principles of COFDM were successfully defined and defended. On the basis of this long experience, the CCETT decided, in 1991, to develop a demonstrator of a digital television broadcasting system using COFDM techniques. The project is known as “STERNE” (*Système de Télévision en Radiodiffusion Numéri-*



que) – which is also the French word for the term (sea–swallow).

The objectives of the STERNE project are:

- to establish itself in the “gap” in terrestrial broadcasting, taking maximum advantage from the advantages of digital techniques in this vital market for broadcasters;
- to establish as the principal, imperative objective of the project, from the very outset, the broadcasting of conventional television signals to portable receivers, with service options linked to access control and to the transmission of assistance data, as well as the multiplexing of several programmes in a single channel;
- to extend the scope of applications to the broadcasting of HDTV to fixed receivers.

The principal objective is based on the following technical characteristics:

- channel bandwidth: 8 MHz
- quality: approaching that of D2–MAC/packets, both for the 625–line image and for the sound component.

#### ■ 4.2. Channel coding

The STERNE project has selected an adaptation of the COFDM system, modified for the requirements of television broadcasting.

The masking conditions applying in reception on a roof–top, in an apartment or two metres above ground are quite different, and there is a substantial difference in terms of propagation losses between fixed and portable services.

The implementation of ambitious coding and modulation techniques for terrestrial broadcasting in a Rayleigh channel remains a challenge to engineers and designers. For instance, to broadcast to portable receivers, the efficiency achieved in the DAB radio system would have to be doubled, for example by the use of 2\*4AM modulation with a 1/2–rate code.

#### ■ 4.3. System characteristics

The multiplexer will perform the synchronization of the various programme components (including access entitlements) as well as their integration within the transmitted data stream. The cost of the multiplex will be reduced as far as possible, whilst ensuring that services can evolve, on the basis of

a mixed circuit/packet approach, as this is an optimal solution for the consumer electronics industry. This approach also leaves the door open to data broadcasting services, whether they be broadcast telematic services or interworking with future ATM networks, which are also made easier with a packet approach.

The proposed system asserts the modular and programmable nature of the different configurations of a broadcast service, while giving high priority to the control of the different channel configurations attributed to broadcasting and to the analysis of the logical and physical architecture of the networks.

EUROCRYPT access control, currently being standardized at European level for MAC/packet services, is also being adopted within the STERNE project.

#### ■ 4.4. Calendar

Three stages of development will punctuate the STERNE project:

- Development of a prototype demonstrator by the end of 1992. This is a derivative of the DAB project and permits the broadcasting of one programme of SECAM–like quality to portable (and mobile) receivers.
- Second demonstrator, at the end of the second quarter of 1993. This will be able to broadcast one programme of 4:2:2–like quality, two channels of SECAM–like quality, or three programmes of MPEG1 quality, to portable receivers.
- The third stage, scheduled for the end of 1993, will demonstrate the possibility of a high bit–rate broadcasting service to fixed receivers, carrying either conventional or high–definition television signals.

The prototypes will serve essentially to illustrate the potential of an overall approach to the broadcasting and distribution of digital television, and will contribute to the attempts to standardize in this area.

#### ■ 5. HDTV–T

SPECTRE and STERNE are each the fruit of work in an individual organization. They are concerned mainly with channel coding, the source coding being considered not as innovative but simply as part of an assessment of overall feasibility. HDTV–T,

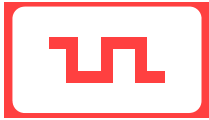


Table 1  
Partners in the  
German HDTV-T  
project.

Bosch
DLR-Institut für Nachrichtentechnik
Grundig
Institut für Rundfunktechnik (IRT)
DAB-Plattform
Heinrich-Hertz-Institut (HHI)
ITT-Intermetall
Siemens
Telekom-FI/DBP
Thomson Consumer Electronics Corporate Research

in contrast, is a German national cooperative project with ten partners (*Table 1*), and it has a budget of about 200 MDM until the end of 1995.

The project is led by a steering committee under the chairmanship of the Heinrich-Hertz-Institut; each participant is represented by one delegate. The work is organized in working groups on system aspects, image compression, modulation and hardware, and in several ad-hoc groups on specific topics. The objective of the project is to investigate the possibilities for digital television and HDTV broadcasting over terrestrial channels, satellite channels and broadband cable networks, by means of theoretical analysis, computer simulations, hardware developments and field trials. On the basis of this work it will then be possible to develop scenarios for the introduction of digital television and HDTV broadcast services offering practical alternatives to the systems of today.

Scalability, graceful degradation and compatibility between future television and HDTV services, as well as flexible utilization of the multiplex, are the basic requirements of future broadcast sys-

Table 2  
Members of the  
dTTb consortium.

<i>European industrial groups:</i>	
	Philips
	Thomson
	Seleco
<i>European broadcasters:</i>	
	BBC, ITC (United Kingdom)
	TDF (France)
	RAI (Italy)
	IRT (Germany)
	Retevisión (Spain)
<i>European Broadcasting Union</i>	
<i>PTT Administrations:</i>	
	DPB-T (Germany)
	France Telecom
	Telecom Denmark

tems. These systems will be data broadcasting systems, rather than television-only systems, so the emphasis is also placed on inter-connectability with broadband cable networks, satellite channels and ATM-based B-ISDN.

In contrast to the two other projects discussed here, a large part of the HDTV-T project is devoted to source coding. In this respect, and also for the multiplexing aspects, the project relies on the proposals made by MPEG; the project is indeed contributing actively to MPEG. OFDM is currently the preferred solution for modulation because of its potential for use in single frequency networks.

The HDTV-T project is organized in three overlapping phases:

- system definition;
- hardware realisation;
- systems trials and optimization.

The definition phase is still under way, although the first hardware developments have already started. It is intended that hardware will be available by mid-1995 so that field trials can begin before the end of that year.

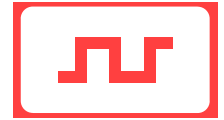
## 6. The dTTb project

### 6.1. Context

The dTTb project is part of the European Plan for Community Research and Development and is operating under the umbrella of EEC RACE projects aiming at the definition of integrated broadband communications systems. This context reinforces the importance of considering digital television broadcasting as a branch of data communications, as mentioned earlier in respect of HDTV-T, and explains the interest of several telecommunications operators in the project.

The service model adopted is the one defined by the European Launching Group for Digital Television Broadcasting, and this serves as the basis for the technical coordination.

The title of the dTTb project contains two key words: *digital* and *terrestrial*. Nonetheless, the situation is rather different in Europe compared to the situation in the United States, where digital terrestrial television is also under development. The partners in the dTTb project are convinced that, because of the specific nature of the European context, it will be easier to reach some degree of standards unification if the studies begin with the terrestrial part of the problem. The reason is that

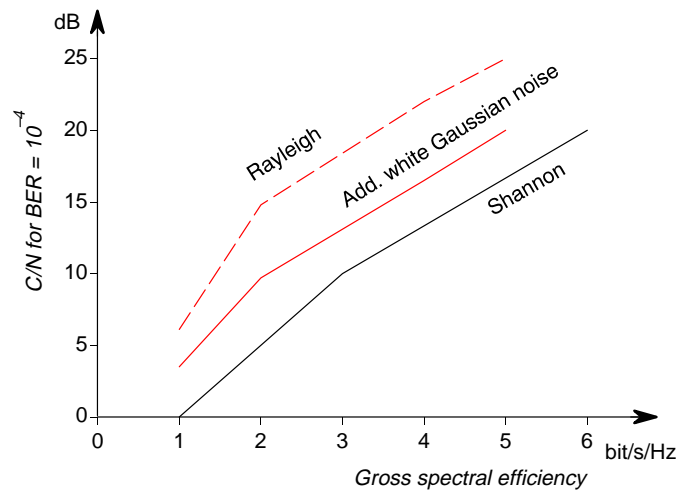


*terrestrial* implies certain constraints, relating to frequency planning in particular, that other network environments do not have (or, at least, not to the same extent). The necessary long-term coexistence of the analogue systems of today and the future digital services (simulcasting), possibly extending for several decades into the next century, means that the situation is completely different in the terrestrial environment and that it would certainly be easier to move from a system designed initially for terrestrial use towards a compatible system on cable or satellite, than it would be to move in the opposite direction.

The second reason for this approach, at least in Europe, is that services have already started an evolution towards higher quality on cable and satellite, using the MAC systems, and it is very unlikely that this kind of system can be adapted for terrestrial broadcasting. It may be technically possible, in some cases, to adapt D2-MAC, but there is no interest, in terms of benefits for frequency planning, in adding a new analogue terrestrial broadcasting system. It is only through the introduction of a digital system that there is a chance of solving the problem of increasing programme quality in the terrestrial environment. It is in this domain that the broadcast network operators have much to gain. Only by using digital techniques can terrestrial broadcasting evolve. In terms of service quality, terrestrial networks offer an advantage that satellite probably – and cable certainly – cannot offer: portability, which means the possibility of having non-connected, moveable receivers.

The technical objectives of the dTTb project are addressing to this problem, and the first step is the definition of techniques allowing the use of single frequency networks as a means of simplifying the frequency planning problems. The term “single frequency network” can be used at various levels. Europe is very regionalised, so SFN can be considered at national level and also at local or sub-local levels. The problem is how to feed transmitters and rebroadcast transmitters all working at the same frequency. The DAB experience has shown that this is possible using spread spectrum techniques, and OFDM in particular.

The dTTb project is currently exploring three types of reception conditions, corresponding to three levels in a hierarchy of sensitivities of the signal to errors. These are the *portable* level which is given a certain priority because it represents the specific feature of terrestrial broadcasting, traditional reception with *fixed* receivers and roof-top antennas, and, in continuity with the DAB project,



Designation	Equivalent quality	Bit-rate (Mbit/s)
LDTV	MPEG1 – VHS	1.5
SDTV	Composite PAL/SECAM	5 – 6
EDTV	Studio (CCIR Rec. 601)	9 – 11
HDTV	≥ HD-MAC	20 – 30

Reception conditions	Efficiency (bit/s/Hz)
Fixed (roof-top antenna)	4 – 5
Portable (“rabbit-ear” antenna)	1.3 – 2
Mobile (Rayleigh channel)	1

Figure 2  
Spectral efficiency and bit-rates.

the possibility of reception by *mobile* receivers, even if the commercial incentives for this last application may be thought less significant than for the first two. In the same way, four types of picture quality are being considered.

SPECTRE and STERNE can be considered as elements of the contributions from ITC and the CCETT to dTTb, while close cooperation with HDTV-T has been agreed through the form of joint meetings of the different working parties.

## 6.2. Goals

In line with the objectives explained above, the dTTb project has two principal goals:

- provision of the technologies required for the broadcasting of digital signals at a bit-rate which will allow the broadcast distribution of digitised and compressed television signals being studied in other projects;
- contribution to the establishment of the necessary standards for the modulation, channel coding and multiplexing systems.



The strategy for the introduction of operational digital television services within Europe requires both technical and marketing studies, although the latter fall outside the framework of the dTTb project. The objectives will have been attained if the required specifications and technologies are ready at the time when the political and economic opportunities for starting such a service occur. Such an opportunity will probably be opened shortly for the introduction of digital television services.

The project is concentrating its contributions on channel modulation/coding and broadcast system aspects. The areas covered are:

1. A broad study of all possible data rates for existing VHF and UHF channels, in order to determine which digital video broadcasting services and products are feasible. This study is to ensure that account is taken of possible future ex-

tensions offering more television channels and/or higher picture quality.

2. As a first step towards defining a service/product, demonstrators will be constructed for broadcast television programmes and will be aimed towards portable (i.e. "plug-free"), or mobile receivers. These demonstrators will serve for the investigation of the network configuration aspects, extendibility towards future services, frequency allocation aspects and chip area analysis. The aim is a service with higher quality than the existing PAL/SECAM systems and featuring 16:9 capability.

### ■ 6.3. Channel coding and modulation

A primary consideration of the project as a whole is to develop the most appropriate modulation and channel coding techniques for the efficient exploitation of the available channel capacity for the



**Ralf Schäfer** graduated in electrical engineering from the Technical University of Berlin in 1977 and 1984.

In 1977 he joined the Heinrich-Hertz-Institut (HHI) in Berlin. He has worked in the fields of signal processing and image coding and was leader of several research projects. Since 1989 he has been Head of the Imaging Processing Department at the HHI.

Dr. Schäfer has participated in several European research activities including COST, Eureka and RACE, and is currently a member of the European coordination group on digital video broadcasting WGDVB. He is also Chairman of the Steering Committee of the German joint research project HDTV-T.



**Philippe Bernard** graduated from the Ecole Polytechnique and Telecom Paris. In 1986 he joined the Centre Commun d'Etudes de Télédiffusion et Télécommunications (CCETT), and he has been involved in studies of bandwidth reduction techniques for HD-MAC since 1991.

Mr. Bernard is Manager of the STERNE project.

**Bernard Marti** graduated from the Ecole Polytechnique and Telecom Paris. In 1968 he joined the ORTF and he participated in the creation of the CCETT in 1972.

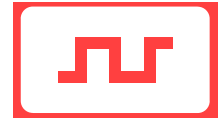
At the CCETT he has worked in turn on digital imaging systems, data broadcasting and teletext, videotex and telematic services.

Mr. Marti is now Technical Director at the CCETT and coordinator of the dTTb project.

**Nick Lodge** graduated from the University of Wales. After a period in industry working on low bit-rate speech and speech encryption systems he joined the Independent Broadcasting Authority (IBA). He was involved in the development of MAC, and then specialised in digital image processing and television coding techniques. After some years as Project Manager dealing with enhanced and high-definition television, he joined the new Independent Television Commission (ITC) in 1991 as R&D Coordinator. He is currently Head of Standards and Technology.

Dr. Lodge is involved in the studies of the EBU and CCIR, as well as many European collaborative projects in the framework of Eureka, RACE and TIDE.





delivery of digital television. The identification of what constitutes optimal use of the channel can only be achieved through consideration of very complex trade-offs involving the performance of source coding methods for video and sound, the data capacity allocated to ancillary services, the service coverage area, the mode of reception (“plug-free”, mobile or fixed), the basic service quality required, the target cost of the receiver and the frequency planning criteria that are adopted.

In the domain of channel coding and modulation, high priority is given to OFDM which allows for single frequency networks. This capability is of prime importance in order to cope adequately with the frequency planning situation in Europe.

All these techniques are under thorough examination and comparison, including the LSI complexity evaluation, within the dTTb project.

A first service of results is shown in *Fig. 2* which compares several modulation and channel coding schemes tested so far. It can be seen that the channel efficiency typically needed for mobile reception is around 1 bit/s/Hz, around 2 bit/s/Hz for portable reception, and around 4 to 5 bit/s/Hz for fixed reception.

#### ■ 6.4. Service and system characteristics

It is difficult to establish parallels between the qualities of digitally-coded pictures and analogue pictures because the impairments created by digital compression schemes are very different to the usual effects of noise, echoes or intermodulation common to analogue systems. It is nonetheless usually reckoned that, to obtain a digitally-coded picture having the quality of a normal composite PAL or SECAM picture, a bit-rate of the order of 4 to 5 Mbit/s is needed. This quality level has become known as “standard” quality (SDTV).

In the same way, extended quality (EDTV) is defined as being “near-transparent” to the quality of the CCIR Recommendation 601 studio standard; this seems to require some 10 Mbit/s. A third level, known as limited quality (LDTV), is also defined; it is often compared with VHS and requires 1.5 Mbit/s. Finally there is HDTV, preliminarily reckoned to require between 20 and 30 Mbit/s, and this is to be at least as good as HD-MAC. *Table 3* shows the service possibilities offered by the combinations of these four quality options and the three receiving environments mentioned earlier.

This range of possible configurations explains why, within the framework of the dTTb project, a very comprehensive multiplex structure is being studied. Another factor relates to two complementary statements:

- the picture quality of digitally-coded television is dependent on picture content;
- the bit-rate of digitally-coded television is dependent on picture content.

Both those statements are true, depending on whether the emphasis is on the quality or on the bit-rate. The multiplex will have to cope also with the situation where a broadcaster imposes a form of “cultural revolution” and considers spectrum space as a statistical entity rather than as a static frequency allocation, enabling better advantage to be taken of the natural flexibility of digital coding.

It will probably be much more difficult to agree on the design of the multiplex, and on how to give due consideration to all the service parameters, including access control, than it will be to agree a choice of efficient modulation or coding scheme. It is now understood, in Europe, that the multiplex is the place where the “digital television war” can be won or lost.

Receiving condition	Expected bit-rate Spectral efficiency	Picture quality			
		HDTV	EDTV	SDTV	LDTV
		30 Mbit/s	10 Mbit/s	5 Mbit/s	1.5 Mbit/s
Fixed	4 – 6 bit/s/Hz	1	2 or 3	4 to 6	15 to 20
Portable	1.2 – 2 bit/s/Hz	–	1	2	6 to 10
Mobile	1 bit/s/Hz	–	–	1	5

Table 3  
Potential of digital terrestrial television (number of available programmes per RF channel).