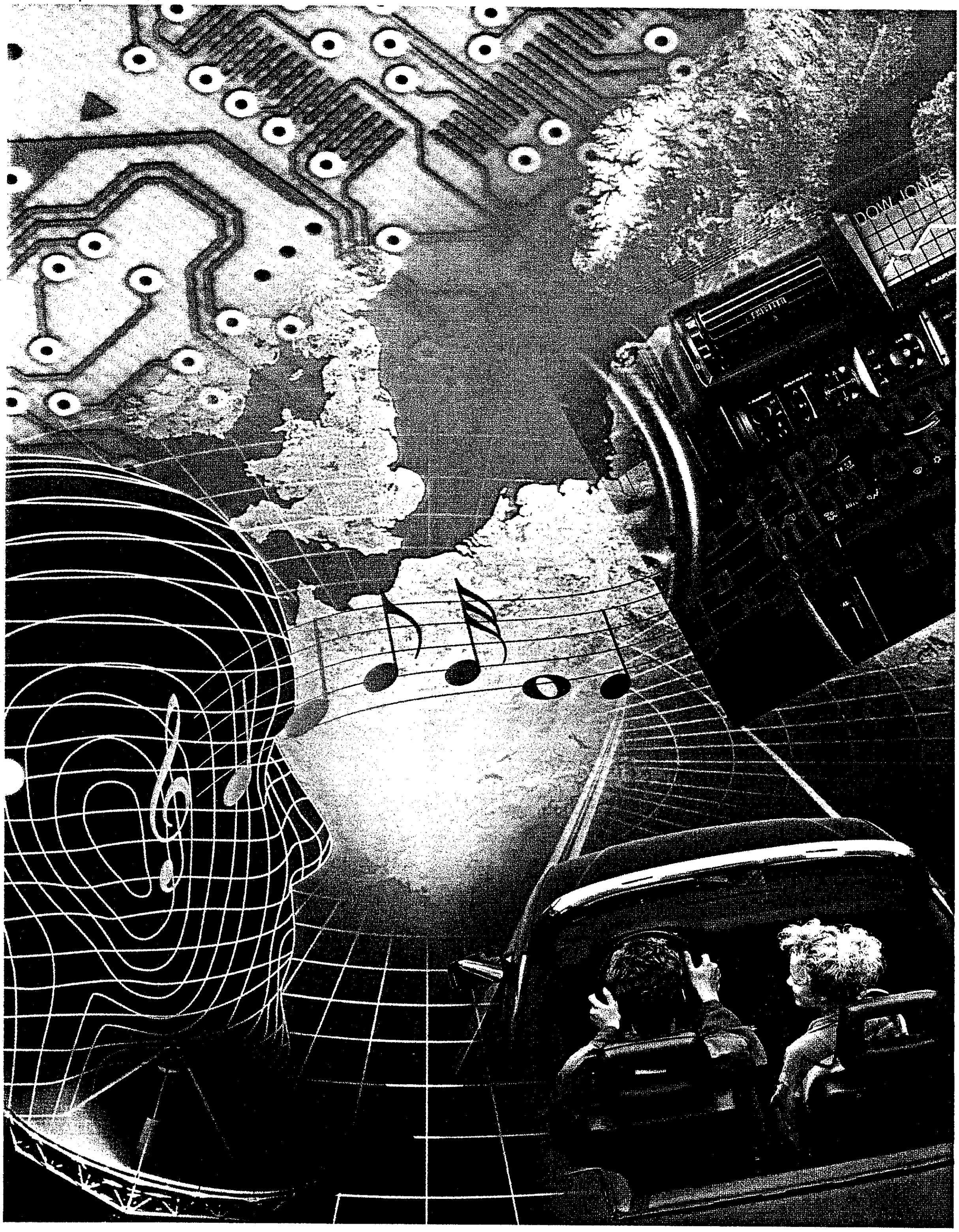
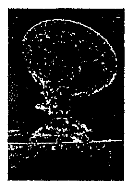
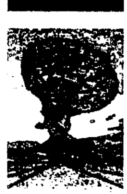
Digital Audio Broadcasting







DAB
Digital Audio Broadcasting

1. Overview and Summary of Main System Features

Introduction

Digital Audio Broadcasting, DAB, is the most fundamental advance in radio technology since the introduction of FM stereo radio. It gives listeners interference-free reception of high-quality sound, easy-to-use radios, and the potential for wider listening choice through many additional stations and services.

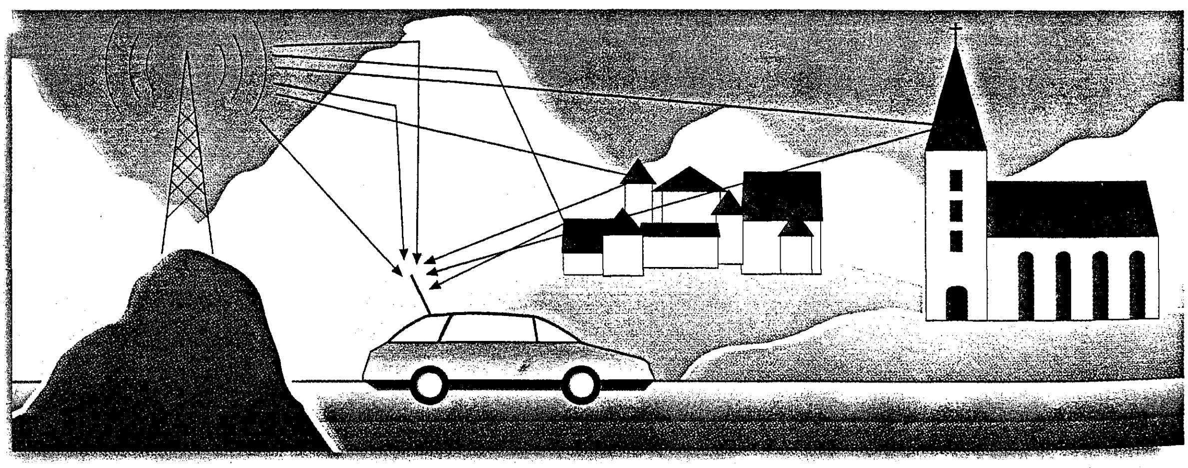
Overview

Eureka DAB is a reliable multi-service digital broadcasting system for reception by mobile, portable, and fixed receivers with a simple, non-directional antenna. It can be operated at any frequency from 30 MHz to 3 GHz for mobile reception (higher for fixed reception) and may be used on terrestrial, satellite, hybrid (satellite with complementary terrestrial), and cable broadcast networks. In addition to supporting audio programmes with a wide range of sound coding rates and hence qualities, it also has a flexible, general purpose digital multiplex which can carry a number of services, including audio-programme associated data and independent data services.

It is the only system available in the world to meet all the demanding requirements drawn up by the International Telecommunications Union (ITU), thus opening horizons for all-digital broadcasting of the future. These requirements are given in ITU-R Recommendations 774 and 789. In 1992, the Eureka-147 System was recommended world-wide by the Inter-Union Technical Committee of the World Conference of Broadcasting Unions. In December 1994, the system achieved a world-wide standard given in ITU-R Recommendations BS. 1114 and BO. 1130 for terrestrial and satellite sound broadcasting, respectively, to vehicular, portable, and fixed receivers in the VHF/UHF frequency range. It is an agreed European Standard (ETS 300401, February 1995), adopted by the European Telecommunications Standards Institute (ETSI).

The Eureka DAB System is a rugged, yet highly spectrum- and power-efficient sound and data broadcasting system. It uses advanced digital audio compression techniques (MPEG 1 Audio Layer II and MPEG 2 Audio Layer II) to achieve a spectrum efficiency equivalent to or higher than that of conventional FM radio. A closely-controlled coding redundancy is applied to the signal in order to provide strong error protection and high power efficiency. The transmitted information is spread in both frequency and time so that the effects of channel distortions and fades are eliminated in the receiver, even under conditions of severe multipath propagation

Fig. 1-1: Multipath Propagation



(Figure 1-1), whether at home or in the car.

The efficiency of spectrum use is increased by a special feature called the Single Frequency Network (SFN). A broadcast network can be extended virtually without limit by operating all transmitters on the same radio frequency.

Nevertheless, the relatively low co-channel protection ratio of the em also permits adjacent local coverage areas to be planned on a continuously extending basis, in most cases with as few as four different frequency blocks.

Summary of the Main System Features

The DAB transmission signal carries a multiplex of several digital services simultaneously. Its overall bandwidth is 1.536 MHz, providing a useful bit-rate capacity of approximately 1.5 Mbit/s in a complete "ensemble". Each service is independently error protected with a coding overhead ranging from about 25% to 300% (25% to % for sound), the amount of which depends on the requirements of the broadcasters (transmitter coverage, reception quality).

The ensemble contains audio programmes, data related to the audio programme, and, optionally, other data services. Usually, the receiver will decode several of these services in parallel.

A specific part of the multiplex contains information on how the multiplex is actually configured, so that the receiver can decode the signal correctly. It may also carry information about the services themselves and the links between different services.

In particular, the following principal features have been specified:

Flexible audio bit-rate, from 8 kbit/s to 384 kbit/s, which allows the multiplex to be configured in such a way that it provides typically 5 to 6 high-quality stereo audio programmes or up to about 20 restricted-quality mono programmes.

Data services, each service can be a separately defined stream or can be divided further by means of a packet structure.

Programme Associated Data (PAD), embedded in the audio bitstream, for data transmitted together with the audio programme (e.g. lyrics, phone-in telephone numbers). The amount of PAD is adjustable (min. 667 bit/s), at the expense of capacity for the coded audio signal within the chosen audio bit-rate.

Conditional Access (CA), applicable to each individual service or packet in the case of packet-mode data. Specific subscriber management does not form part of the DAB System Specification, however, the DAB ensemble transports the CA information and provides the actual signal scrambling mechanisms.

Service Information (SI), used for operation and control of receivers and to provide information for programme selection to the user. SI also establishes links between different services in the multiplex as well as links to services in other DAB ensembles and even to FM/AM broadcasts.



2. Outline of the DAB System

Generation of a DAB Signal

Figure 2-1 shows the block diagram of a conceptual DAB signal generator. Each service signal is coded individually at source level, error protected and time interleaved in the channel coder. Then the services are multiplexed in the Main Service Channel (MSC), according to a pre-determined, but adjustable, multiplex configuration. The multiplexer output is combined with Multiplex Control and Service Information, which travel in the Fast Information Channel (FIC), to form the transmission frames in the Transmission Multiplexer.

Finally, Orthogonal Frequency Division Multiplexing (OFDM) is applied to shape the DAB signal which consists of a large number of carriers. The signal is then transposed to the appropriate radio frequency band, amplified and transmitted.

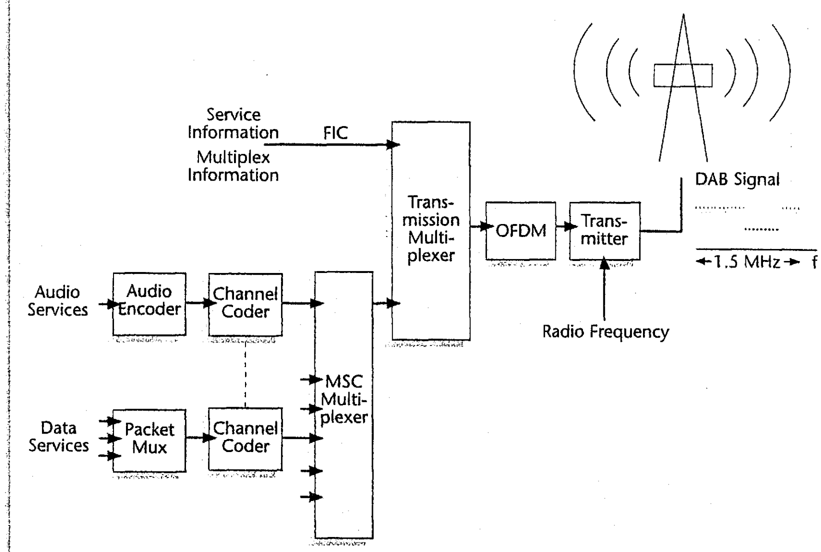


Fig. 2-1: Concept of DAB Signal Generation

Reception of a DAB Signal

Figure 2-2 shows a conceptual DAB receiver. The DAB ensemble is selected in the analogue tuner, the digitised output of which is fed to the OFDM demodulator and channel decoder to eliminate transmission errors. The information contained in the FIC is passed to the user interface for service selection and is used to set up the receiver appropriately. The MSC data is further processed in an audio decoder, to produce the left and right audio signals, or in a data decoder (Packet Demux), as appropriate.

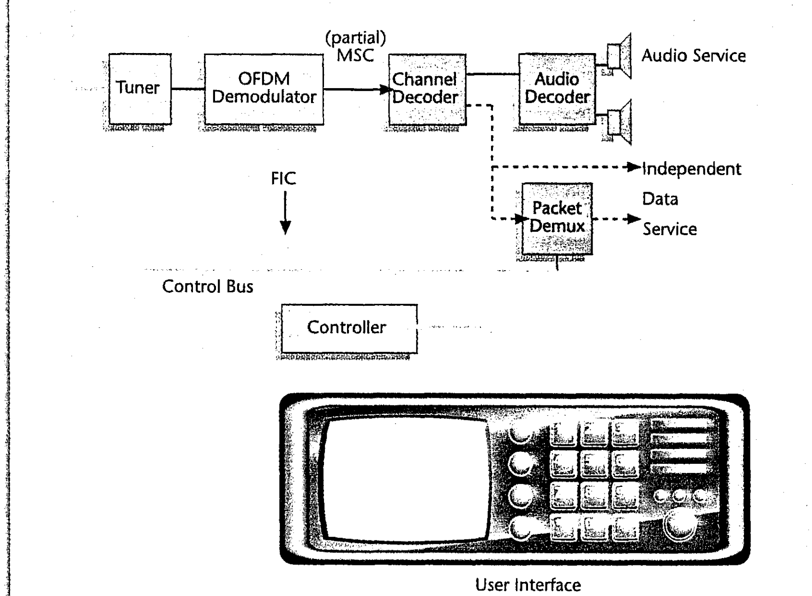


Fig. 2-2: Concept of DAB Reception

3. Details of the DAB System

Audio Services

Compared to conventional PCM sound coding, in DAB the bit-rate is reduced sixfold to twelvefold by means of a digital audio compression technique (see Figure 3-1). It is a low bit-rate sub-band coding system enhanced by a psycho-acoustic model: due to the specific behaviour of the inner ear, the human auditory system perceives only a small part of the complex audio spectrum. Only those parts of the spectrum located above the masking threshold of a given sound contribute to its perception, whereas any acoustic action occurring at the same time but with less intensity and thus situated under the masking threshold will not be heard because it is masked by the main sound event.

To extract the perceptible part of the audio signal the spectrum is split into 32 equally-spaced sub-bands. In each sub-band, the signal is quantised in such a way that the quantising noise matches the masking threshold. This coding system for high-quality audio signals known as MUSICAM is standardised by ISO/IEC 11172-3 (MPEG 1 Audio Layer II) and ISO/IEC 13818-3 (MPEG 2 Audio Layer II).

The DAB Specification permits full use of the flexibility of Layer II except for the fact that only the standard studio sampling frequency of 48 kHz and the half sampling frequency of 24 kHz are used. Layer II is capable of processing mono, stereo, and dual-channel, such as bilingual programmes. Different encoded bit-rate options are available (8, 16, 24, 32, 48, 56, 64, 80, 96, 112, 128, 160, or 192 kbit/s per monophonic channel). In stereophonic or dual-channel mode, the encoder produces twice the bit-rate of a mono channel.

The range of possible options can be utilised flexibly by broadcasters depending on the quality required and the number of sound programmes to be broadcast. A stereophonic signal may be conveyed in the stereo mode, or - particularly at lower bit-rates - in the joint stereo mode. This mode uses the redundancy and interleaving of the two channels of a stereophonic programme to maximise the overall perceived audio quality.

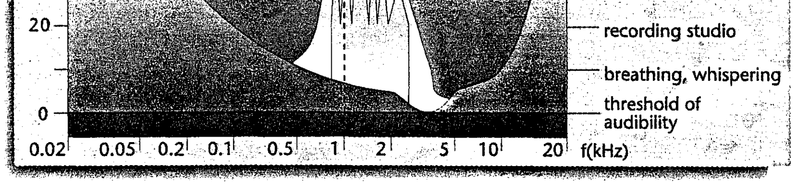


Fig. 3-1: Psychoacoustic Masking

Data Services

Programme Associated Data

Each audio programme contains Programme Associated Data (PAD) with a variable capacity (minimum 667 bit/s, up to 65 kbit/s) which is used to convey information together with the sound programme.

The PAD Channel is incorporated at the end of the DAB/ISO audio frame. Typical examples of PAD applications are dynamic range control information, a dynamic label to display programme titles or lyrics, speech/music indication and text with graphic features.

Independent Data Services

In addition to PAD, general data may be transmitted as a separate service. This may be either in the form of a continuous stream segmented into 24 ms logical frames with a data rate of n x 8 kbit/s (n x 32 kbit/s for some code rates) or in packet mode, where individual packet data services may have much lower capacities and are bundled in a packet sub-multiplex. A third way to carry Independent Data Services is as a part of the FIC (Fast Information Channel).

Typical examples of Independent Data Services are a Traffic Message Channel, correction data for Differential GPS, Paging and an electronic newspaper.

Conditional Access

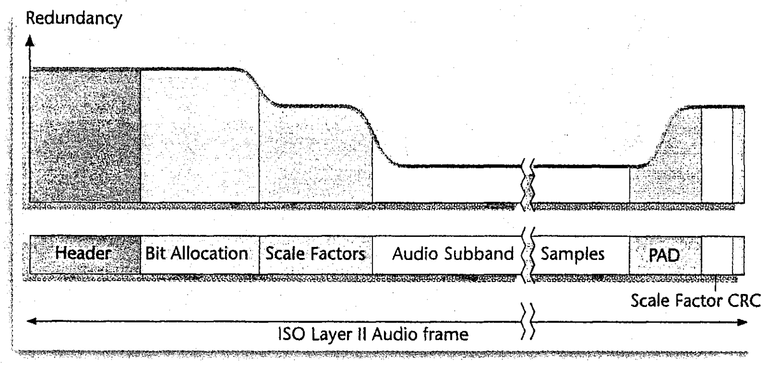
Every service can be fitted with Conditional Access if desired. The Conditional Access (CA) system includes three main functions: scrambling/descrambling, entitlement checking and entitlement management. The scrambling/descrambling function makes the service incomprehensible to unauthorised users. Entitlement checking consists of broadcasting the conditions required to access a service, together with encrypted secret codes to enable descrambling for authorised receivers. The entitlement management function distributes entitlements to receivers.

Service Information (SI)

The following elements of Service Information can be made available to the listener for programme selection and for operation and control of receivers:

- basic programme-service label (i.e. the name of a programme service)
- programme-type label (e.g. news, sports, classical music)
- dynamic text label (e.g. the programme title, lyrics, names of artistes)
- programme language
- time and date, for display or recorder control
- switching to traffic reports, news flashes or announcements on other services
- cross-reference to the same service being transmitted in another DAB ensemble or via AM or FM, and to other services
- transmitter identification information (e.g. for geographical selection of information)

Fig. 3-2: Unequal Error Protection



Essential items of SI that are used for programme selection are carried in the FIC. Information that is not required immediately when switching on a receiver, such as a list of all the day's programmes, may be carried separately as a general data service (Auxiliary Information Channel).

Channel Coding and Time Interleaving

The data representing each of the programme services is subjected to energy dispersal scrambling, convolutional coding and time interleaving. For energy dispersal scrambling a pseudo-random bit sequence is added to the data in order to randomise the shape of the DAB signal and thus efficiently use power amplifiers. The convolutional encoding process involves adding redundancy to the data in order to help the receiver detect and better eliminate transmission errors. In the case of an audio signal, some parts of the audio frame are less sensitive to transmission errors than others and accordingly, the amount of redundancy added is reduced for these. This method is known as Unequal Error Protection (UEP), see Figure 3-2.

Main Service Multiplex

The encoded and interleaved data is fed to the Main Service Multiplexer (MUX) where every 24 ms the data is gathered in sequences. The combined bit-stream output from the multiplexer is known as the Main Service Channel (MSC) and has a gross capacity of 2.3 Mbit/s. Depending on the convolutional code rate, which can differ from one application to another, the net bit-rate ranges from approximately 0.6 to 1.8 Mbit/s, accommodated in a DAB signal with a 1.536 MHz bandwidth.

Table 1 shows the number of audio channels possible in a DAB ensemble at different bit-rates and

Audio bit-rate kbit/s	Protection level (increasing protection) 5	4	3	2	1
24*	n/a	64	48	36	24
32	54	41	36	29	24
64	27	20	18	14	12
128	13	10	9	7	6
192	9	7	6	5	4
224	7	6	5	4	3
256	6	5	4	3	3

Equal Error Protection

Table 1:
Example of DAB Multiplexes: Maximum Number of Audio Channels

protection levels. The DAB system allows the Main Service Multiplex to be reconfigured from time to time. The precise information about the contents of the Main Service Multiplex is carried by the Fast Information Channel to communicate to the receiver how to access the services. This information is known as the Multiplex Configuration Information (MCI). s data is highly protected and repeated frequently to ensure its ruggedness. When the multiplex configuration is about to change, the new information, together with the timing of the change, is transported via the MCI and details in advance what changes are going to take place.

Transmission Frame

In order to facilitate receiver synchronisation, the transmitted signal is designed according to a frame structure with a fixed sequence of symbols. Each transmission frame (see Figure 3-3) begins with a null symbol for coarse synchronisation (when no RF signal is transmitted), followed by a phase reference symbol for differential demodulation. The next symbols are reserved for the FIC, and the remaining symbols provide the MSC. The total frame duration is 96 ms, 48 ms or 24 ms, depending on the transmission mode (see Table 2). Each service within the MSC is allocated a fixed time slot in the frame.

	Transmission Mode			
System Parameter	I	II	III	IV
Frame duration	96 ms	24 ms	24 ms	48 ms
Null symbol duration	1297 μs	324 μs	168 μs	648 μs
Guard interval duration	246 μs	62 μs	31 μs	123 μs
Nominal maximum transmitter separation for SFN	96 km	24 km	12 km	48 km
Nominal frequency range (for mobile reception)	≤ 375 MHz	≤ 1.5 GHz	≤ 3 GHz	≤ 1.5 GHz
Speed/coverage trade-off	No	No	No	Yes
Useful symbol duration	1 ms	250 μs	125 μs	500 μs
Total symbol duration	1246 μs	312 μs	156 μs	623 μs
No. of radiated carriers	1536	384	192	768

Table 2: DAB Transmission Parameters for Each Transmission Mode

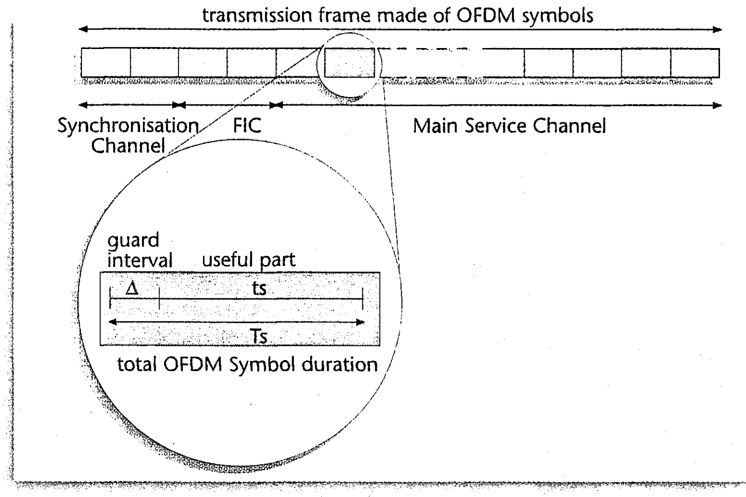
Modulation with OFDM and Transmission Modes

The DAB system uses a multicarrier scheme known as Orthogonal Frequency Division Multiplexing (OFDM). This scheme meets the exacting requirements of high-bit-rate digital broadcasting to mobile, portable, and fixed receivers, especially in multipath environments. Basically, before transmission the information is divided into a large number of bit-streams with low bit-rates each. These are then used to modulate individual orthogonal carriers (differential QPSK) in such a way that the corresponding symbol duration becomes larger than the delay spread of the transmission channels. By inserting a temporal guard interval between successive symbols, channel selectivity and multipath propagation will not cause inter-symbol interference (see Figure 3-4). The system provides four transmission-mode options which allow for a wide range of transmission frequencies between 30 MHz and 3 GHz and network configurations.

For the nominal frequency ranges, the transmission modes have been designed to suffer neither from Doppler spread nor from delay spread, both inherent in mobile reception with multipath echoes.

Table 2 gives the temporal guard interval duration, the nominal maximum transmitter separation and frequency range for mobile reception for the different modes. The noise degradation at the highest frequency is equal to approximately 1 dB at 100km/h under the most critical multipath conditions, which do not occur frequently in practice. The table shows that the higher the frequencies the shorter the guard interval available and hence the smaller the maximum non-destructive echo delay. Mode I is most suitable for a terrestrial Single-Frequency Network in the VHF range,

Fig. 3-3: Total OFDM Symbol Duration



because it allows the greatest transmitter separations. Mode II will preferably be used for medium-scale SFN in L-band and for local radio applications that require one terrestrial transmitter. Larger transmitter spacing can be accommodated by inserting artificial delays at the transmitters and by using directional transmission antennas. Mode III is most appropriate for cable, satellite and complementary terrestrial transmission, since it can be operated at all frequencies up to 3 GHz for mobile reception, and has the greatest phase-noise tolerance. Mode IV is also used in L-band and allows a greater transmitter spacing in SFNs. However, it is less resistant to degradation at higher vehicle speeds.

The large number of orthogonal carriers (see Table 2), which can be easily generated by a Fast Fourier Transformation (FFT) process, is known collectively as a "DAB block". The spectrum of the signal is approximately rectangular, Gaussian noise-like, and occupies a bandwidth of 1.536 MHz.

Figure 3-5 shows an example of the transmitter output spectrum after it has been amplified and filtered. In practice, the peak-to-mean ratio can be limited to about 8 dB by digital processing, although this may be further reduced by additional signal conditioning when amplifying it in a non-linear way in the transmitter. With multipath propagation, some of the carriers are amplified by constructive signals, while others suffer destructive interference (frequency selective fading). Therefore, the OFDM system provides frequency interleaving by a re-arrangement of the digital bit-stream among the carriers, so that successive source samples are not affected by selective fade. In stationary receivers, this diversity in the frequency domain is the prime means to guarantee unimpaired reception; the time diversity due to time-interleaving provides further assistance to a mobile receiver. Consequently, multipath propagation is a form of diversity of which DAB takes advantage, in stark contrast to conventional FM or narrow-band digital systems, where it can completely destroy a service.

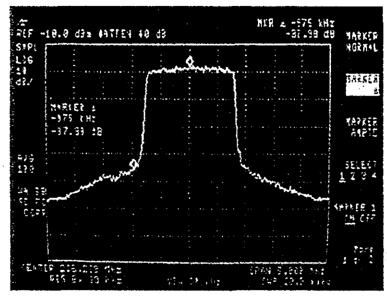
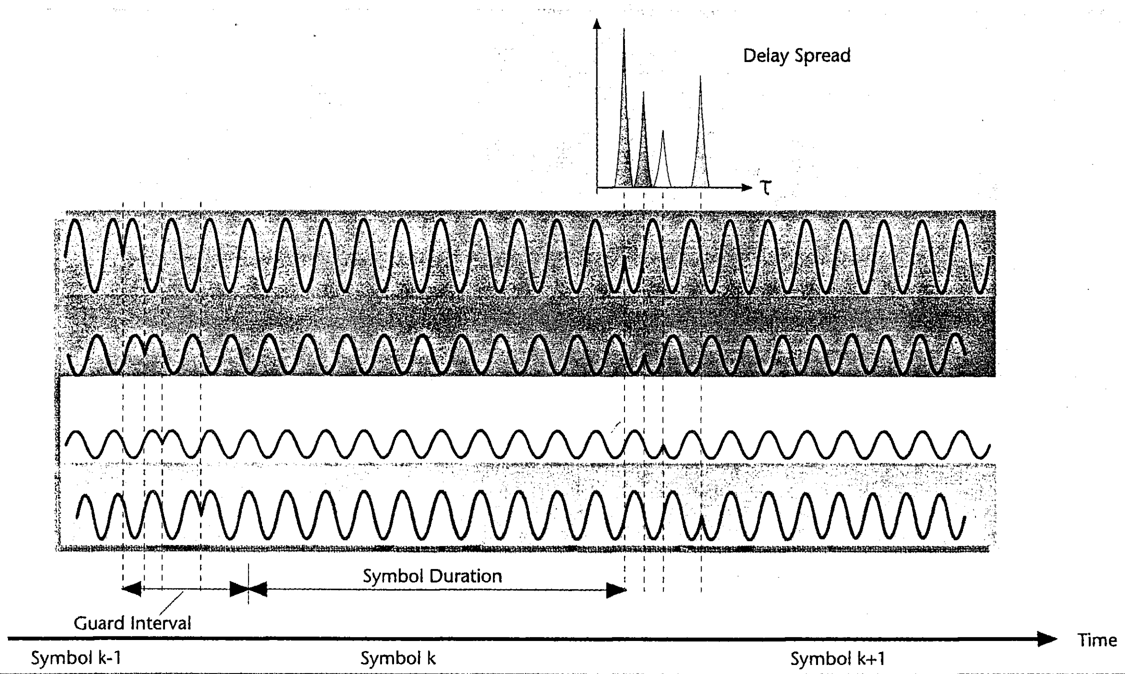


Fig. 3-5: Transmitter Signal Spectrum and Output Filtering (VHF Band III).

Fig. 3-4: Orthogonal Frequency Division Multiplexing (OFDM)



4. Implementation of Terrestrial DAB Networks

The specification of the DAB signal (see Chapter 3) gives full details of the characteristics of a signal which is to be emitted from the transmitters in the form of a DAB ensemble. In practice, however, it may not be the optimum method to distribute the DAB ensemble to the transmitters. Other, more suitable distribution-signal formats have been developed.

A conceptual DAB Distribution Network is shown in Figure 4-1.

The Service Provider creates and manages the data that is to become a service in a DAB ensemble. This data is passed to the Ensemble Provider via the Service Transport Network. The Ensemble Provider manages the capacity of the complete ensemble. Typically, information about services will be received from many different Service Providers. This information will then be assembled into a set of data representing the complete DAB ensemble. The ensemble description is passed to the Transmitter Stations where the DAB ensemble is generated and radiated. The interface between the Ensemble Provider and the Transmission Network is known as the Ensemble Transport Interface (ETI). It allows the efficient distribution of signals from the DAB Ensemble Multiplexer to the COFDM generators of the Transmission Network, for example, a Single Frequency Network.

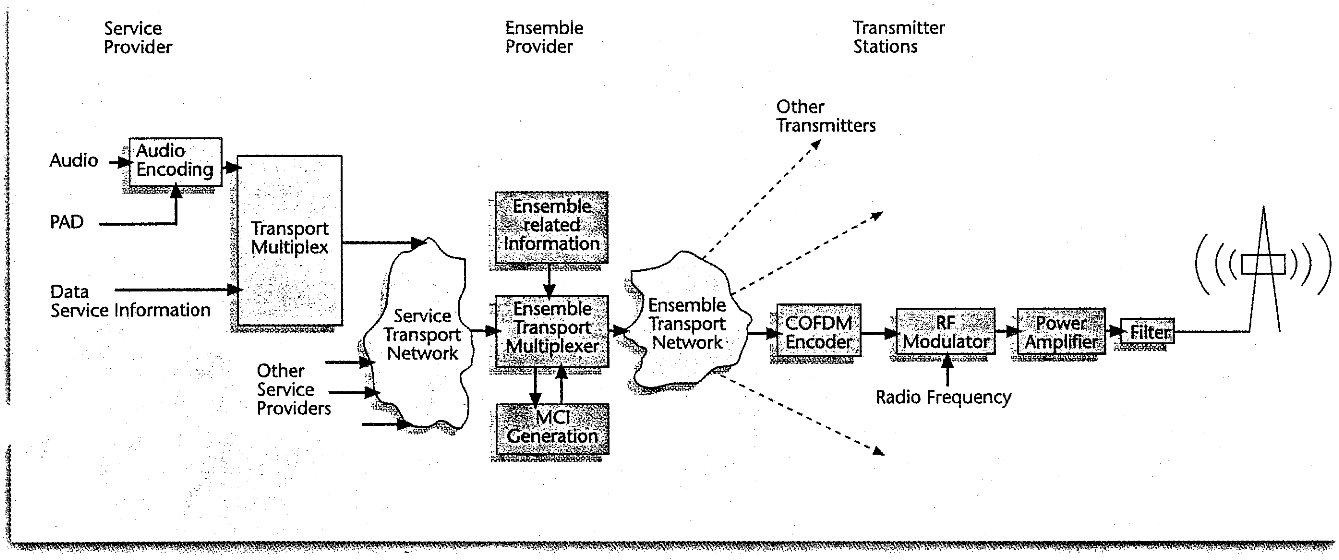
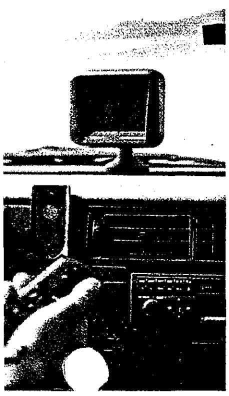


Fig. 4-1: Conceptual DAB Distribution Network

5. DAB-based Multimedia and Data Services



DAB is not only a new system for mobile reception of high audio quality and superior frequency economy, it also opens up opportunities for completely new services.

In the future, there will certainly continue to be programmes similar to current radio programmes, but these will be supplemented by pictures, text, and graphics which increase the information value of the programmes. This combination could be called "Multimedia Radio".

Conceivable examples are traffic and travel information, business information, paging, data to assist navigation and position determination, remote teaching, electronic newspapers, games, electronically stored music and various kinds of moving-picture services.

Some Key Elements of Multimedia Broadcast

A transmission protocol for Multimedia applications and a standard digital interface are both essential for Multimedia radio. The interface enables extra devices such as dedicated decoders for Multimedia applications, or computers, to be connected to a DAB receiver.

Both provisions have been put into practice and will be standardised to encourage the introduction of DAB-based Multimedia services.

Multimedia applications generally rely on files containing relevant data for the selected service (e.g. text, picture, sound or video) together with additional information to allow for data presentation and classification. Each item consisting of a file plus the additional information is referred to as a "Multimedia Object". The transmission of Multimedia Objects using all transport mechanisms provided by the DAB system (Stream mode, Packet mode, and PAD) is managed by a protocol called Multimedia Object Transfer protocol (MOT).

The specification of a Receiver Data Interface (RDI) is an important step to allow DAB receivers and data terminals to be interconnected in a flexible way. It can convey the entire data multiplex, i.e. all audio and data channels are accessible by a computer, car navigation systems or other equipment. The RDI allows high-speed transfer (up to 1.8 Mbit/s) of a wide range of audio and data services in parallel.

Data Management

Due to the steady increase in the number of potential data providers, such as the media, tourism, transport or administration, comprehensive data management has been proved necessary.

Thus, e.g. a German Data Service Centre (DSC) has been set up forming an interface between service providers and DAB networks. The DSC will record data of standardised formats sent in by file transfer, by fax or by telephone, to later process and introduce this data to a central server and a DAB multiplexer.

Traffic and Travel Information

Traffic and Travel Information can be transmitted on DAB in various formats including the TMC (Traffic Message Channel) protocol developed for the FM Radio Data System (RDS). The following services can be foreseen:

- *Traffic messages:* information about traffic problems, suggestions for route selection, etc. may be transmitted via one of the DAB data channels. The informa-

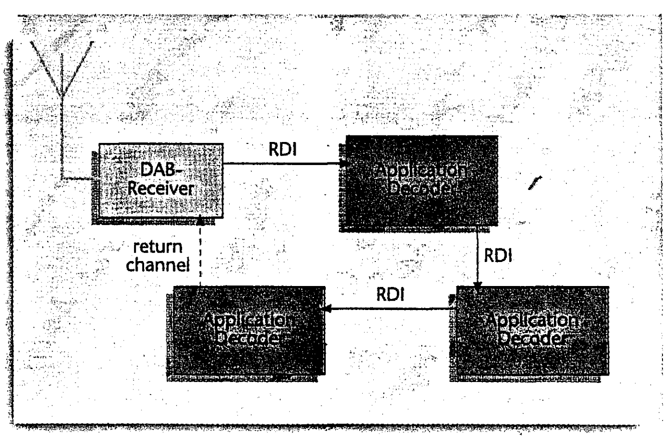


Fig. 5-1: Concept of the Receiver Data Interface

tion can be presented to the motorist by synthesised speech or on a display in the form of text or maps.

- *Traffic navigation:* digitised roadmaps are transmitted and combined with position determination in navigation systems. It will be easy to find one's way around in large cities, which is of great importance especially for emerg-[illegible]y vehicles, taxis, buses and frequent travellers.
- *Travel information:* hotel information (vacancies, room prices, pictures of rooms), local events, location of, and space availibility in car parks, petrol stations, timetables, advertisements from local shops, and other information can be transmitted and stored in the receiver and displayed.

Text Transmission

Textual information is a valuable supplement to an audio programme and may convey details of the name and composer of a record playing, information about the current programme including the phone-in telephone number, an address for more information or even an electronic programme guide.

The DAB specification offers two modes for text transmission:

- *Dynamic Label*

This is similar to the radio text feature known from the FM-Radio Data System (RDS). It is intended for short messages to be shown on a simple receiver display of typically up to 16 characters, used to display information, such as radio-station names, programme types. Dynamic Label messages are limited to 128 characters each.

- *Interactive Text Transmission System (ITTS)*

ITTS is a more sophisticated text transmission system. It allows for menu-driven operation, but can also be used to transmit text at the rate a broadcaster prescribes, for instance in Karaoke-like transmission of lyrics. It can process several streams of textual information simultaneously, which can be used to convey the same information in several languages or to transmit a programme schedule at the same time as giving details of the programme currently on the air. ITTS supports a number of different display formats, from a 12-character one-line display to a large colour display.

Electronic Newspaper

A growing number of print media offer complementary on-line information access services that increasingly integrate multimedia content.

DAB offers novel, innovative electronic media broadcasting services. They will include all the advantages of on-line multimedia information, but also offer the additional benefits of over-the-air transmission:

- real-time coverage of large geographic zones
- immediate delivery: the newspaper is available as soon as its production has been completed, anywhere across the country; updates are possible at any time
- a large readership can be reached at a very low cost per reader
- no consumption of natural resources (paper) required

Le Républicain Lorrain

L'enquête aboutit en Suède

Attentats de Paris : un islamiste arrêté

Explosion d

Bouzon cinq br à l'usin Gerlach

Une rentrée délicate

Bombe à Jérusalem

Münsterischer Anzeiger • Westfälischer Merkur

Westfälische Nachrichten

Wieder mehr junge Familien

LOKALES

Höhere Hürden zum Führerschein

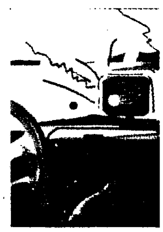
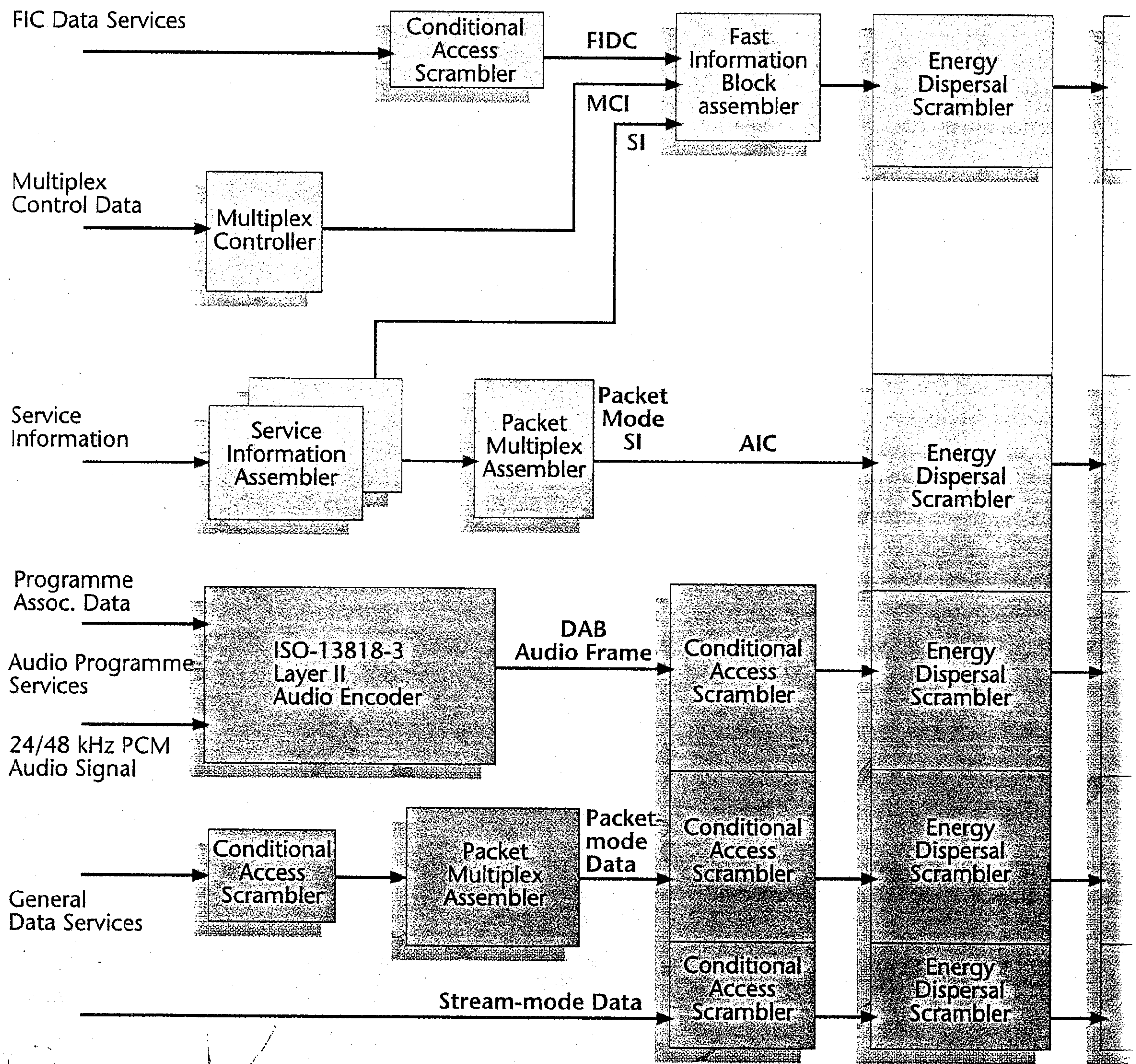
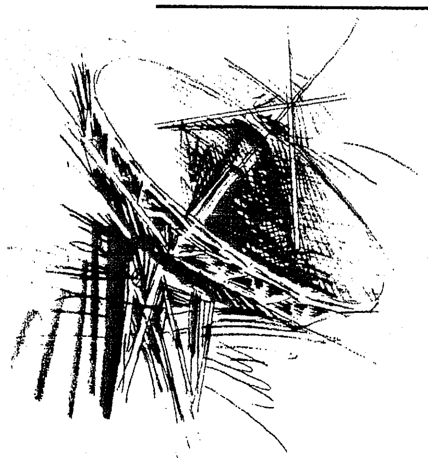


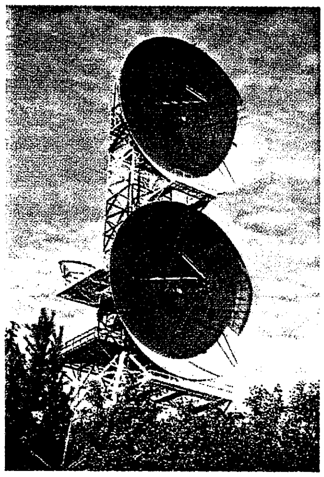
Fig. 5-2: Electronic Newspaper.

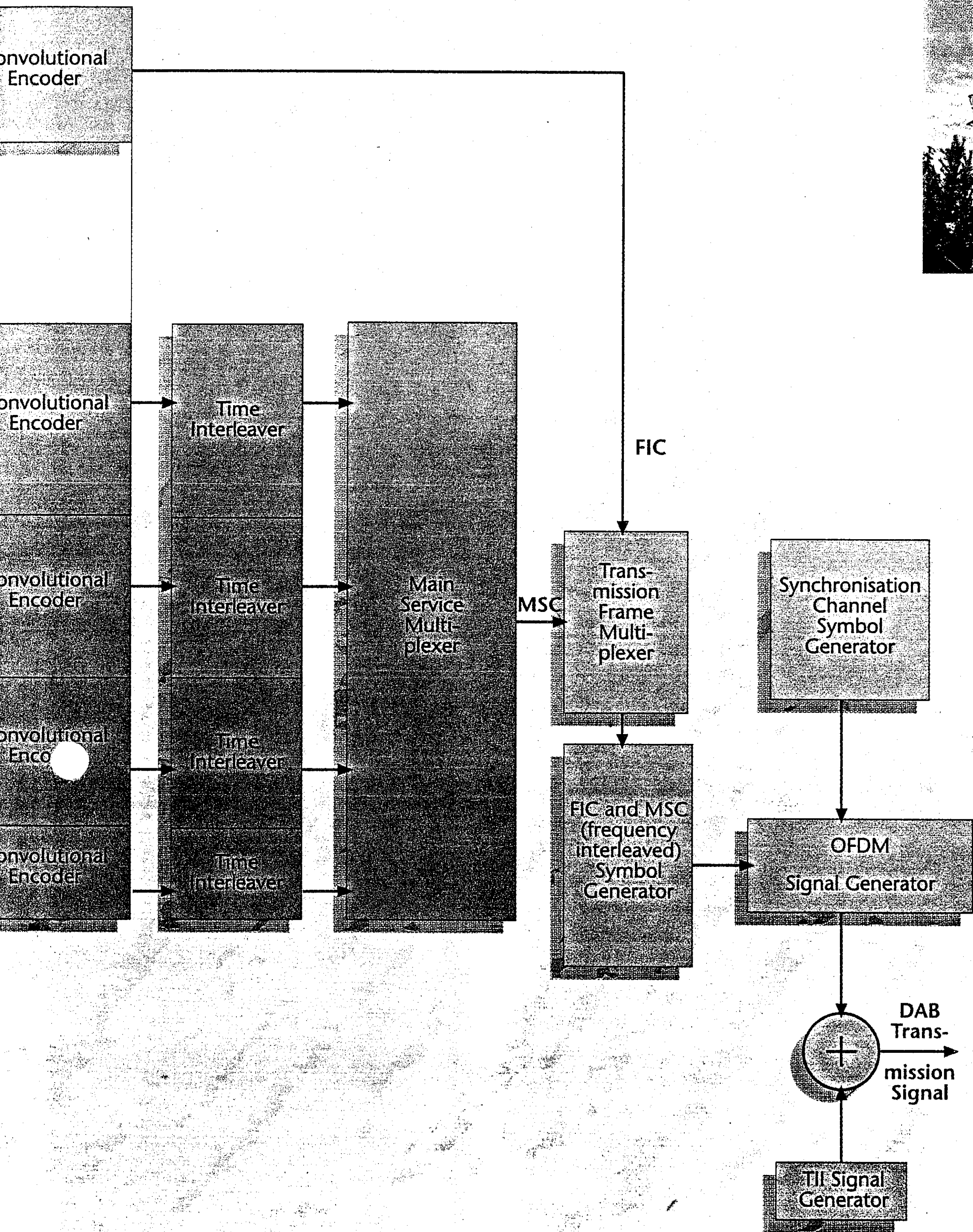
By courtesy of TDF/CCETT, Le Monde, Le Républicain Lorrain and Westfälische Nachrichten

Conceptual DAB Signal Generation








onvolutional Encoder
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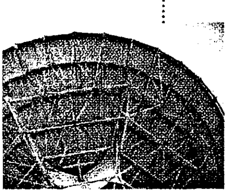
Time Interleaver
Time Interleaver
Time Interleaver
Time Interleaver
Main Service Multi-plexer
FIC
MSC
Trans-mission Frame Multi-plexer
FIC and MSC (frequency interleaved) Symbol Generator
Synchronisation Channel Symbol Generator
OFDM Signal Generator
DAB Trans-mission Signal
TII Signal Generator



The new system also offers attractive benefits for readers:

- wireless reception means complete freedom since information is received as easily as a radio signal. The terminal, for example a PC, may receive the electronic newspaper or magazine directly, without any action required of the user
- the newspaper is stored in the computer and available for access on demand
- mobility: readers can receive a newspaper on a portable computer, even while travelling
- easy access: subscribers use a "smart card" which enables them to receive a broadcast newspaper on a computer
- easy re-use of information (extracting, editing, printing, etc.) novel use of the data, e.g. voice technology
- low network installation costs

Initially, such services will mainly target professional users. They will subsequently be expanded to the consumer market.

Picture Transmission

For still-picture transmission via DAB, a number of innovative applications can be foreseen. For instance, during news bulletins photographs could also be transmitted. Weather forecasts and traffic messages could be illustrated with suitable maps and during music programmes, the CD cover or a photograph of the performers could be displayed.

In order to transmit pictures in a more efficient way, data compression, e.g. according to the JPEG standard, could be used.

Such a "slide-show" broadcast would achieve synchronisation of the still pictures with the audio by transporting the compressed picture files in the PAD of an audio channel. First experiments have shown that at a data rate of 16 kbit/s a picture can be transmitted within 15 to 60 seconds at an acceptable quality if the JPEG compression factor is chosen appropriately. Auxiliary information is fed into a serial command channel which is carried within the PAD. This information indicates the start, continuation or end of a picture file and communicates to the receiver when a new picture has to be shown to synchronise the display with the audio programme. The pictures received can be displayed using a special decoder or transferred to a PC for further processing.

TV Transmission to Mobiles

Several public demonstrations have shown that DAB is a suitable system for the transmission of video and audio signals – even to mobile receivers. A large market for portable TV-sets and monitors on public transport is foreseen. It will be possible to receive news on global and regional events as well as entertainment on the daily way to work, e.g. by train, bus or on the underground. Video spots on current theatre and cinema programmes and other local events will provide both information and advertisement.

Demonstrations have shown that the system can be operated at a rather low video bit-rate of about 1.5 Mbit/s using international standardised compression algorithms (MPEG1 and MPEG2). Combined

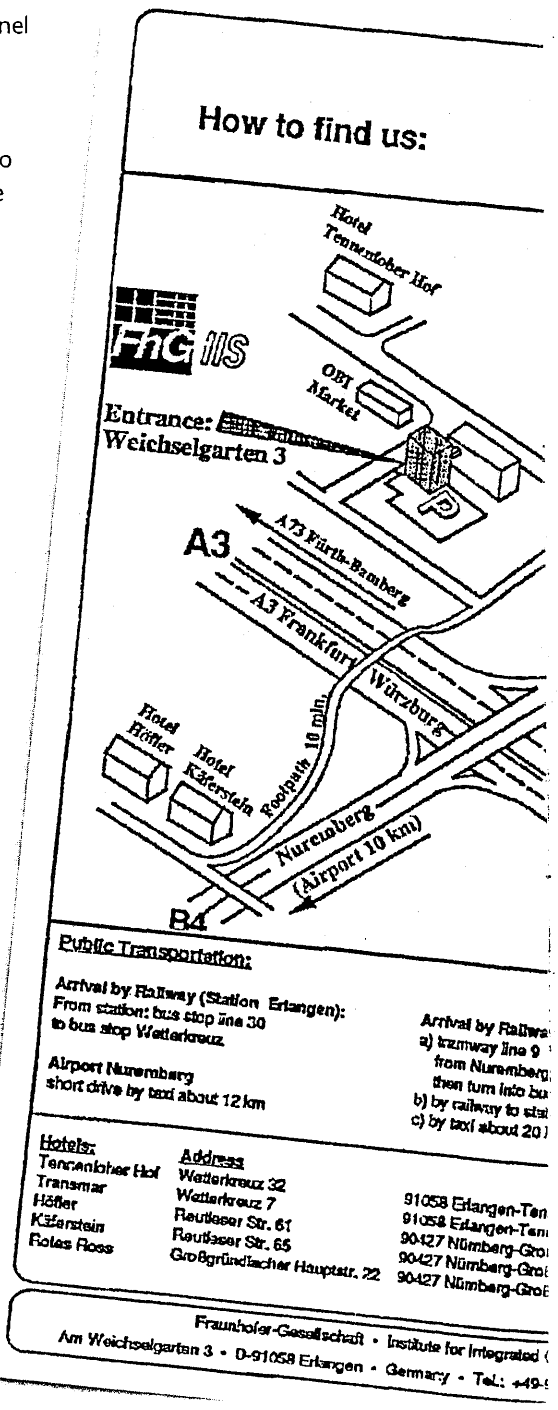


Fig. 5-3: Fax Printout.

video and audio bit-streams will be embedded in one DAB block leaving additional room for data applications.

Fax Printout

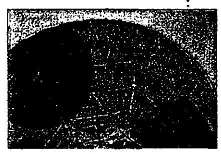
In situations when reading large amounts of information on a display is inconvenient - for example when driving - the possibility of printing graphics or extensive texts can be very attractive. By using the flexibility of the packet mode (e.g. the variable data rate) and coupling the DAB receiver with a compact high-resolution printer Fax transmission and reception is also possible.

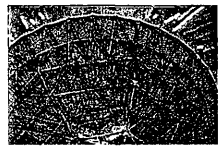
In demonstrators using graphics, grey scales and G3 faxes, the output was still perfectly acceptable, even on small-sized paper.

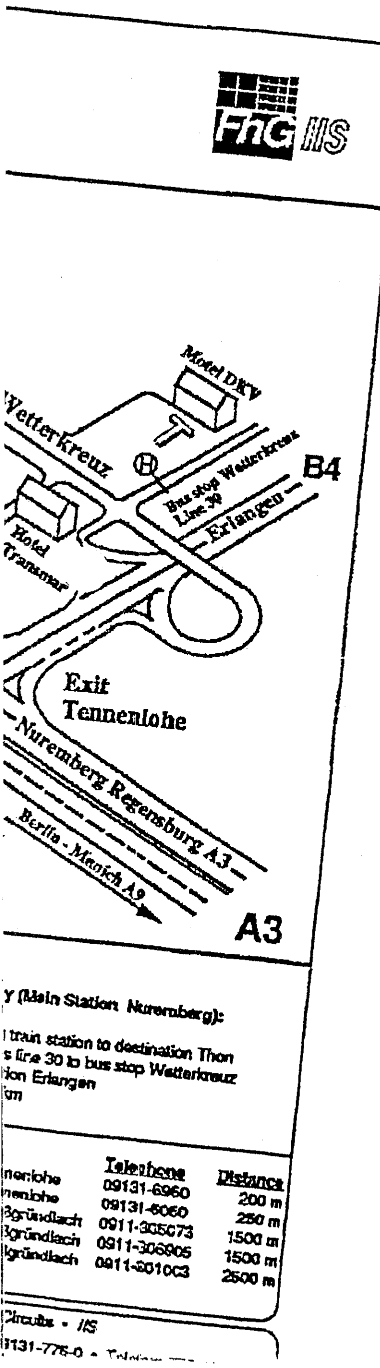
Differential GPS

GPS, the global positioning system, is a satellite-based navigation system available all over the world and provides a positional accuracy of between 300 and 100 metres. By placing an additional GPS receiver at a precisely known location, it is possible to calculate the error. If this "differential" or error signal is then also separately fed to the GPS receiver, position accuracy to better than 20 metres becomes possible. Transmission of such data via a DAB data channel in packet mode is an easy solution for this purpose. By linking mobile GPS receivers to DAB receivers positional accuracy can be increased significantly.

Figure 5-4 shows an error plot of GPS position measurement for a fixed receiver with differential information (inside circle) and without differential information in a first DAB based demonstration of differential GPS.







By courtesy of FhG/IIS

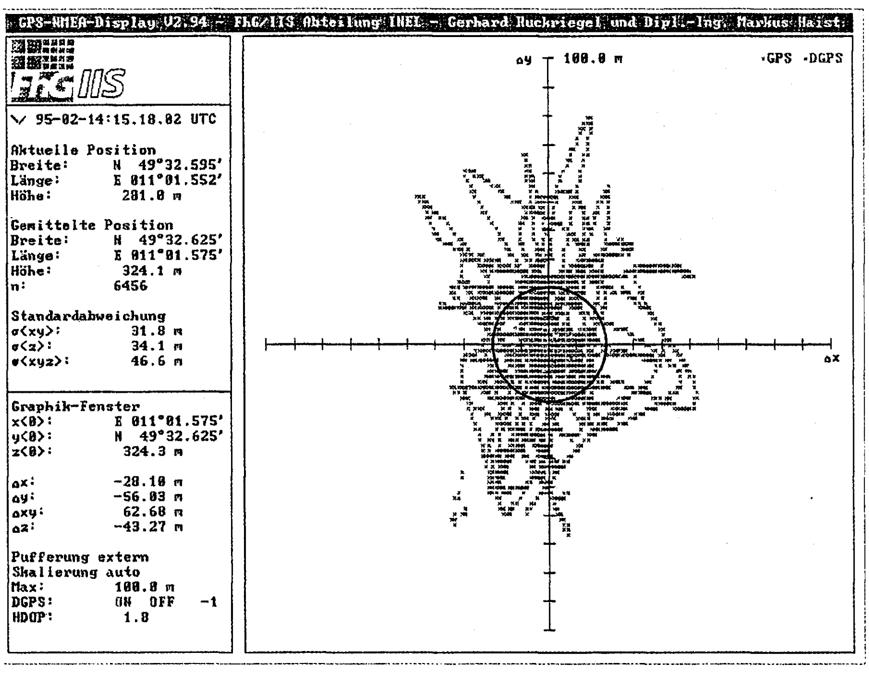


Fig. 5-4: Error Plot of GPS Position Measurement with Differential Information and without Differential Information.

By courtesy of FhG/IIS

6. Evolution of DAB

Figure 6-1 shows the most prominent milestones in the development of DAB: The EUREKA-147 consortium was founded in 1987. Its aim was to develop and define the digital broadcast system which later became known as DAB. The first equipment was assembled for mobile demonstration at the Geneva WARC conference of 1988. By 1990, a small number of test receivers was manufactured. They had a size of about 120 dm ^{3}. In 1992, the frequencies of the L- and S-band were allocated to DAB on a world-wide basis. The third generation receivers, widely used for test purposes since mid-1993 have a size of about 25 dm^3. The fourth generation JESSI-DAB based test receivers, e.g. the DAB452 Test Receivers (see Fig. 6-2) have a size of about 3 dm ^{3}. They are in accordance with the latest DAB standards and recommendations released by ETSI, EBU and ITU.

Since 1990, some of the EUREKA-147 members have participated in a JESSI project, in which custom-designed Integrated Circuits (ICs) for DAB have been developed. The first consumer-type DAB-receivers to be developed for use in pilot projects were presented at the Internationale Funkausstellung (IFA) 1995 in Berlin. Since then, radio-receiver and multimedia-terminal technology is constantly improving. Miniaturisation will continue, and with mass production, prices are expected to drop to a level that is affordable to everybody within the next few years.

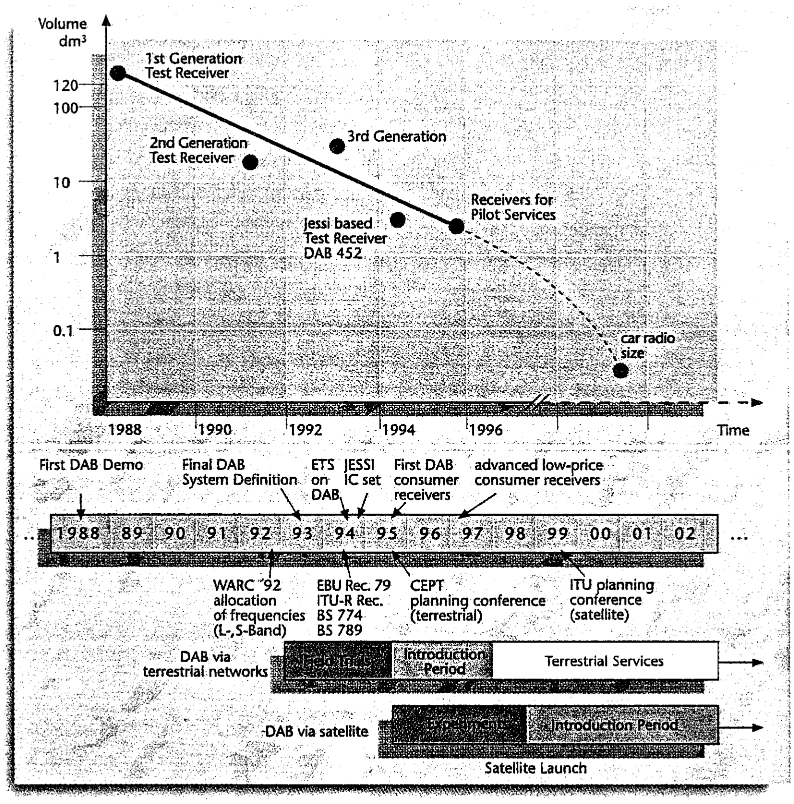


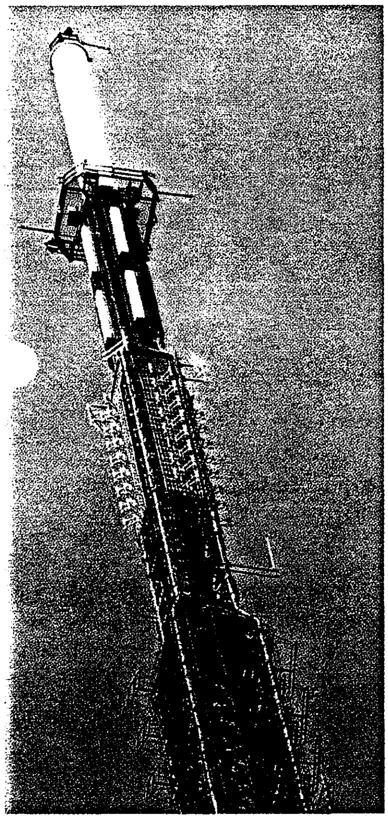
Fig. 6-1: Evolution of DAB Receivers

EIA Test Results

Superior performance of the EUREKA-147 DAB system under noise, interference, and multipath simulations was confirmed during independent laboratory tests conducted by the Electronics Industry Association (EIA) on different types of digital-broadcasting systems in the USA in 1995.

The EIA tests included subjective quality tests on the audio coding system and objective tests on the overall system performance. The main purpose of these tests was to examine the audio quality, system robustness, multipath and noise immunity, anticipated area coverage, operating characteristics and collateral effects such as frequency and bandwidth efficiency, power efficiency and flexibility in terms of added services and extra data capacity.

In contrast to narrow-band digital systems, the EUREKA-147 system using ISO MPEG Layer II (also known as MUSICAM) at 224 kbit/s did not show any deficiencies (e.g. interference) even when being operated in the presence of large echoes.



By courtesy of BBC

roDab Forum

Since March 1995, more than 80 national forums, manufacturers, broadcasters, network providers, media regulators and administrations have joined the European DAB Forum (EuroDab Forum) for the coordination of European activities on DAB. The aim of the EuroDab Forum is to encourage the transfer of technology, to harmonise the activities of national DAB platforms and to lead to global cooperation in the implementation of DAB.

The culminating point of these activities will be the introduction of DAB services and DAB consumer receivers on the market in Autumn 1997.

Introduction of DAB in Europe

In 1995, the introduction of terrestrial DAB was discussed by the European Conference for Posts and Telecommunications (CEPT) in Wiesbaden, Germany.

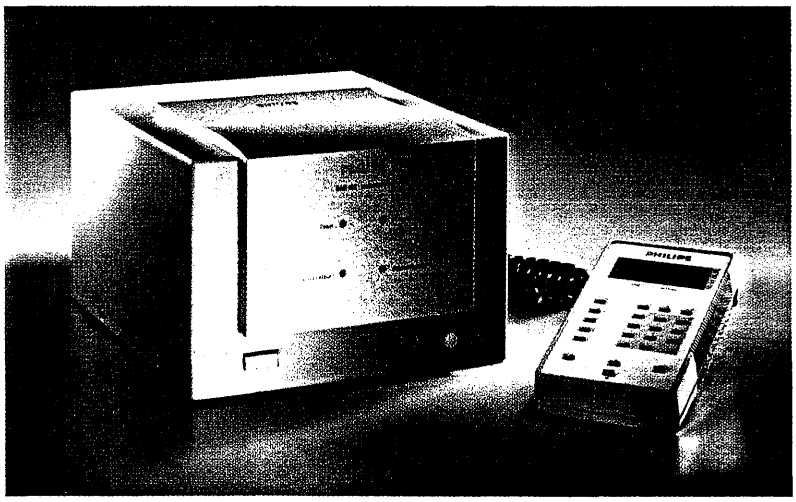
In cooperation with representatives of regional and international organisations such as the European Broadcasting Union (EBU), the European Commission and the International Telecommunications Union (ITU) a total of 73 frequency blocks to be used for future and current DAB services was agreed.

The distribution of these frequency blocks is as follows: 12 blocks in VHF Band II (87 MHz - 108 MHz), 38 blocks in VHF Band III (174 MHz - 240 MHz), and 23 blocks in L-Band (1.452 GHz - 1.492 GHz).

Each frequency block carries a two- or three-character label easy to remember for listeners when programming their receivers.

In addition, the centre frequency of each ensemble (i.e. frequency block) was defined to considerably simplify the receiver design.

Allotments were made to allow for implementation of two DAB ensembles in any given country or area in Europe. The majority of these allotments is in VHF Band III and the lower part of the L-Band (1.452 GHz - 1.467 GHz).



By courtesy of Philips.

Fig. 6-2: DAB452 Test Receiver

With the aim of facilitating a common European radio-frequency usage by the year 2008, the agreement entered into force on January 1, 1996.

The official introduction of DAB in most European countries is planned for 1997, earlier in Great Britain, Sweden and some other countries. By the year 2000, 70-80% of the population in many European countries will be able to receive DAB. At this stage, consumer-type DAB receivers will still be able to receive FM services, as for many years FM and DAB will co-exist. Universal DAB coverage is envisaged to commence in the year 2000.

DAB is also considered outside Europe. In 1990, the first public demonstrations were conducted in Canada. DAB tests were also carried out in Australia, China, South Korea and Mexico.

DAB will either be transmitted over terrestrial networks or via satellite and a wide variety of audio programmes and data services will ensure its success.

courtesy of Bosch

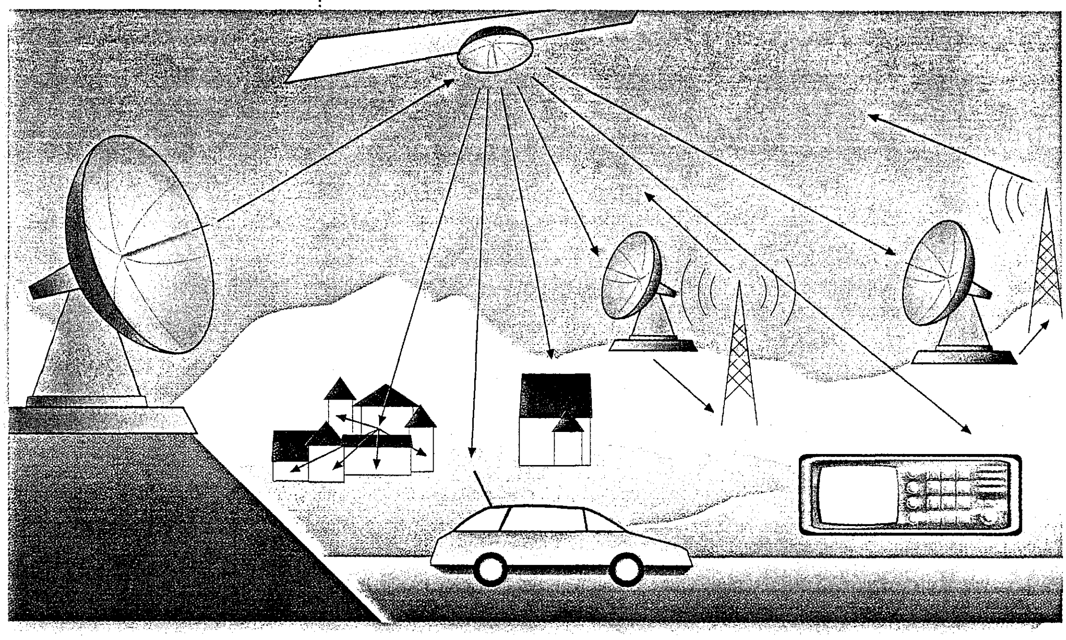


Fig. 6-3: Conceptual DAB Satellite Transmission

Satellite DAB

Besides terrestrial transmission the DAB system is suitable for satellite as well as for hybrid/mixed terrestrial/satellite broadcasting, using a simple, omni-directional receiving antenna.

Satellites will receive the data generated by uplink stations, amplify this data and send it back through special spot beams not only to fixed, but also to mobile, and portable receivers. Complementary terrestrial transmitters may be necessary, e.g. in big cities with high-rise buildings. In contrast to conventional TV-satellites, where radio programmes can only be picked up with the help of special receivers, and dishes have to be installed, the DAB satellite system will have the same modulation/coding system parameters as the terrestrial system. Thus, the same receiver and antenna can be used both for terrestrial and satellite DAB.

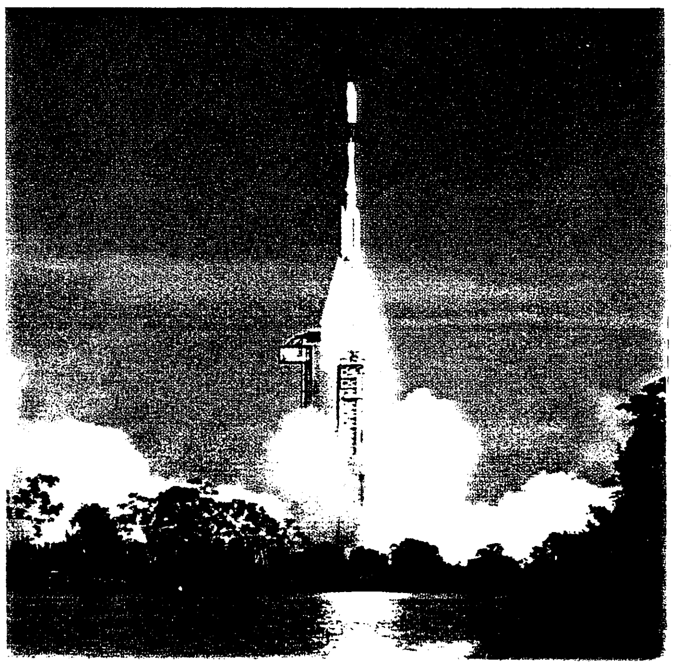
Field tests on Satellite DAB have been conducted recently - one in Australia, the other in Mexico. In the Australian test, the Optus B3 satellite was tested at 1.552 GHz. The trial in Mexico used the Solidaridad satellite. Although both test satellites were not specially designed for multi-carrier systems such as the EUREKA-147 DAB system, but for mobile-phone services, satellite transmission of DAB signals proved technically feasible.

Satellite simulations with helicopters were also carried out. To provide high-quality, mobile reception, elevation angles of 60 to 70 degrees were found to be necessary.

With Satellite DAB it will be possible to cover areas much larger than those covered by terrestrial broadcast stations. A geostationary (GEO) satellite system could cover low-latitude areas, such as most parts of Africa, Central and South America, India, Indonesia. To cover the northern hemisphere including Europe, North America, China and Japan, the highly-inclined elliptical orbit (HEO) system seems to be a possible solution, since it allows greater penetration to mobile receivers in urban areas (due to the high elevation angles of the satellites, and hence less shadowing of the signals). The EUREKA-147 DAB system addresses both GEO and HEO satellite options.

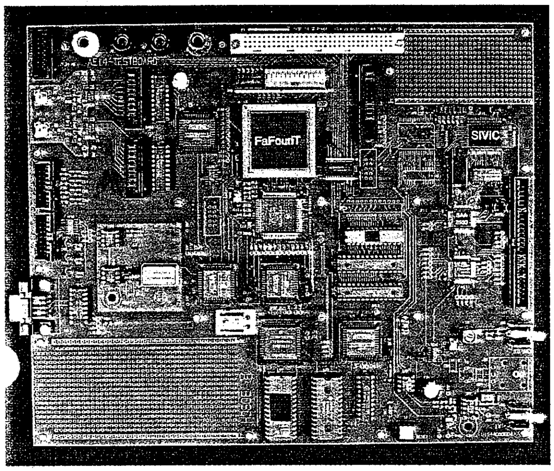
For international broadcasting, all WARC-92 bands (i.e. bands located at 1.5, 2.3 and 2.6 GHz) are to be considered. DAB Transmission Modes II, III or IV can be used at these frequencies.

Satellite transmission is currently in the experimental stage, DAB satellite launches are planned for 1998, and after an introductory period of about 10 years regular satellite services will be initiated.



By courtesy of Daimler-Benz Aerospace

Fig. 6-4: JESSI-Testboard

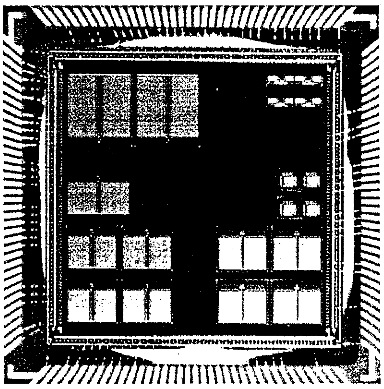


By courtesy of …sch

State-of-the-art equipment

In the JESSI project "Implementation of Prototype Building Blocks for a Digital Audio Broadcasting Standard", a highly-integrated chip set for DAB transmitters and receivers is being developed. The version of the DAB chip set currently available will allow the production of receivers in large quantities at a reasonable price for pilot projects with Digital Audio Broadcasting. Further activities in the JESSI project will provide chip sets with higher integration containing only a few ICs. These ICs pave the way for the mass production of DAB receivers, having a smaller size and lower power consumption, and affordable prices. The partitioning of the current IC set is primarily based on technological arguments; the building blocks in the next design will be organised according to basic functions. It is a challenging task to mix the radio frequency stage with the channel decoder in a combined analogue and digital stage. This would reduce not only the number of pins on the IC package, but also the dissipation and problems with electromagnetic interference. The use of 0.5 and 0.35 µm BiCMOS technologies is already planned.

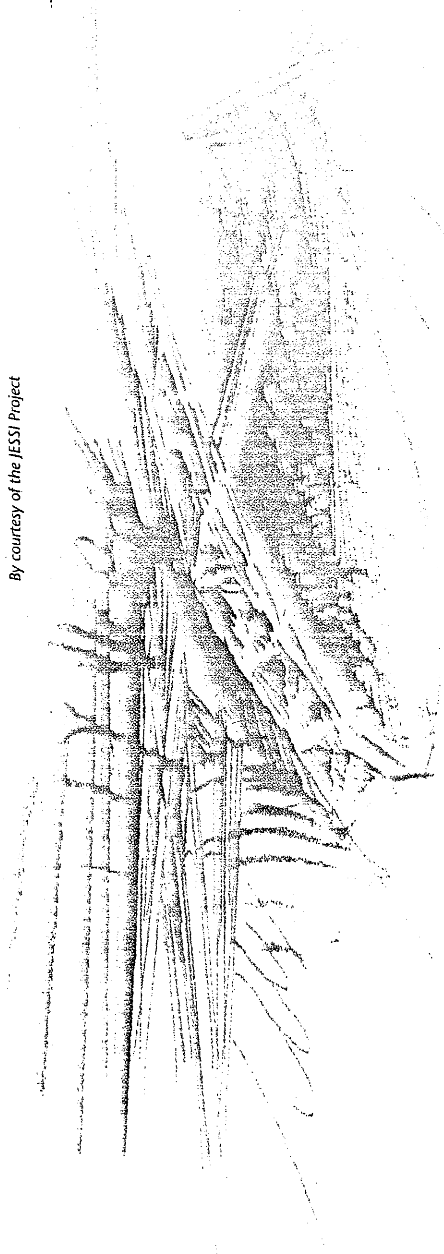
DAB chip sets have to support a variety of receivers, from the affordable portable radio to the state-of-the-art digital receiver for multimedia services. For the latter, advanced single-chip DAB system controllers and data decoders are essential, which will decisively influence costs and performance of DAB receivers for consumer purposes. A number of semiconductor manufacturers have recently joined the EUREKA-147 Consortium and will develop appropriate ICs.



By courtesy of the JESSI Project

Fig. 6-4: IC for performing the FFT.

The development and introduction of DAB represents an exciting phase in the history of radio. The EUREKA-147 Consortium looks forward to cooperating with nations throughout the world.



Glossary

AIC (Auxiliary Information Channel): a part of the Main Service Channel, used to carry information (e.g. SI) redirected from the Fast Information Channel.

Audio frame: a frame of 24 ms duration which contains information of an ISO/IEC 11172-3 [3] Layer II encoded audio signal, corresponding to 1,152 consecutive audio samples at 48 kHz sampling equency. It is the smallest part of the audio bit stream which is decodable on its own.

BiCMOS (Bipolar Complementary Metal Oxide Semiconductor): an integrated circuit combining BIPOLAR and CMOS transistors.

CA (Conditional Access): a mechanism by which the user access to services can be restricted.

CEPT: European Conference for Posts and Telecommunications

COFDM (Coded Orthogonal Frequency Division Multiplex): a transmission technique by which the complete ensemble (= multiplex) is transmitted via several hun-ed (or even several thousand) closely-spaced RF carriers which occupy a total bandwidth of approx. 1.5 MHz, the so-called frequency block. Due to the low data rate of each RF carrier, any delayed reflections of the signal (i.e. "passive echoes") will add to the direct signal already received and thus allow interference-free reception under conditions of multipath propagation.

Convolutional coding: the coding procedure which generates redundancy in the transmitted data stream in order to provide ruggedness against transmission distortions.

DAB: Digital Audio Broadcasting

DAB audio frame: same as audio frame (see above), but includes all the specific DAB audio-related information, e.g. PAD.

DAB transmission signal: the transmitted radio frequency signal.

Doppler effect: an apparent shift in the received frequency of a source due to relative motion between source and receiver.

DQPSK (Differential Quarternary Phase Shift Keying): a modulation principle which consists of encoding the phase rotation of each carrier between consecutive modulation symbols.

Dual-channel mode: the audio mode in which two independent programme contents (e.g. bilingual) are encoded within one audio bit stream. The coding process is the same as for the stereo mode (see below).

Energy dispersal: an operation involving deterministic selective complementing of bits, intended to reduce the possibility that systematic patterns result in unwanted regularity in the transmitted signal.

Ensemble: the transmitted signal (i.e. multiplex). The ensemble is the entity which is received and processed. In general, it contains programme and data services.

ETI (Ensemble Transport Interface): the interface between the Ensemble Provider and the Transmission Network to deliver a full DAB ensemble to each transmitter.

ETS (European Telecommunication Standard): in late 1994, the EUREKA-147 DAB system was adopted by the ETSI as the European Standard. The ETS 300 401 on DAB describes the technical details of the broadcast on-air signal. It is based on the overall system and service requirements adopted by the ITU-R Recommendations 774 and 789.

ETSI: European Telecommunications Standards Institute

FFT (Fast Fourier Transformation): an algorithm to effectively calculate the Fourier Transform of a signal.

FIC (Fast Information Channel): a part of the transmission frame, which contains the multiplex configuration information together with optional Service Information and data service components.

FIDC (Fast Information Data Channel): the dedicated part of the Fast Information Channel which is available for non-audio related data services, such as paging.

FM (Frequency Modulation): the instantaneous variation of the frequency of a carrier wave in response to changes in the amplitude of a modulating signal.

Gaussian noise: the undesirable electrical disturbances whose density function follows normal bell-shaped (Gaussian) distribution.

GEO (Geostationary Orbit): a satellite orbit in the plane of the earth`s equator and 35,880 km above it, at which distance an object has an orbital period of exactly 24 hours and remains fixed in the sky as seen from a given location.

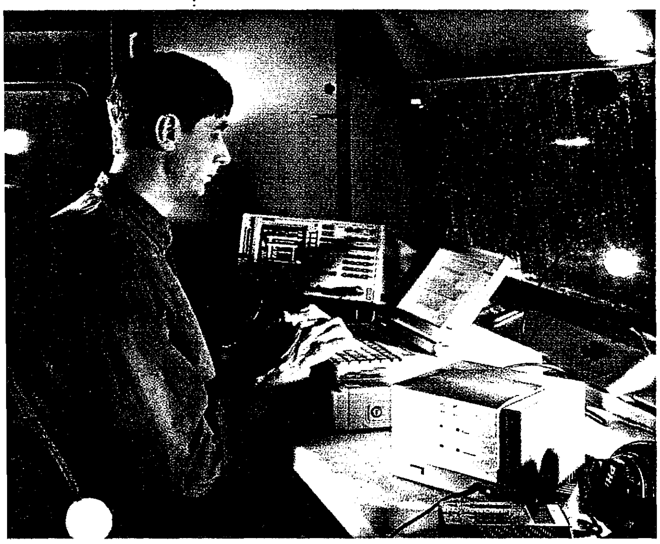
HEO: the Highly-Inclined Elliptical Orbit.

GPS (Global Positioning System): a satellite-based navigation system to provide positional information.

IC (Integrated Circuit): a circuit whose components are formed on a single semiconductor substrate.

ITTS (Interactive Text Transmission System): a text transmission system that maintains an exchange with the user, alternately accepting input and then responding.

ITU (International Telecommunication Union): a global organisation to consider new developments in broadcasting technology and agree the technical standards of broadcast systems - for both radio and TV- on a worldwide basis.



By courtesy of Philips

ITU-R: International Telecommunication Union - Radiocommunication

JESSI (Joint European Submicron Silicon Initiative): the partners in the JESSI project "Implementation of Prototype Building Blocks for a Digital Audio Broadcasting Standard" developed a highly-integrated chip set for DAB transmitters and receivers, thus enabling extensive field studies.

Joint stereo mode: the audio mode in which two channels forming a stereo pair (left and right) are encoded within one bit stream and for which stereophonic irrelevance or redundancy is exploited for further bit reduction.

JPEG (Joint Picture Expert Group): an ISO/IEC standard to digitally encode and compress still pictures.

Keying: the modulation of a signal carrier by varying its amplitude or frequency.

Masking: property of the human auditory system by which an audio signal cannot be perceived in the presence of another audio signal.

Masking threshold: a function of frequency and time, specifying the sound pressure level below which an audio signal cannot be perceived by the human auditory system.

MCI (Multiplex Configuration Information): the information defining the configuration of the multiplex. It contains the current (and in the case of an imminent reconfiguration, the forthcoming) details about the services, service components and sub-channels and the linking between these objects. It is carried in the FIC in order that a receiver may interpret this information in advance to decode the service components carried in the Main Service Channel. It also includes identification of the ensemble itself and a date and time marker.

MOT (Multimedia Object Transfer protocol): the protocol used to support the transfer of the useful data, and the side-information (= multimedia objects) via DAB using all the transport mechanisms provided (Stream mode, Packet mode, and PAD).

MPEG (Moving-Picture Experts Group): a standard (ISO/IEC 11172-3 (MPEG 1 Audio Layer II) and ISO/IEC 13818-3 (MPEG 2 Audio Layer II)) on source-coding systems/audio-compression formats to digitally encode and represent moving pictures and associated audio making use of the phenomenon of Psycho-acoustic Masking. This system is also known as MUSICAM.

MSC (Main Service Channel): a channel which occupies the major part of the transmission frame and which carries all the digital service components (audio and/or data).

Multiplexing: the process of interweaving two or more lower-speed data streams into a single high-speed radio-frequency channel for simultaneous transmission.

MUSICAM (Masking pattern Universal Sub-band Integrated Coding and Multiplexing) : an MPEG ISO-standardised audio-compression technique used in DAB.

Null symbol: the first OFDM symbol of the transmission frame.

OFDM symbol: the transmitted signal for that portion of time when the modulating phase state is held constant on each of the equi-spaced, equal amplitude carriers in the ensemble. Each carrier is four-phase differentially modulated from one symbol to another, giving a gross bit-rate of two bits per carrier per symbol.

Packet mode: the mode of data transmission in which data is carried in addressable blocks called packets.

PAD (Programme Associated Data): information which is transmitted together with the audio data. The PAD field is located at the end of the DAB audio frame.

PCM: Pulse Code Modulation.

Protection level: a level specifying the degree of protection, provided by the convolutional coding, against transmission errors.

RDI (Receiver Data Interface): expected to become the standard interface between DAB receivers and peripheral devices (e.g. computers, printers, dedicated decoders, and devices for audio postprocessing and recording). The RDI can carry the full DAB multiplex including information about which transmitters are being received for location-dependent data evaluation; it can also be used for receiver measurements, since it provides access to the decoded bitstreams of the FIC and MSC Subchannels.

RDS: Radio Data System.

RF (Radio Frequency): a frequency that is useful for radio transmission, usually between 10 kHz and 300,000 MHz.

Service label: alphanumeric characters associated with a particular service and intended for display in a receiver.

SFN (Single Frequency Network): a network of DAB transmitters using the same radio frequency to achieve a large area coverage.

SI (Service Information): auxiliary information about services, such as service labels and programme type codes.

Stereo mode: the audio mode, in which two channels forming a stereo pair (left and right) are encoded within one bit stream and for which the coding process is the same as for the Dual channel mode.

By courtesy of Bosch

Stream mode: the mode of data transmission within the Main Service Channel in which data is carried transparently from source to destination.

Sub-band: a subdivision of the audio frequency range. In the DAB audio coding system, 32 sub-bands of equal bandwidth are used.

TII (Transmitter Identification Information): the symbol included in every second transmission frame instead of the Null-Symbol in order to indicate the current transmitter.

TMC (Traffic Message Channel): an additional service transmitted as a part of the FIC to provide digitally encoded traffic messages.

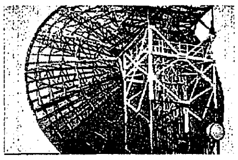
Transmission frame: the actual transmitted frame, specific to the four transmission modes, conveying the Synchronisation Channel, the Fast Information Channel and the Main Service Channel.

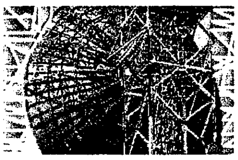
UEP (Unequal Error Protection): an error protection procedure which allows the bit error characteristics to be matched with the bit error sensitivity of the different parts of the audio frame.

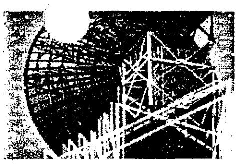
WARC (World Administrative Radio Conference): at the Torremolinos WARC-92 held in 1992 DAB services were allocated at 1.5 GHz (L-Band) occupying a frequency band of 40 MHz.

WARC-88: the World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilising It, Geneva, 1988.

WARC-92 bands: the frequency bands located at 1.5, 2.3 and 2.6 GHz.







Further Information with regard to the legal and administrative aspects of the Eureka-147 Project is available from

Eureka-147 Project Office
Margret Rüther
c/o DLR e.V.
Abt. MD-IT
Linder Höhe
D- 51140 Köln, Germany
Telephone +49 2203 601 2813
Telefax +49 2203 601 2866
e-mail: margret.ruether@dlr.de

Requests for further information regarding e.g. the technical aspects of the DAB system may be directed to the Promotion Engineer of EUREKA-147:

Dr. Thomas Lauterbach
c/o Robert Bosch GmbH
Abt. FV/SLM
P.O. Box 77 77 77
D- 31132 Hildesheim
Telephone +49 5121 49 2118
Telefax +49 5121 49 3970
e-mail: thomas.lauterbach@fr.bosch.de

Up-to-date news on DAB is available on the World Wide Web at http://www.dlr.de/DAB/

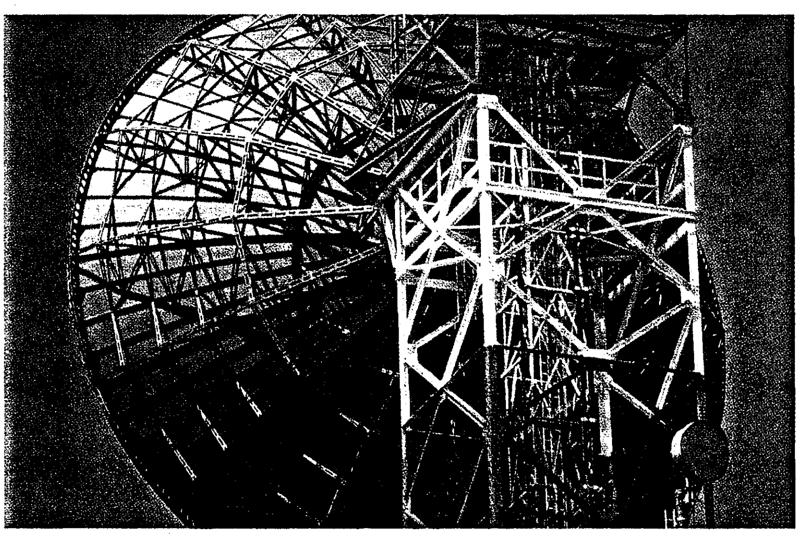
The EuroDab Newsletter informs readers of studies, experiments, services and events in all areas of DAB. It promotes the sharing of ideas, knowledge and experience, and fosters international consensus and agreement. The focal point of the EuroDab Newsletter is the EuroDab Forum which has established itself as the principal coordinating body for DAB in Europe and world-wide.

Regular features include the Calendar of DAB events, DAB frequency assignments, news of DAB Conferences, Seminars and Exhibitions, and reports from broadcasters and from manufacturing industry on new services, new products and new business opportunities.

The EuroDab Newsletter is published every two months. It is free to all EuroDab Forum members; the annual subscription for non-members is 100 Swiss francs.

To subscribe, or to submit your news for publication in the EuroDab Newsletter, contact:

Julie Unsworth
c/o European Broadcasting Union
Ancienne Route 17A
CH-1218 Grand-Saconnex GE, Switzerland.
Telephone +41 22 717 2709
Telefax +41 22 717 2749
e-mail: koza@ebu.ch



The information contained in this brochure provides examples of the possibilities of the DAB system and is in no way binding.