



# The RAI plans for DAB field tests

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## 1. Background

Digital Audio Broadcasting (DAB), the advanced system developed within the Eureka 147 project [1], is mature for introduction in the framework of present-day radio broadcasting services in the next few years. The system provides high-quality, multi-service digital sound broadcasting for reception by vehicular, portable and fixed receivers and allows for efficient spectrum exploitation. It has the potential to revolutionize the radio broadcasting world.

However, practical implementation of a terrestrial service (T-DAB) requires a system-wide examination of relevant factors including network aspects, propagation characteristics, planning criteria, spectrum availability and service reliability. Broadcasters and Administrations in Europe and around the world are deeply involved in this activity.

Specifying the service area for T-DAB requires a trade-off analysis which is somewhat different to that which is applied in conventional allocation planning for analogue FM radio services. Compared to the more gradual nature of FM service degradation in the presence of increasing

*The article briefly describes the plans for DAB field tests conducted in the Aosta Valley test-bed. The tests will assess the system performance, characterise the RF channel and evaluate the coverage of a single frequency network (SFN) including three transmitters on VHF channel 12. These experiments, involving both mobile and fixed reception, are part of the activity of a RAI DAB Working Group aimed at identifying and studying the technical and operational aspects for the introduction of T-DAB services in Italy.*

noise or severe multipath propagation, the abrupt nature of the degradation of digital service suggests the adoption of propagation curves that use more rigorous location and time availability requirements. Thus higher service requirements are necessary than the F(50,50) requirement of ITU-R Recommendation PN.370, e.g. F(90,90), [2] and experimental validation in the field is needed.

An important feature of T-DAB services is the capability to operate with large-area single frequency networks (SFN). The large *guard interval* of DAB operation mode I (i.e. 256  $\mu$ s) allows the system to overcome destructive multipath effects, even in mobile reception, with echo delays of up to 300  $\mu$ s at the maximum channel frequency of

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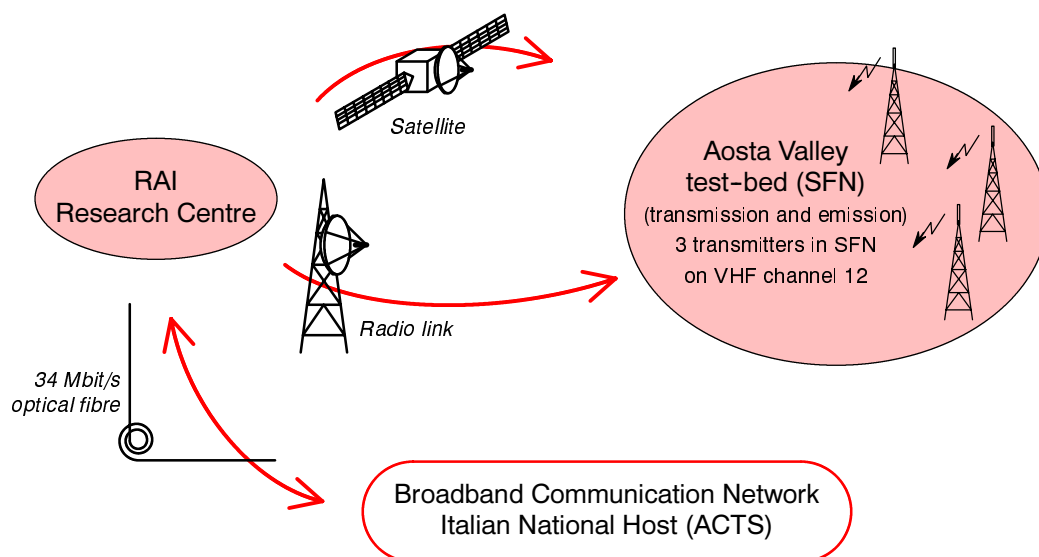


Figure 1  
General configuration  
of the Aosta Valley  
test-bed.

375 MHz. This makes possible to operate cost effective SFNs in the VHF bands with high transmitter separation distances. However, several technical and operational requirements have to be satisfied when two or more transmitters operate in an SFN, e.g. time synchronization, frequency coherence, identical baseband multiplex content.

The concept of *network gain* in an SFN requires careful investigation in the optimisation of the coverage area. The equivalent radiated power (ERP) and the specific requirements of DAB transmitters (e.g. linearity, frequency stability, RF spectrum) are also important technical issues to be investigated.

The introduction of T-DAB services also requires careful consideration of the management of the digital signal along the broadcasting chain, i.e. in production, distribution, emission and reception. Moreover suitable means for system assessment in the field are necessary to identify the parameters needed for efficient spectrum planning of the future services.

In the light of these requirements, the RAI Research Centre, in close cooperation with other RAI Departments, is completing the development of a test-bed in the Aosta Valley in northern Italy. The aim is to create a suitable infrastructure for experimental assessment of T-DAB, in a first phase, and of new digital TV systems, in a second phase. A DAB Working Group has been set up including the Research Centre (Turin), the Technical Directorate (Rome), the Monitoring Centre (Monza) and the Aosta Regional Centre. The experimental investigations should answer the many technical and operational issues that remain open and facilitate

the introduction of digital radio and television services in Italy.

## 2. The digital broadcasting test-bed

The test-bed includes three transmitters in single frequency network on VHF channel 12 (223–230 MHz), which has been made available for this purpose. Frequency synchronization of the transmitters is provided, as well as equalization of the propagation delay of the modulated DAB signals (OFDM) in a service area around the city of Aosta. The transmitters are installed at St. Vincent (the main RAI transmitting centre in the Aosta Valley), Gerdaz and Blavy. The network of the three transmitters has been in operation on an experimental basis since November 1994.

The DAB/OFDM signal, occupying an RF bandwidth of 1.5 MHz, can be positioned arbitrarily within the 7 MHz band of channel 12. Potentially, up to four DAB blocks (ensembles) can be simultaneously transmitted in the RF channel and tested in the field.

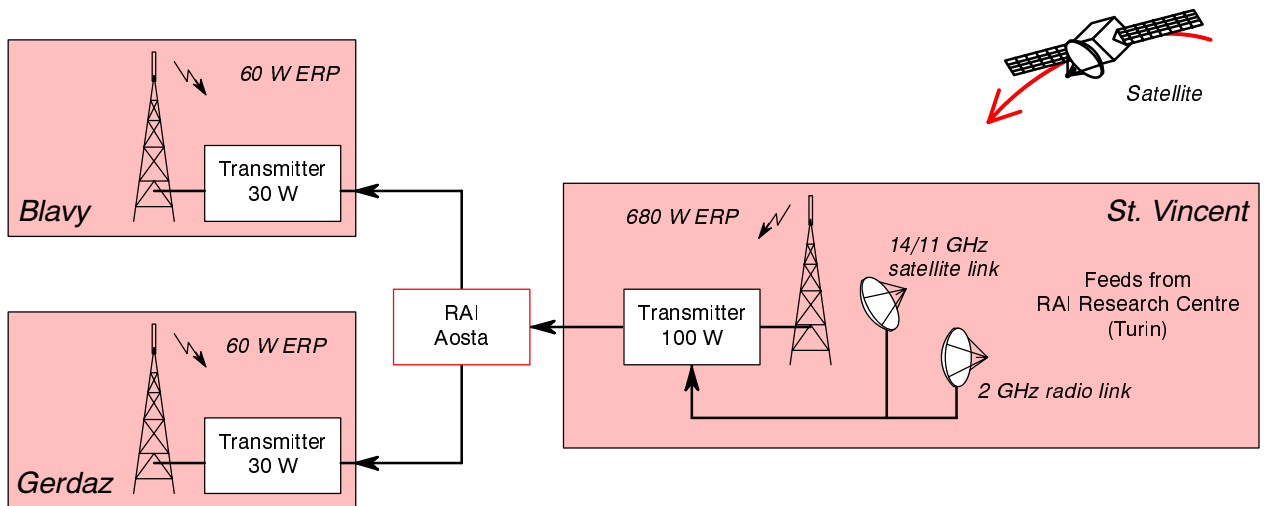
Since the lower adjacent channel (channel 11) is not used in the service area of channel 12, the test-bed will also allow experiments with wide-band television systems having about 7.5 MHz bandwidth, currently being developed within the European dTTb project.

The SFN test-bed includes urban and dense urban areas in Aosta, rural and large flat areas along the A5 Torino–Aosta highway, hilly and mountainous areas, with coverage over distances of up to about 30 km, affected by multipath propagation with long delay echoes.

Figure 2  
SFN transmitter  
locations in the  
Aosta Valley.



Figure 3  
Transmission  
facilities.



The test-bed is proposed as part of the Italian National Host for the future ACTS activity. *Fig. 1* shows the overall network architecture, with an indication of the interconnection between the RAI Research Centre and CSELT via an optical fibre link operating at 34 Mbit/s. This allows possible interfacing with the broadband communication network (BCN) of the Italian National Host. *Figs. 2* and *3* show some details of the network configuration.

In the first network implementation, the transport of the modulated DAB signal (OFDM) from the St. Vincent transmitter (network head-end) to the other transmitters is provided via terrestrial radio-links, with an intermediate distribution point at the

RAI Regional Centre in Aosta. The first hop (St. Vincent-Aosta) operates at 2 GHz, while the other two hops, Aosta-Gerdaz and Aosta-Blavy, operate at 10.5 GHz.

DAB encoding and multiplexing (up to six stereo programmes and additional data) and OFDM digital modulation can be carried out either at the RAI Research Centre in Turin or directly at the main transmitter at St. Vincent. In the first case, the OFDM signal is carried from Turin to St. Vincent via a terrestrial radio-link at 2 GHz or via a satellite link in Ku band (14/11 GHz), using in both cases frequency modulation. A special transmitting terminal with 72 dB EIRP is being developed to allow direct access to the satellite (Eutelsat II or

Intelsat V) from the Research Centre. For satellite reception in St. Vincent a receiving system with  $G/T = 28$  dB/K and a 4-m antenna is used. Error-free DAB reception from Eutelsat II is assured, with at least 3 dB margin on the carrier-to-noise ratio, assuming a 72 MHz satellite transponder sharing the DAB/OFDM signal with a PAL/FM transmission. Better performance is achievable on a 72 MHz Intelsat V transponder which allows single-carrier transmission for most of the time.

In the final network implementation, the functions of DAB encoding and multiplexing and OFDM modulation should be carried-out separately. The multiplexer will be installed at the Research Centre and each transmitter will be equipped with an OFDM modulator. A suitable network adapter will be used for the transport via satellite of the multiplexed DAB signal to the transmitters, at a bit-rate of 2.048 Mbit/s (CCITT Recommendation G.703). The adoption of QPSK modulation, with convolutional coding (rate 1/2) and Viterbi decoding, allows reliable reception from Eutelsat II F6 (Hot Bird 1) and Intelsat V with small receiving antennas (1.2 m.). DAB multiplex synchronization at the three transmitters, required to assure correct SFN operation, is provided by a suitable mechanism in the transmission protocol of the 2.048 Mbit/s data stream.

Table 1 summarizes the transmission parameters for each site. The transmitters operate in a continuous mode below their nominal power without introducing significant non-linearities which might affect the OFDM signal. An output back-off (OBO) of 3 to 5 dB is adopted. If needed, an external output bandpass filter can be inserted to prevent out-of-channel interference to other services. Each transmitter can be remotely controlled from the service area via mobile telephone at 459.25 MHz. The following features are provided at each transmitter:

- power ON / OFF switching

- ERP control (0 dB, -3 dB, -6 dB)
- RF polarization (vertical / horizontal)
- baseband signal (DAB, digital TV, PAL)

At each transmitter, the DAB/OFDM signal, after analogue to digital conversion, is passed through a delay line with maximum delay of 250  $\mu$ s, adjustable in steps of 50 ns. This allows flexible control of the relative delay between the signals emitted from the three transmitters in the SFN service area.

The same transmitting antenna configuration is adopted in all sites. It consists of two vertically-polarized VHF panels; each panel contains four dipoles, providing a gain of about 9 dB. Vertical polarization is required because a monopole receiving antenna is used in a car for mobile DAB reception. Two horizontally-polarized VHF panels are installed on the same transmitting antenna pylon for future experiments with digital television.

The powers radiated by each transmitter in the SFN, the antenna radiation patterns and the relative delay equalization have been adjusted to establish a coverage area with equal field-strength around Aosta.

### 3. Objectives of the DAB tests

The overall test plan includes three types of tests:

- *laboratory tests*, to evaluate the performance of the transmission system and the receiver in the presence of noise, interfering signals and multipath propagation;
- *channel characterisation tests*, aimed at determining type and distribution of echoes and collecting data on critical parameters for the implementation of T-DAB services;

Parameter	Location		
	St. Vincent	Gerdaz	Blavy
Antenna height above ground (m)	18	34	16
Effective height above average terrain (m)	570	830	921
Transmitter: power (W)	100	30	30
output back-off (OBO) (dB)	3	5	5
Antenna gain (dB)	9	9	9
Polarization	V (H)	V (H)	V (H)
ERP (W / dBW)	680 / 28.3	61 / 17.9	61 / 17.9
RF channel	VHF Channel 12 : 223 - 230 MHz		

Table 1  
Characteristics of the transmitting facilities.

- *coverage tests*, to assist in the determination of the propagation model for large and small areas.

### ■ 3.1. Laboratory tests

The main objectives are to verify that the DAB/OFDM generation system and the DAB receiver used in the field trials operate in accordance with the ETSI specification [1], particularly as regards operation Mode I which is intended for DAB services in the VHF bands. The following tests are being carried-out:

- carrier-to-noise ratio (C/N) required at the threshold of audible impairment (ISO/MPEG layer II audio coding);
- bit error ratio (BER) versus C/N;
- receiver front-end characteristics: i.e. input voltage (dB( $\mu$ V)) versus C/N;
- interference from and to B/PAL (co-channel CCI and adjacent channel ACI);
- interference from a DAB signal carrying different programmes (CCI and ACI);
- system performance in a simulated channel affected by Doppler effect and severe multipath.

The laboratory tests provide the necessary background information to prepare and conduct the channel characterisation and coverage tests in the Aosta Valley. Most of the laboratory tests have already been completed.

### ■ 3.2. Channel characterisation tests

These field tests, already in progress, are conducted by the Research Centre with the main objective of assessing the overall network reliability, the DAB system performance in fixed and mobile SFN reception, and to characterise the terrestrial broadcast channel in the VHF band [3]. Moreover, information on the field-strength available in the service area of each individual transmitter will be provided, as well as suggestions for typical routes to be investigated in the coverage tests.

As regards network assessment, the following issues are being investigated:

- required transmitter frequency stability for reliable SFN operation;
- required output power back-off (OBO) to control out-of-band emission, particularly in the case of adjacent DAB block transmission in the same RF channel;

- adjustment of time delays at the three transmitters to meet the service area design objectives;
- assessment of the predicted antenna(s) radiation pattern in the vertical polarization plane.

The DAB assessment and channel characterisation are being carried out by the RAI Research Centre in different locations within the test-bed. This work includes fixed reception measurements, with a directional antenna (Yagi, 7 dB gain) set at 10 m above ground level (agl) and an omni-directional antenna (ground plane) set at 3 m agl, and mobile reception measurements on selected routes. The main objective is the identification of the parameters that have a direct influence on system performance and network design, e.g. power requirements for correct DAB reception, DAB reception failure mode, multipath spread and correlation bandwidth, Doppler spread and correlation time. Particular importance is given to the influence of the environment in which the receiver is placed (i.e. urban, suburban, rural, hilly, mountainous).

A test van, provided by the RAI Monitoring Centre (Monza), has been equipped by the Research Centre for fixed reception measurements on the DAB/OFDM signal. Two consecutive phases are foreseen: a first phase focused on the service area of each individual transmitter (the other two being switched off), and a second phase with the three transmitters in an SFN. The following measurements are being carried out in both network configurations:

- available field-strength (dB( $\mu$ V/m)) in direct reception;
- minimum usable field-strength (dB( $\mu$ V/m)) at the threshold of impaired audio reception (e.g. BER =  $10^{-4}$ ), obtained by attenuating the RF input signal;
- BER measurement;
- acquisition and storage of the DAB RF spectrum, for later computation of wide and narrow-band spectrum power;
- channel impulse response by acquisition of the CAZAC sequence from the OFDM signal (i.e. recording of echo statistics).

From the results of these measurements the network gain of the SFN configuration can be derived. The SFN gain is a characteristic parameter of the network where the signals of all transmitters mutually add each other. However, depending on the guard interval and on the multipath distribution, not all the signals add constructively in the tested area. In addition, in locations sufficiently near any given transmitter the network gain tends



to zero. All these aspects will be considered in the experimental investigation.

In addition to the tests on the DAB/OFDM signal, a method developed by the Research Centre [4] for the characterisation of the radio channel in terms of echo statistics (i.e. number of echoes, magnitude, delay) will be used and compared with the CAZAC method. It is based on the acquisition and digital processing of a  $\sin x/x$  pulse inserted in the field-blanking interval of a PAL signal broadcast by the transmitter and received via a professional synchronous television receiver. This method cannot be generally used in SFN measurements because of the synchronization problems of the television receiver.

A complete system assessment and channel characterisation requires additional mobile measurements. For this purpose, a RAI car has been equipped by the Research Centre. It will also be used as demonstration vehicle for DAB promotion. Direct on-board comparison of audio quality between DAB and VHF/FM, carrying the same programme, will be done. The multipath effects on the CAZAC sequence are visible on a small LCD display.

Objective measurements are carried-out on the DAB/OFDM signal with the car moving at constant speed; the measured parameters include the field-strength (in 1.5 MHz bandwidth), the bit error ratio (BER) obtained by counting the error events in a fixed time interval, and the geographical position identification of the vehicle as provided by a GPS receiver. A spectrum analyser is used to display the received RF spectrum. The acquisition of data is synchronized by the vehicle drive shaft rotation and is controlled by a personal computer. A 1/4-wavelength monopole receiving antenna at 1.5 m agl is used in the car.

The measurements will be made at different speeds on the same routes, e.g. 50, 70 and 100 km/h, in order to assess the influence of the Doppler effect. These tests will concentrate on the A5 highway. Continuous recording of field-strength and error events allow correlation of the local variation statistics with the expected service quality.

Most of these tests will be done in the SFN configuration.

The procedure for data gathering and analysis with both fixed and mobile reception tests will deliver results which are directly comparable to the laboratory multipath simulation tests.

Measurements will be made over the variety of terrain within the test bed. Data will include central city areas, hills and rolling terrain in suburban and rural areas as well as mountainous areas. The typical range of time delay and magnitude of the reflections will be identified within the different areas. The mean and variance of the reflection delay time and complex magnitude will be determined and used to configure the laboratory multipath simulator. From this information other parameters such as the channel frequency domain characteristics and statistical data will be computed. The data that is collected on the multipath characteristics of the VHF channel will be of direct value for planning future T-DAB services. In its processed form, the data is well suited for further analysis ranging from frequency domain characterisation to point-by-point generation of a multipath model.

### ■ 3.3. Coverage tests

Planning of terrestrial analogue television and FM radio services is currently based on propagation prediction methods of the average field-strength available for 50% of a given area, and for 50% of the time, with a receiving antenna height of 10 m

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*He was Chairman of EBU Sub-group V2 (Data broadcasting) and contributed to the activities of EBU Working Parties V and R. He is Special Rapporteur on satellite systems in the European DVB Project and has led the studies for the definition of the transmission standard of the European multi-programme digital television system via satellite.*

*Dr. Cominetti has published several technical articles and conference contributions on digital transmission and data broadcasting. He was awarded the CCIR Diplôme d'Honneur in 1989, and the John Tucker Award at IBC '94 for his contribution to the establishment of standards for digital transmission systems.*



agl. The use of correction curves, taken from “narrow-band” measurements, allows estimates to be made of the field-strength available at a minimum height of about 3 m for an assigned percentage of the coverage area.

Planning of T-DAB mobile services requires the use of propagation prediction methods providing the minimum field-strength at 1.5 m. agl and taking account of the reduced influence of selective fading on the “wide-band” spectrum of the DAB signal (1.5 MHz).

It is then necessary to adjust the point-to-point field prediction methods of ITU-R Recommendation PN. 370 by adopting suitable correction factors related to the “location variation” statistics and to the receiving “antenna height gain”. From the experience so far achieved with T-DAB in Europe and in North America, some preliminary indications on the correction factors and the field-strength statistical distribution are available. These results seem to indicate a field-strength standard deviation, in the VHF band, of the order of 5.5 dB with respect to the 8.3 dB assumed in the ITU-R Recommendation PN.370 for local variation statistics. Nevertheless, these results do not yet represent a sufficiently accurate sample of the real situation. Therefore extensive field trials are still necessary in order to better identify the propagation model, the influence of the terrain and the relative impact of wide and narrow-band reception on the field-strength.

Large-scale DAB coverage tests will then be carried-out in the service area of St. Vincent transmitter, with the other two transmitters switched off. The intention is to collect the necessary information for planning purposes, e.g. service coverage requirements and identification of the correction parameters needed to adjust the current propagation prediction methods to the case of terrestrial digital broadcasting. The propagation environment offered by the test-bed, characterised by different areas, is particularly interesting in this respect.

The field-strength values relevant to the DAB wide-band measurements (1.5 MHz), will be compared with the narrow-band measurements (120 kHz), currently carried-out on analogue FM radio signals, in order to identify the error statistics affecting the measuring methods. Wide and narrow-band measurements will be acquired consecutively on the same routes.

These large-scale coverage tests will be carried-out by the RAI Monitoring Centre, with the assis-

tance of the Research Centre responsible for the operation of the network. Continuous field-strength recording of the T-DAB signal will be carried-out in a mobile van equipped with a professional meter controlled by a personal computer, and a GPS receiver. The field-strength measurements are synchronized to the rotation of the vehicle drive shaft with an acquisition interval of 25 cm., corresponding to about 1/5-wavelength of the RF carrier in channel 12. Every block of 80 measurements, corresponding to a 20-m distance on the route, will be identified by the geographical position of the vehicle as provided by the GPS receiver. This procedure allows detailed acquisition of the field-strength profile along pre-selected routes. The measurements will be carried-out progressively moving away from the transmitter until the threshold of minimum DAB field-strength is reached. The results will then be separately processed in accordance with the type of investigated areas: urban, rural, mountainous, etc.

In a first phase, the field-strength measurements will be carried-out at 1.5 m agl, with a 1/4-wavelength monopole receiving antenna mounted on a RAI car. The measurements will then be repeated, on the most significant routes, at 10 m agl using a 1/2-wavelength dipole antenna installed on the mobile van.

All field-strength measurements, at 1.5 and 10-m heights, will be carried out in both the wide-band mode (1.5 MHz) and the narrow-band mode (120 kHz) around 226 MHz, and are aimed at assessing the influence of selective fading in VHF mobile reception. The acquisition interval of 25 cm (about 1/5 wavelength) allows the separation, in the data processing procedure, of the effects of fast and selective fading, due to multipath, from stable non-selective field attenuations (slow fading) due to obstacles between the receiving antenna and the transmitter.

This information is very useful for the development of suitable computer programs to predict T-DAB coverage.

## 4. Conclusions

The on-going developments in the DAB technology have encouraged an acceleration of the evaluation programme and the pursuit of the planning studies for future T-DAB services. The RAI DAB Working Group is determined to proceed with the necessary studies, laboratory and field-tests to make this exciting prospect a reality as soon as possible. The DAB test-bed on channel 12 imple-

mented by the Research Centre in the Aosta Valley, in close co-operation with other RAI Departments, will allow the assessment of the potential of DAB for mobile, portable and domestic reception in a single frequency network. The first results of the harmonised effort of all the RAI participants in the DAB Working Group should be available in the first quarter of 1995.

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### EuroDab Forum

On 8 December 1994, representatives from national DAB groupings, administrations, broadcasters and the consumer electronics industry met at EBU Headquarters to examine a proposal for the establishment of Europe-wide collaboration in the launching of Digital Audio Broadcasting services. Ten countries and four international organizations were represented at the meeting, which endorsed the proposal and decided to establish the EuroDab Forum.

The EuroDab Forum will promote international consensus and agreement on various issues relating to DAB, and will develop strategies favouring the smooth introduction of DAB services in Europe and worldwide. It will build on the results of work initiated by the EBU in 1986 and continued within the Eureka 147-DAB Project over the past nine years. This essentially technical work has led to the establishment of a European Telecommunication Standard (ETS 300 401) and two draft Recommendations of the ITU Radiocommunication Sector (Recommendations BO.1130 and BS.1114, for terrestrial and satellite services, respectively), all of which effectively establish the Eureka 147-DAB system as the recognised standard for digital sound broadcasting in Europe and worldwide.

In the area of DAB system promotion and preparation for service implementation, much valuable progress has been achieved through the various national DAB promotional groups (the so-called DAB platforms and clubs). A need has nonetheless been felt within these groups for a broader viewpoint on matters of interest across national and regional borders, particularly in relation to frequency planning and management (notably in the period leading to the CEPT DAB planning conference in mid-1995), the coordination of broadcasters' and users' requirements in terms of services and receiver functionalities, and the sharing of experience. It is this need which has led to the creation of the EuroDab Forum. Other topics of common interest will include marketing strategies, legal and regulatory matters, conditional access and copyright, and monitoring of the development of DAB equipment (including conformance with the published standards) and services. It is expected, too, that members will debate the future orientation of sound broadcasting, with consideration of the interrelationships between terrestrial and satellite services, the evolution towards multimedia and interactive radio, and other longer-term concepts.

Membership of the EuroDab Forum is open to all existing and future national groupings, as well as individual manufacturers, service operators, broadcasters and institutes. Applicants for membership will be required to sign a Memorandum of Understanding (MoU) setting out the objectives of the Forum and the conditions accepted by members. The Forum will be self-financing, through a subscription fee. The first meeting, which may be attended by all interested parties intending to sign the MoU, is scheduled to take place in Geneva on 22 March 1995.

For further information about the EuroDab Forum, contact:

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