Introduction of a T-DAB experimental service in Italy

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SUMMARY - The article describes the T-DAB experimental network implemented in the Aosta Valley (Italy) by the RAI Research Centre, in close co-operation with other RAI Departments, and reports the main results of the field trials in fixed and mobile reception. Technical and operational issues related to practical implementation of a T-DAB service have been investigated and reported. The perspectives of a progressive extension of the DAB experimental service to other areas of the territory are also outlined.

1. Background

Practical implementation of a terrestrial DAB service (T-DAB) requires a system-wide examination of relevant factors including network aspects, propagation characteristics, service area planning, spectrum availability and service reliability. In order to investigate the new network concepts and to address all the issues relevant to the network design and coverage planning, the RAI Research Centre, in close co-operation with other RAI Departments, has completed the development of a T-DAB network in the Aosta Valley operating on channel 12 Band III.

The intention has been to create a suitable infrastructure for experimental assessment of T-DAB, in a first phase, and of new digital television 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 results of the experimental investigations and large-scale field trials give a first answer to the many technical and operational issues that remain open.

The paper reports the main results of the work carried out so far and outlines the effort made by RAI towards the introduction of a T-DAB experimental service in Italy.

2. Experimental phase

2.1. Network architecture

The test-bed includes three transmitters in a Single Frequency Network on VHF channel 12 (223÷230 MHz) which are installed at St. Vincent (the main RAI transmitting centre in the Aosta Valley) Gerdaz and Blavy. Frequency synchronisation of the transmitters is provided, as well as equalisation of the propagation delay of the modulated DAB signals (COFDM) in a service area around the city of Aosta. The network is in operation on channel 12 Band III on an experimental basis since November 1994. A fourth transmitter is planned to be activated at Col de Courtil by Summer 1996.

The experimental network includes urban and dense urban areas in Aosta, rural and large flat areas along the A5 Torino-Aosta high-way, hilly and mountainous areas, with

coverage over distances of up to about 30 Km, affected by multipath propagation with long delay echoes. Figure 1 shows the overall network configuration.
The transmission parameters for each site are summarised in Table 1. 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.

2.2. *Objectives of the tests*

The overall test plan has included three types of tests [Ref. 1]:

- *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, such as the "local variation" statistics of the field strength and the "antenna height gain", important to adjust the point-to-point field prediction methods of ITU-R Rec. PN. 370-5 to wideband signals by adopting suitable correction factors.
- *coverage tests*, to assist in the determination of the propagation model for large and small areas and evaluate the "network gain" of the Single Frequency Network (SFN).

3. Results

3.1 *Fixed reception*

A first set of measurements has assessed the correct operation of the transmitters working both individually and in the SFN configuration. The R.F. spectra of the transmitted signals have been monitored to prevent out-of-channel interferences to other services. A first indication of the coverage area has been given measuring the available field strength in a certain number of fixed locations within the test-bed, using a van suitably equipped. The main results of these first field tests are briefly summarised in the following points:

- The **distribution of echoes** in the SFN configuration indicates that the time-delay is within the guard interval (τg = 256 μs); Figure 2 shows one example of the measurements carried out.
- The **minimum field strength**, for a BER of 10^{-4}, for a 3rd generation DAB receiver has been measured in different propagation conditions. The receiver threshold level with omni-directional antenna requires an average value of 4 dB higher with respect to the case of the Gaussian channel (-90 dBm).
- Comparative receptions with two kinds of antennas (Yagi and omni-directional), set at different heights (10 m and 2.5 m above ground level, respectively) have been carried out with the aim to identify the **correction value for the receiving antenna height gain,** which is assumed in 10 dB by the CEPT [Ref. 2]. From the measurements it can be concluded that the value of 10 dB assures adequate margins.

3.2 *Mobile reception*

A second set of measurements has been carried out by the RAI Monitoring Centre (Monza) in mobile reception with the aim to provide indications on the **local variation statistics** of the field strength, important to adjust the point-to-point field prediction methods of ITU-R Rec. PN. 370-5. At the same time a comparison of the signal variation between narrowband (300 kHz) and wideband (1,5 MHz) signals has been carried out. The results showed average values of the standard deviation of 4 dB and 3 dB, respectively, for the two cases ; both figures are significantly lower than the values assumed by the ITU [Ref. 3].

A further extensive measurement campaign in mobile reception has been carried out by the RAI Research Centre on a certain number of selected routes representing typical reception environments (urban, suburban, rural, mountainous). The measuring system was controlled by a personal computer to allow for the acquisition of the field strength within spatially and/or temporally defined segments and of the position of the vehicle by means of a GPS (Global Positioning System) receiver. The acquired data have been subsequently analysed and statistically processed.

The block diagram of Figure 3 reports the measuring and logging system installed in the car, whose photograph is shown in Figure 4. A $\lambda/4$ monopole receiving antenna fitted in the centre of the roof is used and the field strength at the antenna height ($\approx$ 1.5 m) is derived from the power level measured by a Rohde & Schwarz ESVB receiver. The precise individuation of the covered distance is carried out by a measuring device synchronised to the rotation of the driving shaft. This procedure has allowed detailed acquisition of the field-strength profile along eight pre-selected routes.

The measurements, on each route, have been carried out in four different conditions: three for every transmitter operating individually and one for SFN operation, for a global distance of 424 km. At the same time, subjective quality evaluation of the received DAB signal in comparison with the analogue FM signal, carrying the same programme, has been carried out.

After the gathering of the data, a first computing allows for filtering, eliminating the measured Null-Symbols which appear at the header of each COFDM frame. Subsequently the data obtained from the GPS system are corrected using the GPS station installed at the RAI Research Centre premises, obtaining a precision of about 5 m in the identification of the position of the vehicle.

The evaluation software can analyse the raw data taking into account the combined fading (slow + fast fading) and the slow fading. In the first case the measurements, made every 31.25 cm, are averaged over sectors of 300 m, while in the second case the data are first averaged on segments of 25 m and then averaged on sectors of 1 km.

The main results of these large-scale field tests can be summarised in the following points:

- The **coverage** of the each individual transmitter and of the SFN (for the 50% or 99% of the locations) has been measured along the various routes. The obtained values can be presented in x-y diagrams, reporting the field strength as a function of the distance, and on digitised maps by means of the GIS (Geographical Information System) software. The statistical distributions of the field strength values have been computed. Figure 5 reports, as an example, the cumulative distribution of the field strength for the route N° 3.
- The **local area variations of the field strength** (slow+fast fading) have been computed taking into account four different environments for which the log-normal assumption of the signal distribution has been checked. Values of standard deviation between 2.5 and 4 dB have been found (Figure 6), which are lower than

the 5.5 dB value assumed by CEPT, as also reported in the literature [Ref. 4 and Ref. 5].

- The **network gain** at the 99% location level has been evaluated in seven cases for selected segments of some routes in which the ratios between the median levels of the signals received from the different transmitters could have been considered approximately constant. Values of the network gain vary from 0.5 dB to 5.4 dB. The value of 5.4 dB has been obtained in a segment where all the three transmitters contribute (the difference between the signal level of the main transmitter and the other two was 4.5 dB and 6.4 dB respectively), while a value of 5.2 dB has been obtained in a segment where two transmitters mainly contribute (the difference between the signal level of the main transmitter and the other two was 2.7 dB and 18.3 dB, respectively).
- **Subjective evaluations** of the received audio signal have been carried out by comparing the DAB signal with the FM signal carrying the same programme. For several routes inside the coverage area (urban areas, mountainous environment, high-ways) the two received audio signals, digital and analogue, have been recorded together with the video pictures of the routes, preparing a Betacam cassette for demonstration. The quality of the DAB signal is always excellent all over the SFN covered area, without impairments caused by propagation effects, while the quality of the FM signal is often impaired because of multipath propagation.

3.3 Advanced methods for coverage prediction

The coverage prediction of a DAB Single Frequency Network requires the adoption of new methods based on ray-tracing techniques and on the Geometrical Theory of Diffraction in order to take into account the multipath propagation and the contributions due to reflected signals. These new methods, integrated with the use of digital terrain models and the GIS software, are under study and evaluation at the RAI Research Centre by comparing the results of the predictions with the coverage and field strength measurements.

4. Extension of the T-DAB experimental service

After the activation of a fourth transmitter in the Aosta Valley, by Summer '96, the Single Frequency Network should be extended to the Piemonte region, on two other transmitters with a coverage open to a wide audience. New network concepts, such as national/regional multiplexing and programme insertion will be investigated. A further extension to other transmitters are part of a proposal submitted by the RAI Technical Directorate to the Italian PTT Administration for the beginning of experimental DAB transmissions in the most populated towns with a goal of 60% coverage of the population by 1999.

The perspectives of DAB services in Italy highly depend on the availability of frequency spectrum and low-cost commercial receivers. The RAI is open to the collaboration with the national and European manufacturing industry and is making every effort, together with the Association of private national radio networks (RNA) and in consultation with the Italian PTT Administration, for making available the necessary frequency resources.

5. Conclusions

The RAI, as member of the Eureka 147 and the EuroDab Consortium, in its role of public broadcaster, is involved in the technical, operational and promotional activities for the introduction of terrestrial DAB services in Italy. The work carried out on the Aosta Valley Single Frequency Network, whose main results are reported in this paper, is of direct value for planning future T-DAB services. Efforts are being done in consultation with the Italian PTT Administration to progressively extend the DAB experimental service to other areas of the national territory.

References

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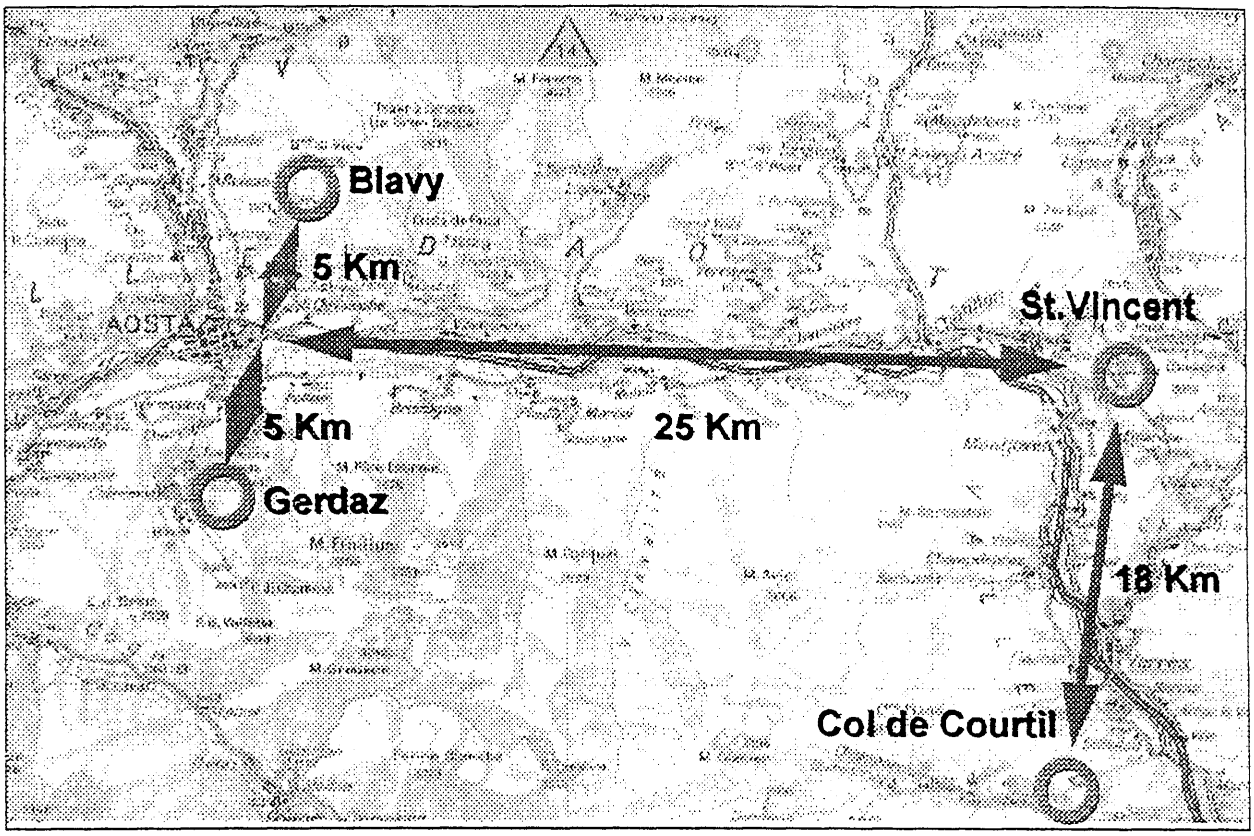

Figure 1 - Digital broadcasting test bed: Aosta Valley network configuration

Table 1 - Characteristics of the transmitting facilities in the Aosta Valley

	Location		
Parameter	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 (3 dB OBO)	30 (5 dB OBO)	30 (5 dB OBO)
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	12/VHF (223÷230 MHz)		

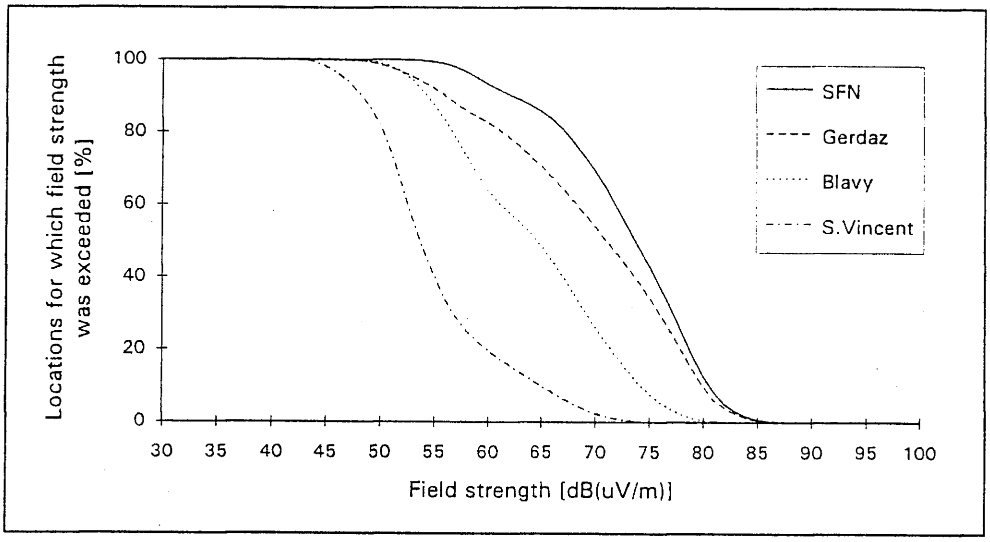

Figure 5: Cumulative distribution of the field strength for route N° 3

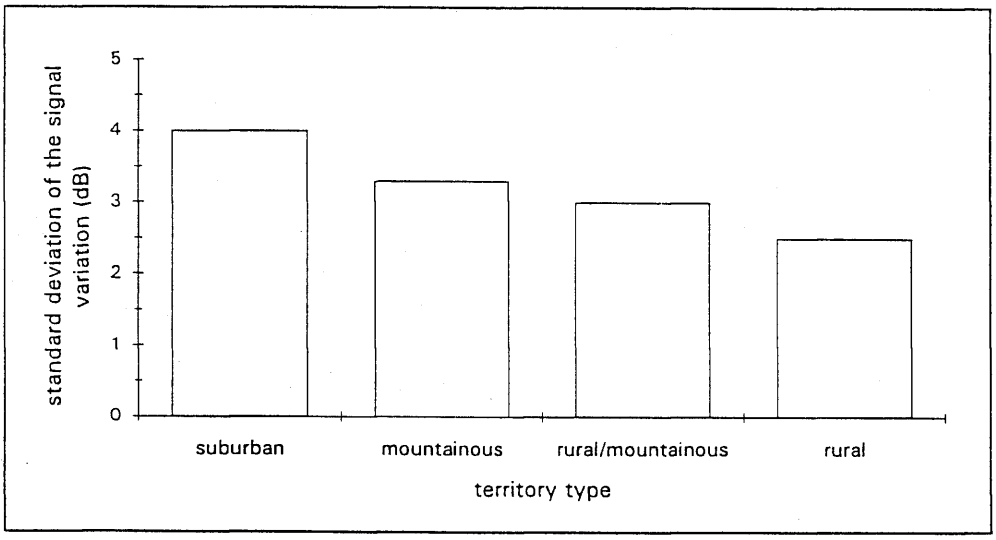

Figure 6: Standard deviation of the signal variation as a function of territory type

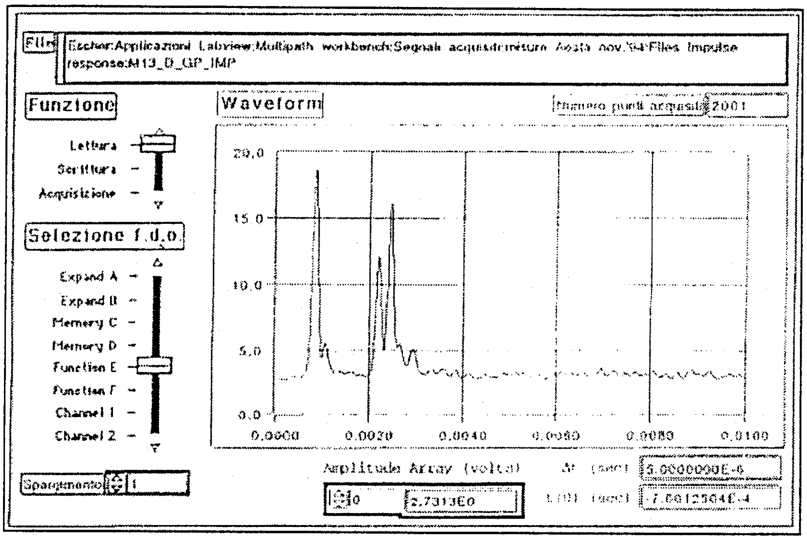

Figure 2: Example of recording of echo distribution
(Hor. Scale: 14 µs/div; Vert. Scale: A.U.)

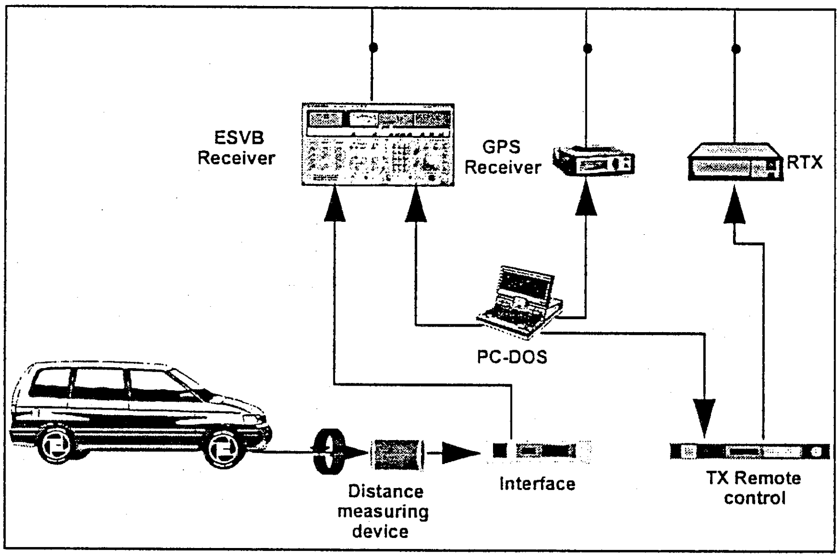

Figure 3: block diagram of the measuring and logging system

Figure 4: The DAB survey car