Digital Audio Broadcasting

The CEPT T-DAB Planning Meeting
Wiesbaden, July 1995

K.J. Hunt (Head of Broadcasting Technology, EBU)

T. Cesky (CEPT ERO)

T. Jeacock (RA)

M. Mägele (BAPT)

T. O'Leary (EBU)

G. Petke (IRT)

In the Autumn 1995 issue of EBU Technical Review, Ken Hunt offered readers some personal reflections on the CEPT T-DAB Planning Conference which took place at Wiesbaden, Germany, last July.

A detailed review of this meeting has now been made and, in this article, several delegates who played leading roles at the Conference offer readers an overview of the preparations and achievements which will permit a smooth introduction of terrestrial Digital Audio Broadcasting.

1. Introduction

It is well known by now that the European Conference of Postal and Telecommunications Administrations (CEPT) organized a Planning Meeting for terrestrial Digital Audio Broadcasting (T-DAB) in July 1995 [1]. The challenges faced by this meeting – held in Wiesbaden, Germany – were very great. There were very many T-DAB services to be accommodated and each was in the form of an allotment which represented coverage of a much larger area than that associated with the single transmitters which form the basis for most planning conferences. The interference potential of these allotments was thus large. At the same time, the bands in which it was proposed to accommodate T-DAB were very heavily used by a large number of other service requirements, comprising a mixture of broadcasting (television) and non-broadcasting (civil and military) services.

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In view of all these potential problems, it would not have been surprising if the Planning Meeting had been unsuccessful. In fact, as is also well known, the Planning Meeting was very successful. This is a tribute to the careful preparations that had been made and to the spirit of compromise which was very much in evidence, especially towards the end of the Planning Meeting itself.

The Wiesbaden Meeting was unable to complete its work in just one respect, and that was the establishment of the procedures which would need to be followed when converting an allotment[1] into the set of assignments[2] needed to represent a real service. When this article was originally planned, it was hoped that these procedures would have been completed (by a CEPT project team) by the time the article was published. In the event, the task has proven to be even more difficult than originally expected and thus, only an overview of what might be proposed in that respect can be given here.

2. Preparations within the EBU

In order to consider the possibilities of planning for T-DAB services and to make preparations for any planning conference which might take place, the EBU established a working group. This was originally know as R1/DIG but, after the EBU Technical Committee activities were re-organized, the group's designation was changed to B/TAP.

Because T-DAB introduced new opportunities and new challenges, the group was required to investigate new planning approaches and methods. It was able to do this effectively because it was kept fairly small, with a core of planning experts, and could thus rapidly investigate the advantages and disadvantages of new ideas. Those ideas which seemed likely to be successful could then be discussed in larger groups, such as the CEPT project teams, without too much risk of unforeseen problems.

This part of the EBU work resulted in the production of a detailed document on the technical criteria for T-DAB planning. The remaining parts of *Section 2.* of the present article give an overview of the main elements of these technical criteria.

1. A DAB frequency allotment refers only to the allocation of frequency blocks to specific service areas.
2. A DAB frequency assignment refers to individual transmitters and their technical characteristics.

2.1. VHF band

Apart from the internal compatibility of a DAB network operating in the VHF range, its compatibility with other VHF services – mainly the television service in Band III and the military aeronautical service above 230 MHz – plays an important role. In general, the DAB signal is more robust against interference from other services than vice versa. Hence, the interference effect into the DAB channel is, in general, less critical than the outgoing interference and can be neglected in the following considerations (although when the quality of a DAB network is being assessed, interference into the DAB channel has to be considered too).

This leaves us with three important types of interference to be considered in the VHF range:

– DAB interferes with DAB;

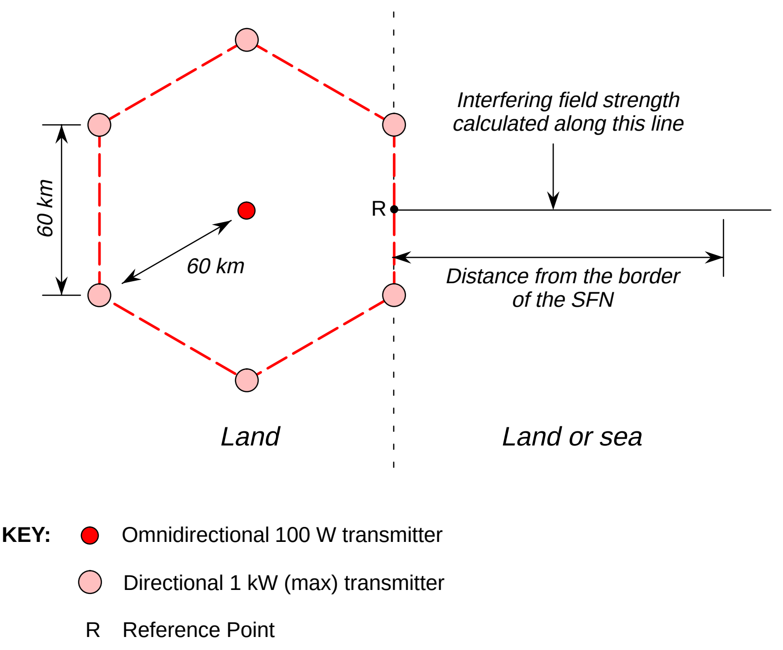
– DAB interferes with television;

– DAB interferes with the military aeronautical service.

2.1.1. DAB interferes with DAB

Since the establishment of the T-DAB Plan assumes the use of Single Frequency Networks (SFNs), all the calculations are based on a reference network. This consists of a hexagon with six peripheral and one central transmitter *(Fig. 1)*. The distance between transmitters is 60 km. The central transmitter has an effective radiated power of 100 W, whereas each peripheral transmitters has a

Figure 1
Reference network for the VHF bands.



power of 1 kW and uses a directional antenna which reduces its radiation outside the hexagon by 12 dB. A value of 150 m is assumed for the effective antenna height above ground level.

The interfering field strength generated by the reference network can be calculated for 50 % of locations by using the propagation curves of ITU-R Recommendation PN.370 [2] and is depicted for different percentages of time in *Fig. 2* (over a land path) and *Fig. 3* (over a warm sea path). It can be seen that there are considerable differences, especially for 1 % time.

In the case where DAB interferes with DAB, the calculations are based on a protection ratio[3] of

3. The minimum value of wanted-to-unwanted signal ratio, usually expressed in decibels at the receiver input, determined under specified conditions such that a specific reception quality is achieved at the receiver output.

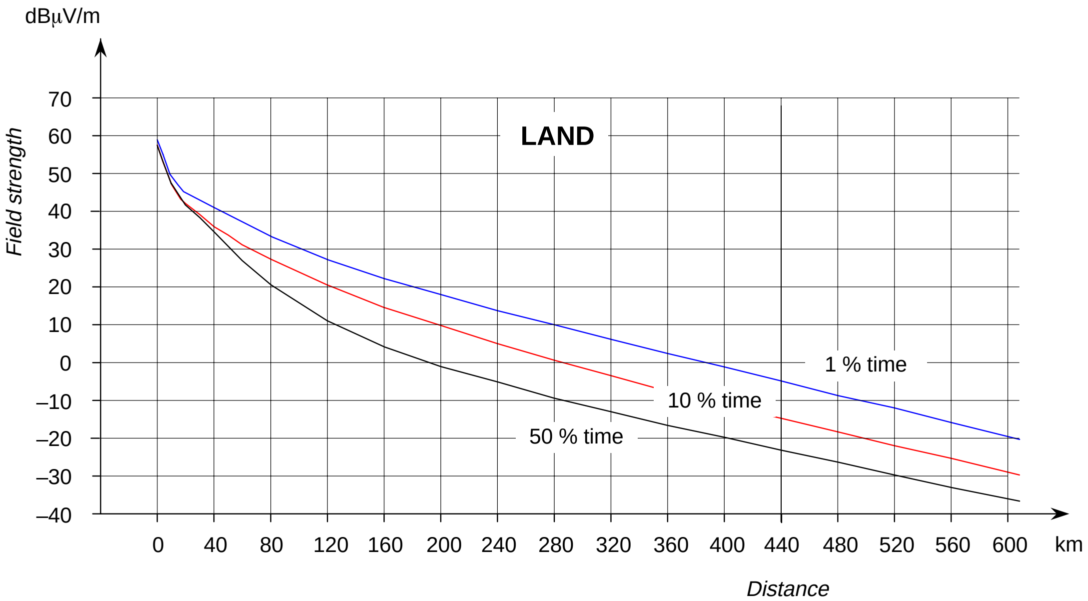


Figure 2
Variation of Band III field strength with distance over a land path.

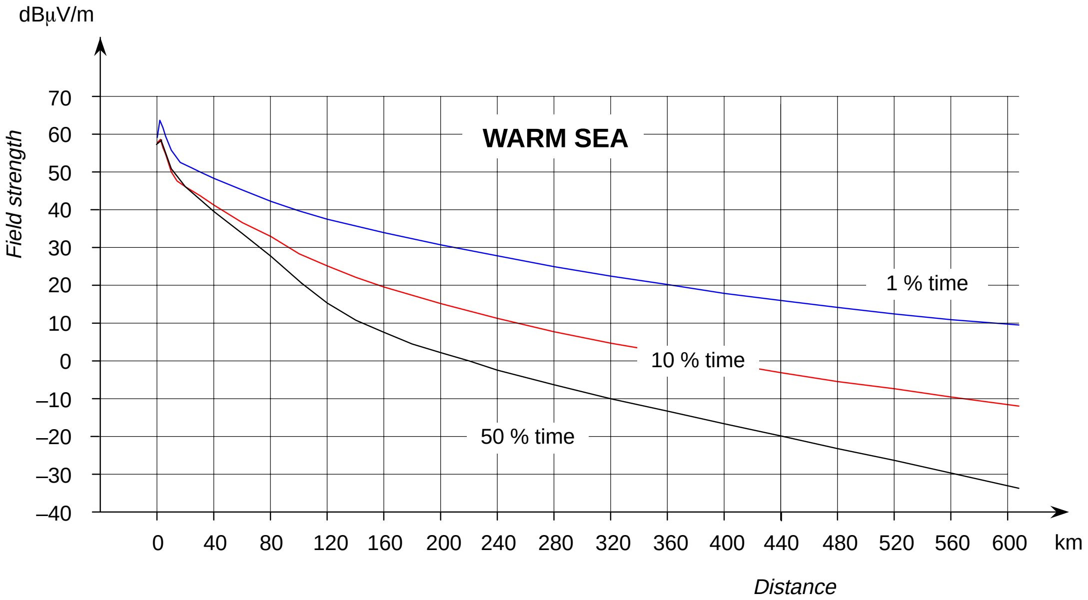


Figure 3
Variation of Band III field strength with distance over a warm sea path.

10 dB. However, use of the aforementioned ITU-R propagation curves would lead to intolerable system failure rates if they were applied directly to digital systems. In the case of DAB (which has been developed to provide for mobile reception using a receiving antenna at 1.5 m above ground level), 99 % of locations have to be covered. Thus, in order to protect the DAB signal at 99 % of locations, a propagation margin[4] of 18 dB has to be taken into account when using these 50 % location propagation curves. This results in a minimum usable field strength of 58 dBµV/m (for Band III) and a maximum permissible interfering field strength of 30 dBµV/m. In this case of interference, i.e. DAB interferes with DAB, a 3 dB higher value is assumed, since the actual field strength at the border of the hexagon is 3 dB higher than the minimum usable field strength. It can be shown that, based on such a reference model, the same frequency block can be re-used at a distance of 80 km.

4. Propagation margin may be defined as the difference, expressed in decibels, between the 50 % location value of a signal and the value for some target percentage of locations. In the case of T-DAB, this target is normally taken to be that the wanted signal is free from impairment due to noise or interference for 99 % of locations.

2.1.2. *DAB interferes with television*

Since DAB and television have to coexist in channel 12 as well as in other television channels, this sharing situation is of great importance. In the compatibility analysis, the same reference network as above and the field strength curves given in *Figs. 2* and *3* are used. The required protection criteria for the television signal largely depend on:

– the position of the considered T-DAB block within the television channel;

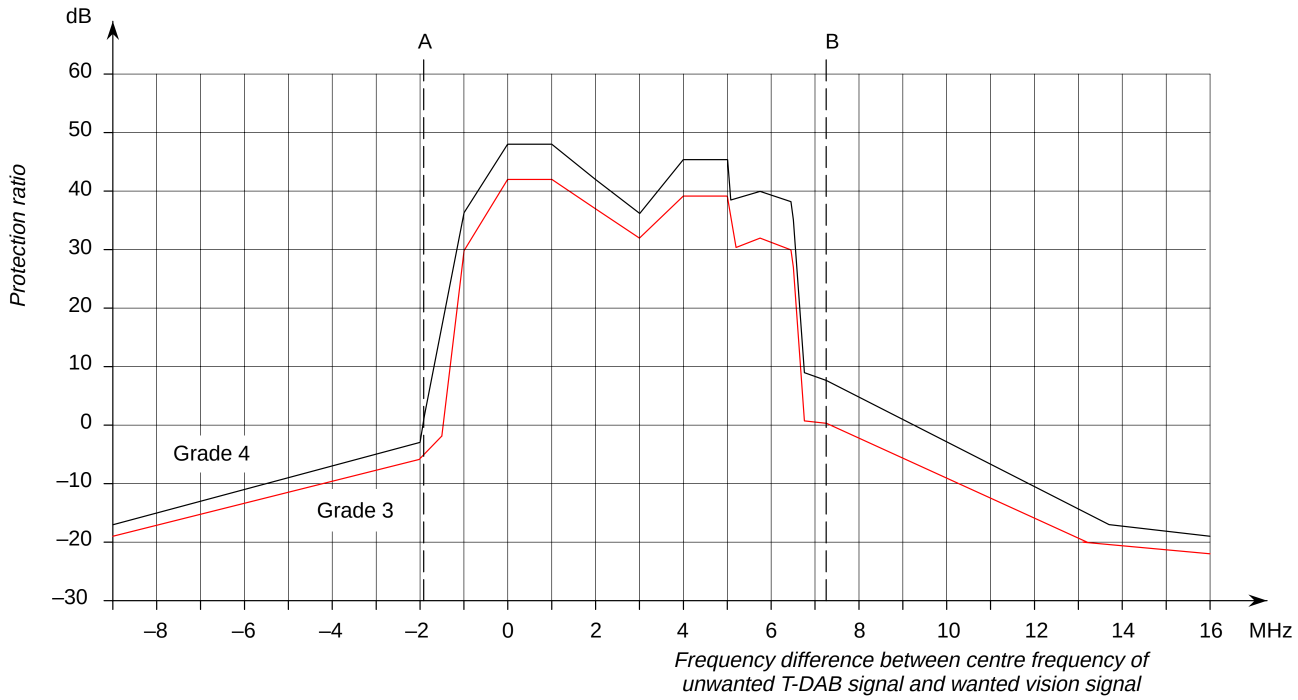
– the television system concerned.

For system B/PAL, the corresponding protection ratio curve is depicted in *Fig. 4*; analogous curves exist for all the other television systems. If the television receiving antenna discrimination is taken into account, considerable relaxations in channel sharing can occur.

2.1.3. *DAB interferes with military aeronautical services*

In the calculations for this case of interference, a simplified reference model is used. A receiving antenna at a height of 10,000 m has to be taken into account. Within line-of-sight, free-space propaga-

Figure 4
Protection ratios for B-PAL with two FM sound signals against interference from T-DAB.



Note 1: The results for grade 4 are used if the interference is “continuous”.
The results for grade 3 are used if the interference is “tropospheric”.

Note 2: Only the values between the vertical lines A and B were taken into account during the Wiesbaden Planning Meeting.

tion has to be assumed when determining the interfering field strength. Therefore in the planning software, the seven transmitters of the hexagon are replaced by a single transmitter with 2.4 kW e.r.p. in the centre of the hexagon. Due to free-space propagation, this transmitter still provides an interfering field strength of 71 dBμV/m at a distance of 100 km.

2.2. 1.5-GHz band

The 1.5-GHz band will become fully available for broadcasting on a primary basis in the year 2007 but will be used by some countries for T-DAB before this date. In this frequency band, other services had to be taken into account when establishing the T-DAB Plan. These services are mainly civil or military fixed links. At a rather late stage during the Planning Meeting, the Russian Federation submitted details of an aeronautical telemetry service. This created severe incompatibilities in Eastern European countries and in the eastern part of Germany. Thus, three important cases of interference had to be studied in the 1.5-GHz band and the appropriate interferences/sharing parameters had to be established for:

- DAB interferes with DAB;
- DAB interferes with fixed links (civil and/or military);
- DAB interferes with an aeronautical telemetry service.

As in the case of the VHF Band, the DAB signal in the 1.5-GHz band is, in general, more robust against other services than vice-versa. For this reason, interference into the T-DAB channel is generally less critical than interference to other services.

2.2.1. DAB interferes with DAB

Before it became evident that it could be necessary to use the 1.5-GHz band in addition to the VHF bands, most work had been carried out to determine the required network parameters for VHF only. Fortunately, the results of much of that work could be applied to the 1.5-GHz band, simply by suitably modifying the parameters. Again, the basis of T-DAB planning was a hexagonal network structure. However, a different reference model was required for this frequency range, because of the different propagation conditions and the higher required minimum field strength when compared with the VHF band. In this model *(Fig. 5)*, the distance between transmitters is reduced to 15 km and the radiated power is modified. The peripheral transmitters of the hexagon radiate an e.r.p. of 1 kW with an omnidirectional antenna. The central transmitter has an effective radiated power of 500 W and is also omnidirectional.

The interfering field strength generated by the 1.5-GHz reference network can also be calculated, and the relevant field strength versus distance curves are shown in *Fig. 6* (for a land path) and *Fig. 7* (for a warm sea path). The high values of field strength at long distances over sea paths led to many planning difficulties.

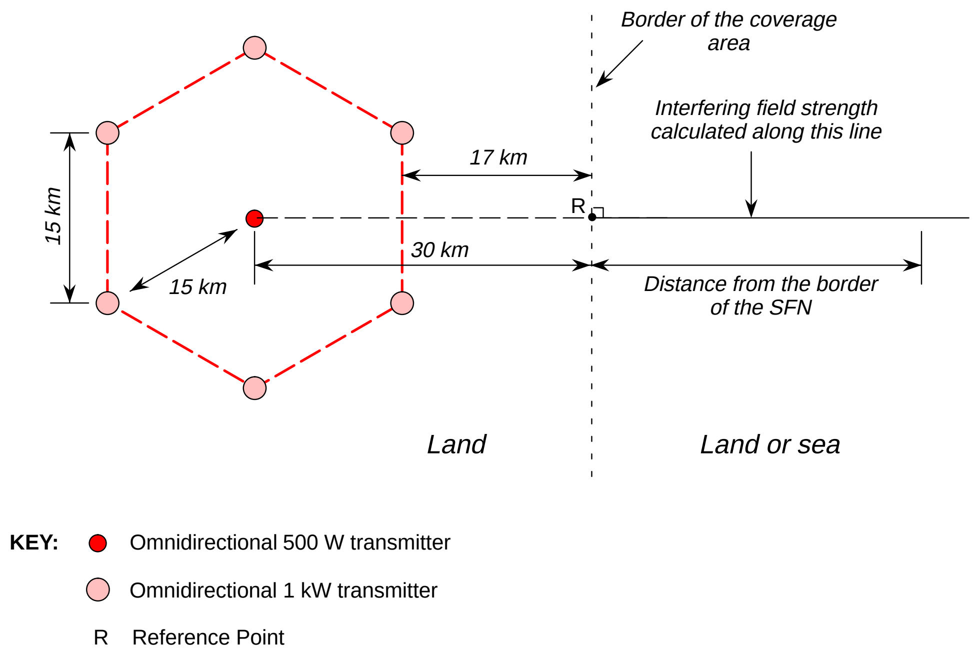


Figure 5
Reference network for the 1.5-GHz band.

As in the VHF case, the interference calculations were based on a 10 dB protection ratio and a propagation margin of 18 dB (to protect the DAB signal at 99 % of locations). These margins, together with a minimum usable field strength of 66 dBµV/m lead to a maximum permissible interfering field strength of 38 dBµV/m. On this basis, a T-DAB frequency-block re-use distance of 50 km was derived.

2.2.2. *DAB interferes with other services (fixed links and aeronautical telemetry)*

Due to a lack of technical data and other relevant information concerning some of the other services considered here, it was not possible to derive the required protections ratios, minimum field strengths to be protected, etc., for all cases. In

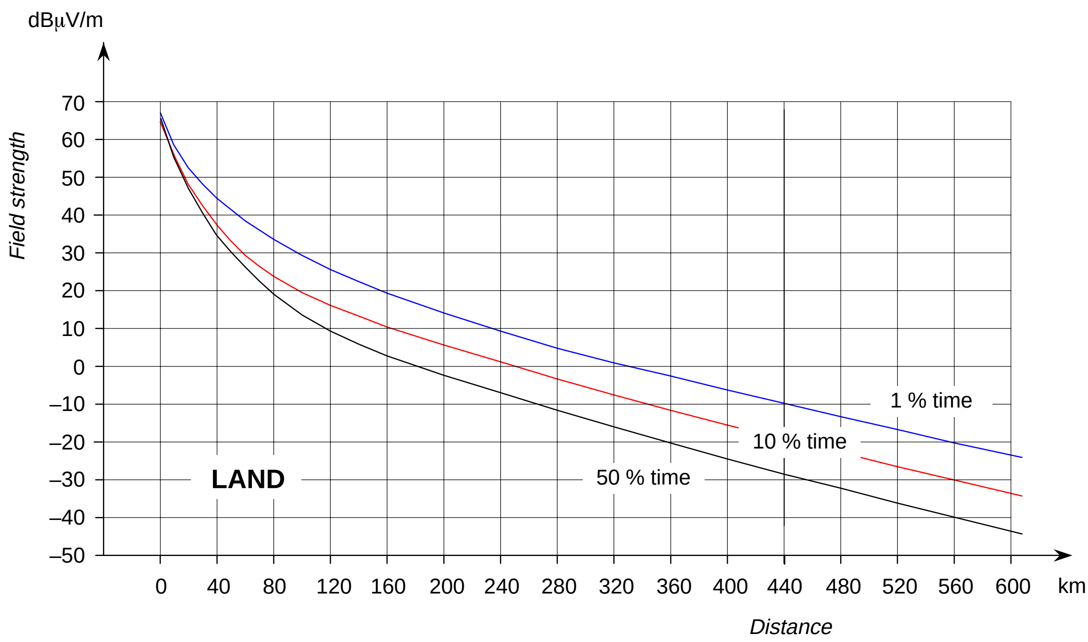


Figure 6
Variation of 1.5 GHz band field strength with distance over a land path.

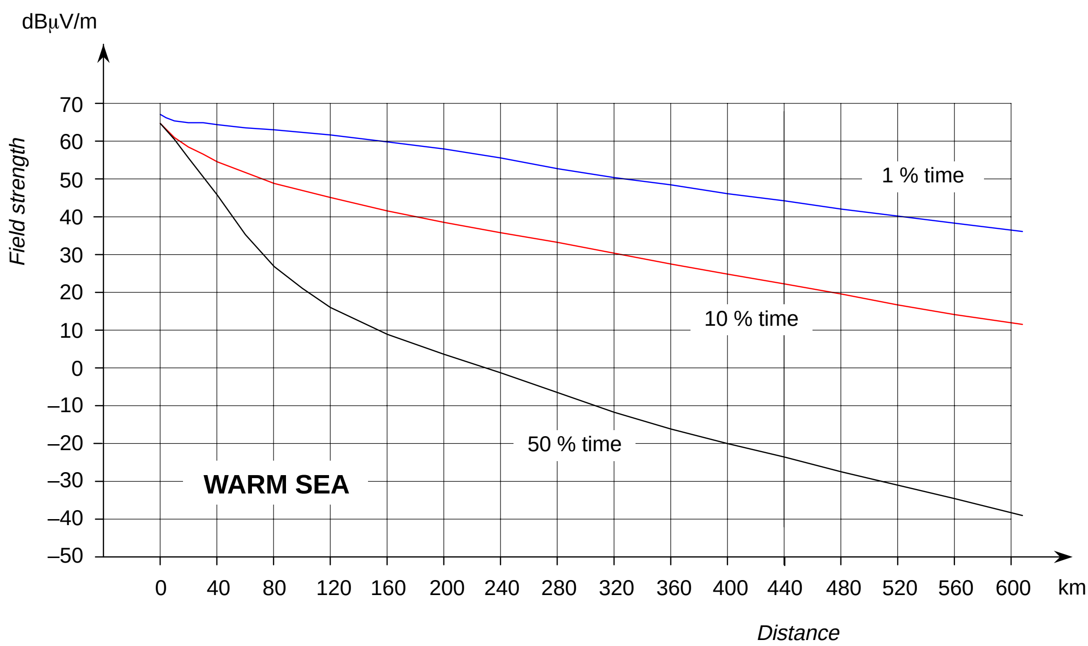


Figure 7
Variation of 1.5 GHz band field strength with distance over a warm sea path.

some cases, this information was received only during the Planning Meeting, leading to extreme difficulties in objectively assessing the interference potential; e.g. a “compatibility” between the mobile aeronautical telemetry service and T-DAB could only be achieved by special agreements with the Russian Federation, involving a very long time delay in Eastern Europe before T-DAB services in the 1.5-GHz band can be started.

In general, though, when data was agreed, the calculation procedures were similar to those carried out in the VHF band. For the aeronautical service, the reference hexagon was replaced by a central transmitter with an e.r.p. of 6.3 kW. The calculations for all other services were based on the 1.5-GHz reference model shown in *Fig. 5*.

3. Preparations within the CEPT

The CEPT has closely followed the development of digital audio broadcasting in Europe, in particular the efforts made within the Eureka-147 project.

Some years ago, a few European administrations started to consider how and where to find frequencies for this new service and, in 1991, the CEPT took on board this task as a common effort. To cope with this challenge, it installed two project teams within its Frequency Management (FM) and Spectrum Engineering (SE) Working Parties. One of these project teams, FM14, had responsibility for planning while the other team, SE11, had responsibility for technical matters.

As more and more European countries developed an interest in the introduction of DAB services, the CEPT decided in 1993 to hold a Planning Meeting for terrestrial DAB.

The basic proposals prepared by the two project teams are discussed in this *Section*.

Band	Frequency range (MHz)
VHF Band I	47 – 68
VHF Band II	87.5 – 108
VHF Band III	174 – 230
VHF military aeronautical	230 – 240
1.5-GHz band	1452 – 1492

Table 1
Frequency bands for T-DAB as recommended by the CEPT.

3.1. Frequency bands for terrestrial DAB

An examination of the frequency utilization for the various existing services showed that frequencies for DAB must primarily be obtained from the existing broadcasting frequency bands. Even so, it was quite difficult to find a common frequency range which might actually be used for DAB because of the many national allocations to different services. This effect became even more difficult when the eastern European countries which also use these frequency bands joined the CEPT.

After much consideration, the CEPT recommended that DAB should start in the frequency bands listed in *Table 1*.

The actual frequency band or bands to be used in any given country depends on national decisions. The Wiesbaden conference actually planned for all of these bands, except for 87.5 to 108 MHz since this band will still be utilized by VHF/FM analogue services for a long time and may be the subject of a later replanning conference. In practice, the sub-band 1452 to 1467 MHz was considered at the Planning Meeting, not the full 1.5 GHz band, 1452 to 1492 MHz.

3.2. Assignment or Allotment planning

The recommended frequency bands should allow the introduction of terrestrial DAB in all CEPT countries. Since, however, most of the countries did not have detailed network plans available, the planning for DAB had to be flexible. Frequency blocks should be available at the time needed and should allow for the development of DAB networks. The plan should allow for national DAB coverage as well as regional, urban and local coverage.

Frequency planning is often done on the basis of a theoretical lattice scheme – as was the case at the Geneva VHF Band II conference in 1984. Theoretical transmitter sites and frequencies are then shifted to the locations actually required and the transmission characteristics tailored to the required service area.

The data pertaining to the actual locations is then made the subject of negotiations and agreements and forms the basis of an assignment plan. (There may also be later coordination if it is necessary to make other changes to the characteristics of the stations.) This whole process requires that reasonably detailed knowledge of the network structure be available during the preparation of the plan.

For DAB, this planning method was not practical because insufficient data was available. However, the single frequency network (SFN) concept for DAB gives sufficient freedom for development of an operational network within certain limiting conditions, e.g., certain limits of field strength at the border of a service area. Therefore, the concept of an *allotment* plan, which allocates frequency blocks to specific service areas, was chosen.

3.3. Frequency re-use distances

The limit of coverage of a DAB service area is defined by a reference minimum field strength, below which an area is considered to be unserved.

In the absence of known locations and characteristics of real T-DAB transmitters, the planning had to be based on the DAB reference networks shown in *Figs. 1* and *5*. From these, the frequency re-use distances between DAB service areas were calculated using propagation curves derived from ITU-R Recommendation PN.370 [2] (see *Sections 2.1.1.* and *2.2.1.*).

For DAB against DAB, a re-use distance of about 80 km for VHF and 50 km for the 1.5-GHz band corresponds to the respective reference networks, at least when the areas are separated by land-only paths.

3.4. Planning principles

Planning should be done on the general principle of all CEPT countries having equitable access to the frequencies required by them to provide DAB services. These may be national coverages requiring one frequency block each, or a combination of regional (or even local) services together covering the whole national territory. It is of course up to each administration to decide on the services and service areas it requires and even to provide its own definition of what is meant by "national".

The allotment plan should be built on realistic criteria so that coordination is not necessary in most cases when an allotment is turned into an assignment.

In addition to these basic ideas, the CEPT project teams also prepared a draft text of the Arrangement (that is, the Plan and its associated provisions) and a set of defined planning parameters. Draft plans elaborated by Project Team FM 14 ensured that the delegates were familiar at an early stage with the restricted scope of the planning process, in view of the limited frequency spectrum available. A questionnaire was distributed to each administration six months prior to the Planning Meeting, requesting their T-DAB requirements together with details of existing services entitled to protection (including television, fixed and mobile services) and which needed to be taken into account when T-DAB is introduced. This information was processed by the European Radiocommunications Office (ERO) in Copenhagen and was supplied as input data at the beginning of the Planning Meeting. In parallel with the work of the ERO, the EBU developed computer programs to facilitate the planning process.

4. CEPT group FM19

In addition to the technical project teams established by the CEPT (i.e teams FM14 and SE11), a further group was established to oversee the physical arrangements – in particular to establish the suitability of the venue for the Planning Meeting. In fact, the venue itself was proposed by the German administration which hosted the Meeting. The building was the Kurhaus in the old spa town of Wiesbaden. This elegant building provided a very large conference room, capable of comfortably seating the 300 or so delegates during the main meetings and, in addition, a number of smaller rooms for meetings of working groups, for the computer pool, for translators and for the EBU and ERO computer facilities.

In addition to its primary functions, FM19 also set up a drafting group, referred to as FM19 DG1, in order to establish what would be the input data requirements *if* it were decided to attempt to establish a T-DAB plan using computer facilities. At the time of the first meeting of DG1, less than one year before the Planning Meeting took place, it was far from clear what computer assistance, if any, would be used. Indeed, many people were of the opinion that it would be impossible to collect the required data and produce the computer software for the establishment of a plan – at least, certainly not in the time available. Indeed, the people who thought that it would be possible were very much in the minority.

DG1 made a series of proposals with regard to the data and the ways in which software could be used to help establish a plan. First of all it would be necessary to collect data relevant to the T-DAB requirements themselves, including geographic coordinates representing the area to be served and the frequency blocks which might be available. For other services, coordinates of the area to be served (or the reception points) and information about transmission and reception requirements were needed. For some of the other services, additional information would have been useful but was not available because the nature of the services was not known sufficiently early.

The basic idea which was developed by FM19 DG1 was that:

- compatibility analyses would be carried out to determine which of the potentially-available frequency blocks for a given T-DAB requirement could be used while continuing to respect the mutual protection requirements;
- these results would be examined by the administrations to permit adjustments to be made, e.g. to take into account the information which was not available within the computer files;
- new sets of available frequency blocks would be created and a plan synthesis would be carried out.

In practice, the second of these steps was not implemented because of time pressures during the Planning Meeting. Instead, these adjustments were incorporated into agreements between the administrations which were reached after a synthesis had been carried out and were thus only implemented in the next round of the compatibility analyses and plan synthesis.

These DG1 proposals were largely included in the overall process endorsed by FM14 and SE11 and then formally agreed at the start of the Planning Meeting itself.

With the benefit of hindsight, improvements could have been made, particularly with regard to the acquisition of receiving antenna patterns for fixed services using relatively directional antennas. This could have eliminated some of the problems encountered during the Planning Meeting itself. The difficulty, as noted above, was that the detailed requirements of such services were not identified sufficiently early for them to be taken fully into account.

It is perhaps not inappropriate to speculate how the planning process could have been undertaken without computer assistance. It seems unlikely that the compatibility between T-DAB and other services could have been considered, except perhaps in a very simplified way. This matter would have been left as an outstanding item to be taken into account when an attempt was made to coordinate T-DAB assignments and it is likely that many problems would then have arisen. Compatibility between T-DAB requirements on overland paths is fairly easy to assess with the aid of maps. It is substantially less easy to do so when mixed land–sea paths are involved and it is doubtful if it can be done reliably. The manual synthesis of a plan is generally much less efficient and effective than doing it with computer assistance, although the manual approach is easier when it involves accepting a lack of protection in order to complete a plan in a difficult area.

5. Data collection and processing

5.1. Introduction

The design, development and implementation of the data collection and the processing of the computer support for the Planning Meeting was one of the ERO's responsibilities. A set of attributes to be met by the target system was laid down, the four main attributes being:

- correctness;
- robustness;
- flexibility;
- openness.

The principal desired functions of the system were data collection, validation, rectification as well as presentation of data and presentation of results. A key part of the system functionality was the export and import of data to facilitate communication with the Compatibility Analysis and Plan Synthesis modules developed and operated by the EBU.

5.2. DACAN

Based on the given requirements, a system called DACAN (DAB Computer Analysis) was designed. It consists of several programs for general use and also has a number of utilities for data manipulation. A Microsoft Windows platform was chosen for the implementation. The core of the system was written in the C^{++} language. Some applications were developed in the Delphi environment.

5.3. File types

Three different file types were used throughout the system:

- a relational database – in a Paradox format – was set up for native use within DACAN;
- flat (i.e. sequential) ASCII files were designed for communication with the administrations and with the EBU's programs;

– specific binary files were used for the import of the compatibility analysis results.

5.4. Time constraints

The time constraint was the most critical factor in the DACAN design and implementation. The following example illustrates the overall scale:

The first part of the DACAN software – input and validation tool for the Questionnaire – had to be delivered less than six months after the decision to provide computer support for the Planning Meeting. Moreover, the final specification for the contents and for the format of the input data became stable and was approved less than one month before the Questionnaire was sent out. Data obtained as a response to the Questionnaire amounted to more than 50,000 entries. Its validation, rectification and compilation was completed within three weeks after the deadline for data submission.

In order to meet the tight schedule of releasing relatively complex programs into a substantially large domain of users, without the opportunity of beta-testing in real life conditions, a decision was taken to apply object-oriented-programming (OOP) techniques. Experience showed that this was a crucial factor in the successful completion of the task.

5.5. Data input

Project Team FM14 had defined three different types of database record, based on the analysis outline and formats proposed by Drafting Group FM19 DG1. Separately, these three record types described:

– the T-DAB requirements;

– the requirements to be considered regarding compatibility with other services;

– country boundaries.

The administrations were requested to formulate all their requirements in terms of these record types and submit them to the ERO in ASCII files on one or more PC-compatible diskettes. The administrations were given a software package (DACPAK) – which contained example records, an input tool and validation software – to facilitate data input.

The input tool was an interactive program for entering and amending records of all three types. The ITU's Digitized World Map (IDWM) was included in the programme, which helped considerably when entering the geographical data. The use of this tool was optional; it was particularly useful for entering small to medium amounts of data and, as such, was utilized by virtually all the administrations.

The validation software checked the formal correctness of input data files. It came in two versions – a Windows version and a simple MS-DOS command-line utility. Every administration was expected to validate their input data using this tool before submitting their data files to the ERO.

The implementation of input data structures was the central point of the DACAN design. The generic object, *Item*, had been designed to describe all general properties and methods of an input element. The basic elements – such as centre frequency, geographical coordinate, etc. – were then implemented as direct descendants of an *Item* object. A record was also implemented as a descendant of an *Item* (polymorphism) which includes a collection of elements. One of the properties of an *Item* was its full description, thus making the software self-documenting. Validation of a record was then facilitated via the "Validate" method of an *Item*. Similar encapsulation was done for the input/output functions, making data access independent of the storage implementation (ASCII and/or Paradox).

The level of abstraction might seem to be unnecessarily high. However, this was the only way to develop and debug a substantial part of the system without having a specification of input data format and contents. Moreover, the experience in later stages of the process clearly proved that the overhead of the OOP abstraction was negligible compared to increased flexibility in the system maintenance and its expansion potential.

5.6. Received data

In theory, all data received at the ERO should have conformed to a validity test and only compilation of data should have been required. In practice, however, a substantial part of the data contained formal errors, which had to be rectified. Many problems were found in files which had been generated automatically from the databases of administrations. Because of an unfortunate problem in the validation software when checking larger files, automatically-generated files were generally submitted without formal checking. As a result, each input had to be treated individually and a number of rectification filters were created on an ad-hoc basis.

All data received at the ERO was compiled into a database. The database, original data, rectified data and a browsing software were distributed to all CEPT administrations on a CD-ROM and, in parallel, a first run of the compatibility analysis was done at the EBU.

The results of the first run of the compatibility analysis confirmed that the requirements, at that point in time, were such that a successful planning would not be possible and a revision of the input data was needed. Another iteration in data input was therefore performed and a revised version of the CD-ROM data compilation was published just before the start of the Planning Meeting.

5.7. Lessons learned

The experience from the data collection fully confirmed that this was the correct approach. The clear definition of the input format, together with the appropriate software, allowed the administrations to deliver the input data on schedule; the openness of the process, facilitated by the CD-ROM feedback, led to efficient data processing and revision by the administrations.

The primary importance of a clear and comprehensive definition of data input was apparent from the very beginning and maximum attention was given to this by both FM19 DG1 and FM14. However, the data collection exercise showed that there was still room for improvement.

The criteria for formal validation of data were defined in the course of the software development. The data input process would have been greatly improved if the validation criteria had been a part of the data format definition. However, this was not really possible in the time available.

6. Activities at the Planning Meeting

6.1. The T-DAB Frequency Block Allotment Plan

The T-DAB Frequency Block Allotment Plan was developed by CEPT Committee 3 in accordance with the guidelines agreed by the the CEPT's European Radiocommunications Committee (ERC), prior to the meeting. These guidelines included the designation of the frequency bands to be used for planning, namely Band I, Band III and the 1.5-GHz band. Another fundamental guideline was that the plan to be drawn up should only be an allotment plan, since the administrations did not have sufficiently detailed information (e.g. specific details of transmitter sites and heights) in order to be able to develop an assignment plan. The ERC had also specified that, in view of the limited frequency resources, only two T-DAB coverages for each country (providing for coverage by one national service area or for joint coverage of the whole country by several non-overlapping service areas) were allowed to be entered in the Plan.

The information provided by the administrations on their T-DAB requirements, and the other services requiring protection, served as the input data. These data were formally submitted at the beginning of the meeting on a CD-ROM (owing to the volume of data). The requirements of those CEPT countries not represented at the meeting were specified collectively by all of the administrations present and were taken into account in the planning process.

In order to put the planning process on a mutual basis, firstly, all of the data supplied by the administrations had to be confirmed. Likewise, the validity of the EBU planning software as the T-DAB planning tool had to be verified. The first planning run was then carried out (see *Sections 6.3.* and *6.4.*) after a number of misinterpretations regarding the conversion of the planning parameters in the planning software had been clarified.

The results were devastating: out of a total of approximately 750 T-DAB requirements, far less than half could be accommodated. An analysis of the results revealed the cause to be the high number of other existing radiocommunication services, and the high protection criteria for these services (although initial analyses and syntheses carried out using test data before the Planning Meeting had provided an early warning of this problem). The successful elaboration of a plan was conditional on a substantial reduction of both the number and the level of protection of these services. This was finally achieved after a series of tough and lengthy negotiations, mostly conducted outside normal meeting hours.

A solution had to be found for the problems of incompatibility between the allotment of T-DAB blocks in Channel 12 and the military aeronautical service operating in the upper adjacent frequency range, 230 – 240 MHz. In this case, the military aeronautical service is required to take any necessary measures in the short or, at the latest, in the medium term to permit the unrestricted use of all T-DAB blocks in Channel 12. At the same time, the fact had to be accepted that the 230 – 240 MHz frequency range would be reserved for military applications in the long term. This led many countries to modify their initial requests for T-DAB blocks within this range, in favour of blocks in other frequency ranges.

Large-scale obstacles to the planning process were also posed by existing television and mobile radio services in the bands identified for T-DAB. A large number of the administrations had submitted T-DAB requirements in areas in which they had also asked for protection for their own existing services. The prospect of not having any T-DAB allotments included in the Plan, owing to the existence of these other services, provoked the majority of countries into sacrificing the protection of these services, i.e. either stopping the operation of, or relocating, all these services in the short or medium term.

An additional problem concerned the constraint on the use of frequencies for T-DAB applications in continental Europe, owing to fixed link services with a high susceptibility to interference operated in the 1.5-GHz band in the United Kingdom. (Protection of these services had been the subject of a fervent plea by the United Kingdom at the World Administrative Radio Conference in 1992). An acceptable solution was also found in this case, thanks to extensive negotiations – which resulted in the adoption of improved antenna patterns – and to account being taken only of some fixed links with receiving antennas directed towards the continent.

No complete settlement could, however, be reached on the problem of incompatibility between applications in T-DAB blocks in the 1.5-GHz band and the (military) aeronautical telemetry service operating throughout the 1.5-GHz frequency range in the Russian Federation. Resolution of these cases of incompatibility, primarily affecting the eastern countries of the CEPT, was to require individual coordination after the meeting, together with restrictions on starting dates for the T-DAB services. The end result of all these negotiations was the conclusion of more than five thousand individual agreements, involving the acceptance of incompatibilities revealed by the analysis programme or the cessation of operation of other services (which is an extreme form of acceptance of incompatibility).

Many intermediate planning runs were made and the results were used to assist further negotiations. Two approaches were adopted for the planning runs, firstly, using the automatic EBU computer block allotment program only and, secondly, taking as a basis a specified core plan drawn up and comprising 72 pre-planned allotments in central Europe. Since most of the individual administrative agreements had been taken into account in both cases, there were no major differences between the two alternative plans. The T-DAB Planning Meeting did, however, decide in favour of the plan incorporating the pre-determined core allotments (and the implied agreements regarding acceptance of interference margins). A plan was finally established in which as many as 700 out of a total of 759 T-DAB requirements could be fulfilled by the allotment of frequency blocks.

The remaining 59 T-DAB requirements were subsequently fulfilled by means of further administrative agreements, relocation to other frequency ranges, or the definition of fixed solutions on a non-computerized, case-by-case basis. In some cases, this entailed the relaxation of T-DAB parameters or the sacrifice of protection for other services.

The Russian Federation was the only CEPT country not to have presented any T-DAB requirements, since it has yet to frame clear concepts in respect of the introduction of T-DAB services. The protection of all of its other services is, however, taken into account in the Plan.

As a whole, the Plan appears to be a balanced one and better than many had thought possible. In fact, this success is a result of a common European effort of good understanding and cooperation between the CEPT, the EBU and the ERO.

6.2. Data processing

A DACAN database was used to keep all relevant data during the Planning Meeting. Its function was essential since a considerable number of iterations in the allotment planning process were performed during the Planning Meeting. The flexibility of the DACAN system, stemming from its OOP design, proved its value when a number of new and unforeseen features had to be incorporated into the system.

A table containing Agreements was added to the DACAN database, together with interface and output functions. As the Planning Meeting progressed, the number of Agreements in the database increased to a total of five and a half thousand. Finally, the volume of the processing of the Agreements equalled that of the processing of the requirements.

6.2.1. Presentation of data

A number of utilities for the presentation of input data as well as for the planning of results were available in DACAN. The software was able to meet diverse requirements such as detailed graphical presentation of the planning situation, on the one hand, and concise and condensed printouts of data, suitable for bulk distribution, on the other hand.

The Planning Meeting was provided with a computer pool, consisting of a number of stand-alone PCs. Relevant DACAN programmes were installed in each computer. Together with the EBU software, it offered a set of tools which accommodated the requirements of virtually all participants.

6.2.2. Lessons learned

The utilities for graphical presentation of the planning situation were greatly appreciated and contributed considerably to the success of the planning process.

The supply of data from the master database into the computer pool had been built into the DACAN system. However, it did not have highest priority in the design stage. In practice, a delay of about five hours elapsed before detailed data, relevant to a particular planning iteration, became available in the pool. It seems that the planning process could have been further improved if this delay had been reduced. The overhead of connecting the pool into the network and adapting DACAN to the network concurrence would have been negligible compared to the flexibility achieved.

6.3. Compatibility analyses

In order to simplify the overall planning process as much as possible, the compatibility analyses were split into several distinct phases. The results were then combined in order to provide:

– an input to the synthesis process;

– detailed results for examination by the administrations.

In all cases, the analyses involved the calculation of "unwanted" signal levels at a set of test points which represented either the boundary of the service area of the "wanted" service, or a discrete set of receiver locations for the wanted service. These boundary or receiver test points were provided by the administrations as part of the input data for the T-DAB or other service requirements.

It is worth noting that, in addition to the approximately 750 T-DAB requirements, there were some 50,000 other service requirements. Some of these contained only a single receiver or transmitter location. However, most of them related to services intended to cover large areas with multiple test points. The large number of other service requirements meant that the computer run-times were long.

As noted earlier, the administrations were required to supply a list of the potentially-available frequency blocks for each T-DAB requirement, as part of the input data. For the compatibility analy-

Dr. Tomás Cesky *graduated in radio engineering from the Czech Technical University in 1975. In 1980, he gained a Ph.D. in antenna theory.*

From 1981, Dr. Cesky worked at the Czechoslovak PTT Research Institute. After initial involvement in microwave propagation studies, he headed the team which was developing the computer support systems for frequency spectrum management.

In 1991, Tomás Cesky joined the CEPT's European Radiocommunications Office in Copenhagen where he is presently engaged in broadcasting issues and with computer-aided spectrum management techniques.

Mr. Terry Jeacock *began his professional career with the UK Ministry of Posts and Telecommunications (the predecessor of the Radiocommunications Agency) in 1972.*

Since 1989, he has become increasingly involved in international work and is now responsible for UK international frequency coordination and regulatory issues.

Terry Jeacock was elected Chairman of the CEPT/ERC Spectrum Engineering Working Group in 1994 and Vice-Chairman of ITU-R Study Group 1 in 1995.

ses, it was necessary to assume that a given T-DAB requirement might operate on any of the apparently-available blocks, even though some might not be available for reasons of compatibility. Analyses were exhaustive in the sense that they were not terminated when the first case of incompatibility was found. This was done in order to provide full information and to ensure that if one case of incompatibility could be "cured", information remained available about any non-cured cases.

6.3.1. T-DAB to T-DAB compatibility

These compatibility analyses were made using the VHF and the 1.5-GHz band reference networks described in *Section 2*. (The reference network for Band I was taken to be the same as that for Band III with the transmitter powers reduced by 10 dB, to allow for the difference in minimum wanted signal level between Bands I and III):

For any given pair of T-DAB requirements, it was only necessary to consider the results for three bands, not for individual frequency blocks. In principle, some computer time could have been saved by only considering a given band if both T-DAB requirements had at least one potentially-available block in common. In practice this was not done as it was considered more helpful to provide guidance to the administrations on what might happen if the two requirements were to share a frequency block. This guidance was intended to help the administrations when they needed to search for any additional frequency blocks for a given T-DAB requirement.

Because of the large differences in signal level at a given distance over all-land, mixed and all-sea paths, a "brute-force" calculation process was needed. In this method, each test point in turn for one T-DAB requirement is regarded as a signal source (that is, it is taken to be the reference point of a reference network) and each test point in turn of the other T-DAB requirement is regarded as a receiver location. The distance and proportions of land and sea for this individual path are calculated and the unwanted signal level is derived by interpolation between the individual land and sea path signal level values from a reference network at this distance.

As already discussed in *Section 2.*, T-DAB is intended to provide a service to a high proportion of locations (taken to be represented by 99 % location statistics). Because both the wanted and unwanted signal levels vary with location, a propagation margin needs to be added to the unwanted signal (or subtracted from the wanted one) to ensure that 99 % of locations can be protected against interference. This propagation margin has been calculated to be 18 dB. No allowance is made for receiving antenna discrimination, because T-DAB is intended to be receivable on both portable and mobile receivers. This process is repeated for all combinations of test points for the two T-DAB requirements. The 10 worst-case results are retained as being representative of the compatibility situation between this pair of T-DAB requirements. In principle, only the single worst-case test point need have been retained but it was considered that the additional information would be useful, both to identify anomalies and to permit a better assessment of marginally acceptable situations.

As far as input to the plan synthesis programme was concerned, any incompatibility was regarded as unacceptable *except* where it had been specifically accepted by the administrations concerned and recorded in an agreement (see *Section 6.3.4.*).

Most T-DAB requirements contained 36 test points. Some contained up to 99 test points when it was intended to serve the whole of a country; other requirements contained fewer than 36 test points, if the service area was small. This meant that about 36 x 36 propagation paths needed to be examined to establish if there was an incompatibility between two T-DAB requirements. In principle, this process had to be repeated for each pair of T-DAB requirements and could take quite a large amount of computer time. In practice, it was possible to effect considerable savings in computer run-time if the two requirements were either overlapping or very far apart.

6.3.2. Potential interference from T-DAB to other services

As noted earlier, the spectrum proposed for use by T-DAB (and the immediately adjacent spectrum) is occupied by other services. Indeed, as some 50,000 other service requirements were submitted to the Planning Meeting for the compatibility calculation process, it is reasonable to say that the spectrum is *heavily* occupied. These other service requirements represented use by about 100 different types of service, and protection criteria were required for all of them. In practice, at least in some cases, the same protection criteria values were used for different but similar types of service, as the particular data required for each service could not be obtained in the time available.

Some simplifications could be made by dividing the other services into two broad categories, mobile and non-mobile. For mobile services, no receiving antenna discrimination could be taken into account (this means neither directivity nor polarization discrimination) while for non-mobile services, such discrimination could be used to improve compatibility. In order to do this, the administrations had to make available information about the receiving antenna directivity and the polarization. In addition, the location of the other service transmitter needed to be known so that the correct orientation of the receiving antenna could be calculated. In cases where this location was not known, the other service was regarded as mobile. Because the input data requirements were defined before the range of other services was fully known, there were simplifications with regard to the way in which the receiving antenna directivity was specified; this led to serious problems in the consideration of one other service (see *Sections 6.1.* and *6.3.5.*). In the special case where television is the other service, it was not necessary for the receiving antenna discrimination to be specified as there is an ITU-R Recommendation which deals with this [3].

In all cases, the minimum field strength which needed to be protected for each other service requirement could be specified. The only constraint placed on this value was that it would not be less than the default value agreed for the relevant type of service.

There was a further general sub-division of the other services into aeronautical and non-aeronautical variants. Consideration of the former will be deferred. Subject to the above considerations, the calculation of potential interference from T-DAB allotments to other services was the same for all services. The first question is whether there is a frequency overlap between any of the blocks potentially available for the T-DAB allotment and the other service under consideration. For this purpose, the frequency-difference versus protection-ratio tables of Annex 2 to the Special Arrangement (see *Section 6.5.3.*) were used. If the difference between the centre frequency of a T-DAB block and the reference frequency for the other service was outside the range of values in the relevant table of Annex 2, it was assumed that no interference could arise from the use of that block. Where there was a frequency overlap, the compatibility was calculated for all test points of the other service, with each test point in turn of the T-DAB allotment being regarded as the reference location of a reference network.

Some differences occurred when considering aeronautical services. It was assumed that free-space propagation would occur if there was a line-of-sight path between the aeronautical test point and the centre of the hexagon representing the reference network. The radiated power of the reference network was taken to be the power sum of its individual transmitters; in the case of the VHF reference network, account was taken of the transmitting antenna directivity. All aeronautical services were regarded as mobile and no receiving antenna discrimination was included.

As in the case of T-DAB to T-DAB compatibility calculations, up to 10 worst-case results were stored for examination by the administrations but only the worst one of these results was taken into account when preparing input for the synthesis programme.

6.3.3. *Potential interference from other services to T-DAB*

In general terms, the process of calculating potential interference from other service requirements to T-DAB requirements is very similar to that described in *Section 6.3.2.* for the reverse situation. The primary differences were that no receiving antenna discrimination was taken into account and that a propagation margin was needed to ensure that the T-DAB service could be protected for 99 % of locations.

As in the other cases of compatibility analysis, up to 10 worst-case values were presented to the administrations for guidance in making a choice between acceptability and non-acceptability of a given potential interference situation. However, the input to the synthesis programme was based only on the worst one of these values.

6.3.4. *Interface between compatibility analyses and plan synthesis*

In very simple terms, the only data which the plan synthesis programme required from the compatibility analyses were:

– a list of all T-DAB requirements to be considered, together with the set of frequency blocks which could be used;

– a list of all T-DAB requirements, together with the set of other T-DAB requirements which could not share a frequency block.

The first of these lists took account of:

– the frequency blocks declared by the responsible administration to be available;

– the frequency blocks found by the software to be unusable because of interference from or to some other services.

The list of mutually-incompatible T-DAB requirements was actually created in three parts, one each for Band I, Band III and the 1.5-GHz band.

These inputs to the synthesis software were created from the detailed results obtained from the compatibility analysis, account being taken at this stage of the agreements reached by the administrations. In this way, these agreements did not affect the results of the technical calculations; they just affected (in a major way) the use made of those results.

There were *basically* two types of agreement. In the first type, two administrations would agree that two T-DAB requirements could share a frequency block in a given band. This allowed the propagation elements not known to the analysis software to be taken into account and also permitted the acceptance of higher-than-minimum levels of interference. The other type of agreement was where one administration agreed the use of a given frequency block by a T-DAB requirement of another administration even though the software indicated that there was a potential incompatibility with some other service(s).

For the purposes of this exercise, it did not matter if there were additional constraints on the agreements, such as a need to coordinate the introduction of T-DAB services or to accept a time delay before their implementation. The fact that there was an agreement meant that the plan synthesis could proceed and could ignore some of the constraints identified by the compatibility analyses. Without these agreements, there would not have been a successful plan.

6.3.5. Fixed links at 1.5 GHz

There have been several references to the special difficulties of achieving agreements relating to the use of 1.5-GHz-band T-DAB allotments in France and 1.5-GHz fixed links in the United Kingdom. To some extent, these difficulties arose because the format and content of the input data for other services did not permit an adequate description of the

Dipl.-Ing. Manfred Mägele *studied communication engineering at the Technical University, Munich.*

After graduation, he worked for a short time in the development department of Rohde & Schwarz, Munich, before joining the Deutsche Bundespost. Here, he initially worked in the section responsible for satellite communication and, in this capacity, represented the Bundespost in the Intelsat and Eutelsat consortia. Later, he was responsible for the payloads of the German projects, TV-SAT and DFS-Kopernikus.

Since 1990, Manfred Mägele has been head of the New Broadcasting Services section of the Bundesamt für Post und Telekommunikation (Federal Office for Post and Telecommunication).

Dr. Terence O'Leary *received his doctorat in physics at the University of California. In 1975, he joined the Institut für Rundfunktechnik (IRT Munich) where he conducted research on a range of topics including propagation antennas, networks and satellite planning.*

In 1979, Terry O'Leary joined the EBU Technical Department where he became involved in many projects within the framework of EBU Working Party R. From 1984 to 1990, the IFRB benefitted from Dr. O'Leary's specialist knowledge of HF and television network planning. He is currently working with EBU Project Group B/TAP (Terrestrial DAB Planning).

Mr. Gerd Petke *studied transmission technology and telecommunications at the University of Hanover and, in 1971, he joined the Institut für Rundfunktechnik (IRT Munich). He is now Head of the Frequency Planning Section where he is involved in the planning aspects of future transmission systems.*

Mr. Petke is Project Manager of EBU Project Group B/TAP (Terrestrial DAB Planning) whose current task is to provide planning and implementation strategies and techniques for terrestrial DAB.

directivity and bearing of the receiving antennas in use. This problem existed simply because of the lack of sufficient time for the input data specification to be extended suitably. During the Planning Meeting itself, there was clearly not enough time to permit this.

The solution adopted was to use the software to detect the relevant other service requirements and to use the limited amount of data associated with these requirements to synthesize an appropriate but simplified receiving antenna pattern. This can only be regarded as a partial solution as there may still be significant differences between the real patterns and the simplified pattern which was synthesized. The final solutions in this case had to be left to the coordination process after the Planning Meeting was finished.

6.4. Plan synthesis

There are 59 possible T-DAB frequency blocks. The efficient distribution of these allotments to between 700 and 800 requirements is a daunting task. All conceivable combinations would amount to at least 59^{700} choices or, expressed as a power of 10, about 10^{1200} possibilities, i.e. "1" followed by more "0s" than there were requirements! Fortunately – from the point of view of the one who has to examine these possibilities – there were usually severe restrictions on the total number of frequency blocks available to any given requirement (on average, about 6 available blocks per requirement). This reduces the number of possibilities to about 10^{600} which, nevertheless, is still a very large number.

However, even such a large number of possible combinations may not possess an acceptable solution. In fact, it cannot guarantee that even one acceptable allotment plan can be established: an acceptable solution is a function of the configuration of incompatibilities existing between requirements which may have available blocks in common.

This large number of combinations would suggest the use of a fast computer in order to find solutions. In cases where the number of blocks is comparatively low and the number of requirements and their incompatibilities are relatively high, solutions (if they exist at all) can be found only through a thorough search (which takes a long time) or by the use of "clever" quick-search methods.

However, specific "rules" for searching in an efficient manner are not obvious and experience has shown that "rules" which may work well with a given planning configuration might not work well with another.

Two approaches were possible:

– develop a computer search algorithm which was complex and would thus take long running times, or;

– develop a set of, say, 200 to 300 algorithms, each of which would run quickly but still be "clever" enough to find reasonable solutions.

In the event, the second approach was adopted (as the planning Meeting was scheduled for *three* weeks only). In addition, when making this decision, it was felt that the chances of finding a good solution using several hundred (simple) approaches might be more likely to succeed. The use of only one (complex) approach, while possibly being more "clever" than any one of the simpler ones, may not have been the best approach for the particular planning situation being considered at Wiesbaden.

We will not go into the details of the algorithms in this article. Suffice it to say that various strategies for "compacting" the requirements in a limited amount of spectrum were developed, based on previous experience and on planning "logic" (which did not always seem to give consistent results!). After numerous tests had been carried out on a multitude of different planning scenarios, the "good" algorithms were separated from the "not so good" ones which were then discarded. It was found that not all good solutions were generated by any one single algorithm, but rather that a small subset of algorithms usually yielded the best results. Nevertheless, even a "poor" algorithm may hit the jackpot occasionally (even a blind chicken can find a grain of corn sometimes!).

During the CEPT preparations prior to the Planning Meeting, certain other planning constraints were deemed to be necessary; for example a distinction was to be made between "Priority 1" and "Priority 2" requirements, as well as between three possible levels of "preference" with respect to available frequency blocks. As it is turned out, due to the initial intractability of the incompatibilities, it made no sense to take block "preferences" into account, and this part of the software was never used.

During the Planning Meeting itself, further restrictions were imposed which had to be respected (which meant additional computer programming, under pressure): for example, the allotment of block 13 C (13 D) to an allotment area "near" to another such area which already had been allotted block 13 D (13 C) had to be prevented, because of a potential incompatibility resulting from the smaller guard band between these blocks than is the case between other pairs of adjacent T-DAB blocks. These extra refinements meant an increase in computer running time and also (with respect to differentiating between priorities and preferences) to a somewhat less efficient planning algorithm.

In the weeks just prior to the start of the Planning Meeting, the synthesis program was "tested" using the real T-DAB database (about 500 requirements) established by CEPT project team FM 14. This was the first time the program had run on other than about 80 – 100 artificially generated "requirements". Several "bugs" in the software were removed but the running time remained relatively long. With a few corrections and further optimization, confidence in the software was established (at least in the eyes of the developers), and the running time was also significantly reduced (finally to about 5 hours for 750 requirements) to ensure an efficient, speedy application during the Planning Meeting.

During the three weeks of the Planning Meeting many "partial" plans were synthesized, "partial" in the sense that not all requirements were able to receive an allotment. This failure was due, in large part, to the very strict sharing conditions for T-DAB with other services, which severely reduced the number of available T-DAB blocks, in many cases right down to zero. Gradually, after many negotiations, these restrictions were reduced or eliminated by mutual agreement. It followed that more blocks became available to more requirements, and more requirements were able to receive a T-DAB allocation. This process, though efficient in determining and helping to solve planning "bottlenecks", also led to some confusion. This was due to the fact that each new "partial" draft Plan looked very different from the preceding "partial" draft Plans, in part because of the generally increased number of satisfied requirements, but also because of the sometimes complete rearrangement of the allotments themselves. The latter is an inevitable result of the optimization process, defined as the accommodation of as many requirements as possible while simultaneously respecting all relevant constraints.

At a point in the latter half of the Planning Meeting, it was decided that the successful allotments of each successive draft Plan would be "frozen" to provide an input to the subsequent draft Plan. In this way, attempts could be made to find blocks for as many as possible of the non-allocated requirements, at each sussessive step. It was thus possible to concentrate on a dwindling set of remaining incompatibilities at each new round of negotiations. Following this procedure, iteratively, the Plan was finally established.

6.5. Committee 4

Committee 4 of the T-DAB Planning Meeting had the following tasks:

– development of the Special Arrangement text for the operation of the Plan;

– determination of the rights to protection for the many existing services and systems operating in the bands designated for T-DAB;

– establishment of the responsibilities of, and the resources required for, a central body to manage the plan (the "Plan Management Body").

6.5.1. Regulatory basis for the Special Arrangement

The T-DAB Planning Meeting was convened under the provisions of the ITU Constitution and the Radio Regulations relating to special agreements or arrangements (Constitution: Article 42; Radio Regulations: Article 7). These articles require that special arrangements shall not be in conflict with the Constitution, the Convention or the Radio Regulations and they shall be notified to the Secretary-General of the ITU.

Existing broadcasting *assignment* plans, for example the Stockholm Plan of 1961 and the Geneva Plan of 1984, were developed by regional conferences held under the auspices of the ITU and they are managed by the ITU Radiocommunication Bureau (ITU-R). The "Vienna Agreement" for frequency coordination of fixed and mobile services in the frequency range 29.7 – 960 MHz is notified to the ITU as a "special arrangement" between a number of European countries and has a managing administration, although it does not include a plan.

In regulatory terms, the T-DAB Special Arrangement falls between the Stockholm/Geneva plans and the Vienna Agreement. It will be notified to the ITU and contains an *allotment* plan which will be managed by a "Plan Management Body", appointed by the ERC.

6.5.2. Concept of an allotment plan

An allotment plan provides a means to designate frequencies for use within geographical areas. Such plans are particularly useful as they provide an equitable means of sharing the available spectrum for the introduction of a new system when specific details of transmitter sites or networks are in the very early stages of development. Each administration participating in the plan is therefore provided with allotments which it may convert into assignments in timescales suited to meet its national requirements, without further coordination if the proposed assignment does not exceed the technical parameters of the allotment.

The agreement or "special arrangement" associated with the plan must therefore contain procedures and specify the conditions under which the administrations may convert their allotments into assignments. Further, the arrangement must contain provisions which permit the process of introducing changes to the plan (additional allotments or modified allotments) in order to meet changing needs.

In order to ensure satisfactory operation of the plan, central records must be maintained of the allotments and subsequent modifications, together with all assignments coordinated and notified in accordance with the provisions of the agreement.

6.5.3. Development of the Special Arrangement Text

a) Structure of the Special Arrangement

The Special Arrangement is modelled on similar previous agreements, for example the Stockholm Plan of 1961 and the Geneva Plan of 1984. The Table of Contents is shown in *Table 2*.

However, additional provisions and procedures were required to take into account that:

– the Special Arrangement contains an *allotment* plan (instead of an *assignment* plan);

	Preamble
Article 1	Definitions
Article 2	Execution of the Special Arrangement
Article 3	Annexes to the Special Arrangement
Article 4	Procedure Concerning Modifications to the Plan
Article 5	Compatibility and sharing with other radiocommunications services
Article 6	Conversion of an allotment into one or more assignments and the associated coordination and notification procedures
Article 7	Accession to the Special Arrangement
Article 8	Scope of application of the Special Arrangement
Article 9	Notification of this Special Arrangement to the ITU
Article 10	Denunciation of the Special Arrangement
Article 11	Revision of the Special Arrangement
Article 12	Entry into force and duration of the Special Arrangement
Article 13	Cases where ratification is required
	Signatures / Final protocol
Annex 1	The T-DAB Frequency block Allotment Plan
Annex 2	Technical bases for T-DAB planning
Annex 3a	Basic characteristics to be communicated in order to obtain a modification to the Allotment Plan
Annex 3b	Basic characteristics to be communicated for the conversion of an allotment into one or more assignments
Annex 4	Technical procedures for coordination
Annex 5	T-DAB frequency block allotments in the band 87.5 – 108 MHz agreed between the administrations concerned, but not forming part of the Plan
Annex 6	T-DAB frequency block allotments in the band 1467.5 – 1492 MHz agreed between the administrations concerned, but not forming part of the Plan

Table 2
Table of Contents of the Special Arrangement.

– some of the frequency bands designated by the ERC for T-DAB are:

- not allocated to the Broadcasting Service (230 – 240 MHz);
- subject to the provisions of other agreements (47 – 68 MHz, 174 – 223 MHz);
- subject to special provisions of the Radio Regulations (1452– 1467.5 MHz, Resolution 528, WARC-92);

– some administrations intend to use frequency bands which are:

- not part of the T-DAB Allotment Plan (1467.5 – 1492 MHz, 87.5 – 108 MHz)

b) General provisions

Many of the articles of the Special Arrangement are "standard" provisions which specify its execution, scope, procedure for revision, date of entry into force, duration, and the conditions for a CEPT administration to join, leave or ratify the Special Arrangement. Annexes contain the Allotment Plan, technical bases for T-DAB planning (e.g. protection criteria) and technical characteristics which must be supplied by the administrations in order to obtain modifications or to convert allotments into assignments.

c) Provisions dealing with assignment, modification and notification

The articles dealing with modification of the Plan (Article 4) and the conversion of allotments into assignments (Article 6) contain complex procedures that have a number of aspects unique to the introduction of T-DAB. Committee 4 established separate sub-groups to examine carefully the procedures required and to draft the appropriate text.

There are both common and specific elements to the procedures of Articles 4 and 6, as shown in *Table 3.*

d) Technical procedures for coordination

The administrative procedures specified in Articles 4 and 6 of the Special Arrangement require complementary technical procedures to determine when coordination is required and to identify which administrations may be affected. The same technical procedures must be used by all administrations to avoid confusion and dispute; therefore, these procedures must be described in detail and included as provisions within the Arrangement.

Procedures common to Articles 4 and 6
Identify the administrations (if any) whose services may be affected by the proposed assignment/modification
Send a request for coordination to these identified administrations, with a copy to the Plan Management Body for "publication"
Exchange additional technical details, if required
Reach agreement with all the administrations identified as potentially affected by the proposed assignment/modification, including any additional administrations which may have responded to the published information
Notify the Plan Management Body that coordination has been successfully concluded
The Plan Management Body to update the Plan or Assignment List (as appropriate)
Additional provisions in Article 4
Define what constitutes a modification
Specify the procedure to be followed, should an administration not reply to the coordination requests
Give timescales
Additional provisions in Article 6
Describe the basic principles of how to convert allotments into assignments
Give the procedures to be followed for cases where coordination is not required, that is when the assignment is within the parameters of the allotment
Give the procedures to be followed for cases where coordination is required
Coordinate new assignments with other radiocommunications services
Give instructions for notifying the assignments to the Radiocommunications Bureau of the ITU, including T-DAB assignments in non-broadcast bands, and T-DAB assignments in bands subject to the Stockholm and Geneva Plans
Define the status and degree of protection of T-DAB assignments between signatories to the Special Arrangement and between signatories and non-signatories (see *Section 6.6.*).

Table 3
Elements that are both common and specific to Articles 4 and 6 of the Wiesbaden Plan.

The technical procedures must be developed from the planning principles and from the methods used to develop the Plan, which are extremely complex as they take into account the different protection requirements of other services from and to T-DAB, in addition to protection between T-DAB allotments.

Unfortunately, there was insufficient time to develop detailed technical procedures during the Planning Meeting. An interim procedure was developed to meet initial coordination requirements but this considers the "worst case interference scenario" and will result in many unnecessary coordination requests. The ERC has subsequently established a project team, ERC/PT19, to develop more detailed and flexible technical procedures to replace the interim procedure contained in Annex 4 of the Special Arrangement (see *Section 7.2*.)

6.6. Protection Rights

The frequency bands designated by the ERC for the introduction of T-DAB are shared with existing services or, in some cases, are adjacent to bands allocated by other services potentially at risk from interference mechanisms such as receiver blocking or out-of-band-emissions from T-DAB transmitters.

In preparation for the Planning Meeting, protection criteria for most existing services had been developed and details of the existing services had been supplied on diskette by each administration.

It became clear in the early days of the Meeting that it would be necessary to consider, on a case-by-case basis, each of the existing services or systems to determine if they had the right to protection from T-DAB.

The examination was based on the provisions of the Radio Regulations, taking into account the service category of the system (broadcast, mobile, fixed); the allocation category (primary, permitted, secondary); the status of allocations in footnotes of the Regulations; and whether assignments had been coordinated between the administrations or registered in the (ITU) International Frequency Register.

In addition to the status of existing systems in relation to the development of the T-DAB Plan, consideration had to be given to the rights of new T-DAB allotments requested as modifications to the Plan and the rights of other radiocommunication systems requiring new assignments after the Planning Meeting.

Some examples of the cases considered are given below to illustrate the regulatory complexities involved:

Existing television transmitters notified and conforming to the Stockholm Plan clearly have the right to protection. However, the technical characteristics of T-DAB do not conform to those specified in the Stockholm Plan. New assignments to stations in conformity with the Stockholm Plan could have a higher status than T-DAB assignments;

One band designated for T-DAB is used in some countries for transportable links. In this band, the Regulations provide a secondary allocation for fixed and mobile services and a footnote provides a permitted allocation for land mobile. Transportable links would be treated as secondary and not protected if considered as a fixed service or, if land mobile, would be treated as permitted and protected.

T-DAB assignments in the band 230 – 240 MHz, which is not allocated to the broadcasting service, must operate under the provisions of No. 342 of the Radio Regulations (in effect: no protection, no interference).

Committee 4 prepared a document for Plenary which set out the general principles for the right to protection for other services and T-DAB. For example, it was proposed that, *in relations between signatories to the Special Arrangement*, T-DAB assignments in bands designated by the ERC for T-DAB and conforming to allotments agreed during the Planning Meeting should have the right to operate and to be protected. The Allotment Plan takes into account the protection requirements for existing assignments to other services.

This assisted in resolving all but the most complex cases. These required separate negotiation between the administrations concerned. The principles contained in this document may be used by the administrations in future development of the Plan.

6.7. The Plan Management Body

As described earlier, the implementation of the Plan will involve conversion of allotments into assignments and modifications to the Plan. An essential element of any plan is to ensure that it is managed in an orderly way by a central plan management body, responsible for recording changes and circulating notices of proposed changes to other signatories for information and comment. In some plans, the management body may have additional responsibilities to examine notifications, to ensure that they conform to the provisions of the arrangement and to assist signatories in the application of the procedures.

The Radiocommunication Bureau has responsibility for managing the Stockholm and Geneva plans. However, as noted in *Section 6.5.3.a*, there are certain regulatory aspects which could cause the Bureau some difficulty in applying the provisions of the T-DAB Plan. In addition, there would be difficulties in deciding how the costs incurred by the Bureau could be attributed fairly between only those ITU Members that would benefit from this work.

Committee 4 prepared a document describing the tasks of the Plan Management Body and an estimate of the resources required. Based on this document, the Planning Meeting proposed, and the ERC subsequently agreed, that the European Radiocommunications Office (of the CEPT) should undertake the responsibilities of the Plan Management Body.

7. Activities after the Planning Meeting

7.1. Analysis of results

7.1.1. General

The T-DAB Planning Meeting in Wiesbaden provided frequency allotments for more than 750 requirements. In general, it can be concluded that most countries have their first priority for national or large regional coverage in Band III and their second priority for regional or local coverage in the 1.5-GHz band. A notable exception is France which requested and received all of its requirements in the 1.5-GHz band. Countries around the North Sea, the Atlantic (with the exception of France) and the Nordic countries also have (part of) their second priority allotments in Band III.

In the VHF band, most of the allotments are in the range 223 to 230 MHz (channel 12) which, in many western European countries, will become available in the short term. However, in eastern Europe generally and in some parts of western Europe, T-DAB in this range can only be implemented after the channel 12 television transmissions have been closed. This is unlikely to occur in the coming years. In some countries, these are also allotments to T-DAB below 223 MHz and in the range 230 – 240 MHz (also known as channel 13). In only two cases have frequency blocks in Band I and Band II been allotted.

In the 1.5-GHz band, most allotments are within the range 1452 – 1467 MHz. In four cases, there was no solution other than to make an allotment above 1467 MHz.

The number of allotments in the different bands are summarized in *Tables 4, 5* and *6*.

7.1.2. Presentation of results

At the end of the Planning Meeting, the DACAN database contained all data relevant to the Plan. A post-processing software was developed at the ERO for analysis of data and for presentation of the Plan. Two hypertext files were generated, one in the HTML format and the other in Windows Help (WinHelp) format. The HTML file is available on the ERO's World Wide Web site (http://www.ero.dk), while the WinHelp version has been added to a CD-ROM (DACAN September 95) containing all data and software used during the Planning Meeting. As agreed by the Planning Meeting, access to this CD-ROM is restricted to CEPT administrations. A public version will be produced by the ERO in 1996 as one of the functions of the Plan Management Body.

7.2. Conversion of an allotment into assignments

In very simple terms, an allotment gives a country the right to use a frequency block to provide a T-DAB service (containing up to 6 programmes) within a defined area, which may be the whole country or only part of it. However, the T-DAB service must actually be implemented by a set of transmitters and it is extremely unlikely that these could occupy the same physical locations or have the same electrical characteristics as the "transmitters" which were represented in the reference networks. This is, perhaps, especially true at VHF where the reference networks contained transmitters which were, by implication, located on the

Band	Number of allotments	Number of allotments with a reference to an agreement
Band I	1	0
Band II	1	0
Band III	278	205
1.5 GHz	467	177
L +	4	0
Total:	**751**	**382**

Table 4
Number of allotments in the different bands (absolute figures).

Band	Percentage of the total number of allotments (%)	Percentage of allotments with a reference to an agreement (%)
Band I	0.13	0.00
Band II	0.13	0.00
Band III	37.02	73.74
1.5 GHz	62.18	37.90
L +	0.53	0.00
Total:	**100.00**	**50.87**

Table 5
Number of allotments in the different bands (relative figures).

Admini-stration	Band I	Band II	Band III	1.5 GHz	L + *(note)*
ALB			1		1
AUT			7	11	
BEL			7	6	
BIH			1		1
BUL			5	8	
CVA			1	1	
CYP	1		1		
CZE			2	1	
DNK			7		
D			22	102	
EST			1	4	
E			19	19	
FIN			21	2	
F				128	
GRC			5	4	
G			8	1	
HNG			5	7	
HOL			5	1	
HRV			7	9	
IRL			2		
ISL			2		
I			21	21	
LIE				2	
LTU			1	5	
LUX			1	1	
LVA			1	4	
MCO				2	
MDA			1		1
MKD			1		1
MLT			3		
NOR			8		
POL		1	17	49	
POR			15		
ROU			11	11	
SMR			1	1	
SUI			6	33	
SVK			3	1	
SVN			2	2	
S			26		
TUR			6	6	
UKR			25	25	

Note: Outside the 1.5 GHz band.

Table 6
Allotments per administration.

very boundaries of the territory to be served – and which radiated very little power outside that territory. This somewhat artificial construction was adopted in order to make the planning easier. Of course, it has the side-effect of making the implementation more difficult.

The challenge facing the CEPT project team which is preparing the relevant procedures (ERC PT 19) is thus quite considerable and is unlikely to be resolved easily. However, it can be expressed relatively simply. How can one ensure that the cumulative interference from the set of transmitters needed to implement a T-DAB service does not cause excessive interference to other T-DAB allotments or to other services *while* at the same time actually achieving its own service targets?

In addition, there is the complication that during the Planning Meeting there were more than 5000 agreements between the administrations relating (in one way or another) to the acceptance of some degree of (mutual) interference. The content (or intent) of these agreements must also be respected during the implementation process. To add even more complication, there are some cases where implementation could take place without any consideration of interference to other services or to T-DAB. Even here, constraints usually need to be observed in order to provide enough flexibility for future development of T-DAB.

At the time of writing this article, a draft set of proposals has been prepared to deal with each of the problems outlined above. However, they are complex and it is important that their application should not lead to anomalies. For this reason, they are being considered and tested theoretically to ensure that they meet, as far as possible, the mutually-conflicting aims of preserving the rights of other users of the spectrum while not unduly restricting the development of T-DAB services.

Bibliography

[1] Hunt, K.J.: **Personal reflections on the CEPT T-DAB Planning Conference: Wiesbaden, 3 – 21 July 1995**
EBU Technical Review No. 265, Autumn 1995.

[2] ITU-R Recommendation PN.370: **VHF and UHF propagation curves for the frequency range from 30 MHz to 1000 MHz. Broadcasting services.**

[3] ITU-R Recommendation BT.419: **Directivity and polarization discrimination of antennas in the reception of television broadcasting.**

Code	Description	Count
M2	Mobile services – narrow band FM (12.5 kHz) from two or more T-DAB blocks	28301
T2	B/G-PAL television (VHF)	3000
F2	Civil fixed links analogue (1.5 GHz)	2062
T7	B/G-PAL television (VHF) – NICAM	1098
T6	D/K-PAL television (VHF)	1067
T3	D/K-SECAM television (VHF)	1011
MA	Land mobile (173 – 174 MHz)	803
S1	Wide-band FM sound mono	669
ME	Military air-ground-air system analogue (230 – 243 MHz)	598
S2	Wide-band FM sound stereo	568
MT	Military mobile/fixed (tactical) services	551
F3	Civil fixed links digital (1.5 GHz)	473
MB	Military narrow band FM analogue (47 – 68 MHz)	304
T4	L-SECAM television (VHF)	209
MU	Mobile radio – low power devices	184
R1	Medical telemetry service (223 – 225 MHz)	112
FA	Special Service in Finland (FIN)	91
MM	Military tactical links (1.5 GHz)	68
F1	Civil fixed service (VHF)	58
T1	I-PAL television (VHF)	55
SB	Civil fixed links (50 kHz) (SUI)	54
ML	Military fixed services (230 – 243 MHz)	48
MI	Mobile Navy analogue (230 – 243 MHz)	37
YC	Air-Ground-Air 1 (F)	36
SC	Civil fixed links (250 kHz) (SUI)	33
MF	Military air-ground-air system digital (230 – 243 MHz)	32
MC	Military narrow band FM digital (47 – 68 MHz)	31
YZ	Video DGPT (F)	25
YF	Tactical Radio Relays (F)	17
SD	Civil fixed links (500 kHz) (SUI)	17
MG	Military air-ground-air system frequency hopping (230 – 243 MHz)	15
MJ	Mobile Navy digital (230 – 243 MHz)	14
R3	Mobile service – remote control (223 – 225 MHz)	13
YD	Air-Ground-Air 2 (F)	12
MK	Mobile Navy frequency hopping (230 – 243 MHz)	12
YY	Short range systems DGPT (F)	8

Table 7
Total numbers of protection requirements to other services
(continued overleaf).

Code	Description	Count
MD	Military narrow band FM frequency hopping (47 – 68 MHz)	8
R4	Cordless telephones (Band I)	7
T5	B/G-SECAM television (VHF)	5
YX	Video SNCF (F)	5
MN	243 MHz distress frequency	4
M1	Mobile services – narrow band FM (12.5 kHz) from single T-DAB block	4
MQ	Military air-ground-air system analogue (230 – 243 MHz), –1 dB 2.625 MHz	4
MR	Military air-ground-air system analogue (230 – 243 MHz), –1 dB 2.500 MHz	4
AL	Aeronautical radio navigation service (above 108 MHz)	2
DA	Aero Safety Service (D)	1
YG	Safety and distress (F)	1
YW	Aeronautical Telemetry (F)	1

Table 7 *(continued)* Total numbers of protection requirements to other services *(courtesy of the ERO).*