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TECHNICAL CRITERIA OF DIGITAL VIDEO BROADCASTING TERRESTRIAL (DVB-T) AND TERRESTRIAL – DIGITAL AUDIO BROADCASTING (T-DAB) ALLOTMENT PLANNING

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PLANNING CONFIGURATIONS AND REFERENCE NETWORKS FOR T-DAB 33

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EXECUTIVE SUMMARY

A decision to revise the Stockholm 1961 Regional Agreement (ST61) and Geneva 1989 Regional Agreement for digital broadcasting services has been taken and the ITU Council has decided on the agenda and date for the first session of a Regional Radiocommunication Conference in 2004 (RRC04/05).

This report provides ideas on the principles and technical criteria issues for frequency planning especially for an allotment planning for T-DAB (Terrestrial – Digital Audio Broadcasting) and DVB-T (Digital Video Broadcasting – Terrestrial).

Starting from the Wiesbaden Arrangement which has introduced allotment planning for digital sound broadcasting service in CEPT Countries, it is proposed to extend the same process for digital television broadcasting service.

The following report examines the principles and details the technical criteria of DVB-T and T-DAB to be used in an allotment frequency planning in CEPT Countries. It develops and explains the construction of Reference planning configurations to be taken into account for frequency allotment planning for:

- fixed roof-level antenna, mobile and outdoor receptions and portable indoor reception for DVB-T
- mobile reception and portable indoor reception for T-DAB.

Reference planning configurations are based on C/N and minimum median field strengths for Band III and Band IV/V. The report explains in details how the values are chosen.

In the allotment planning, Reference Networks may be used for interference calculations; the report contains details of a number of Reference Networks which can be used.

This report has been prepared in an ad hoc group of CEPT FM PT24. It has been established by experts from EBU-Technical Department, Administrations, broadcasting institutes and companies.

The calculations are based on ITU-R Recommendations, EBU Technical documents and results of recent studies agreed between experts from last implementations of T-DAB and DVB-T networks in CEPT countries.

This report is used within CEPT when preparing RRC 04/05 to support technical proposals from CEPT.

Technical criteria of Digital Video Broadcasting – Terrestrial (DVB-T) and Terrestrial – Digital Audio Broadcasting (T-DAB) allotment planning

1 INTRODUCTION

The mandate of RRC 04/05 is to establish a new regional agreement and an associated frequency plan for digital terrestrial broadcasting in the frequency bands 174-230 MHz and 470-862 MHz. These frequency bands are currently covered by the Stockholm ’61 Agreement (for the European Broadcasting Area) and the Geneva ’89 Agreement (for the African Broadcasting Area). After the new agreement is established, relevant parts of the ST61 and GE89 Agreements will be revised or abrogated, as appropriate.

The planning of terrestrial analogue broadcasting services during the Stockholm and Geneva Conferences was based on the concept of an ‘assignment’ defined in RR1.18 as:

> ***“Authorization given by an administration for a radio station to use a radio frequency or radio frequency channel under specified conditions.”***

In the context of producing a plan, using an assignment planning approach, an assignment consists of a (single) transmitter site (specified in terms of longitude and latitude), with given effective radiated power (e.r.p.), effective antenna height, transmitter radiation pattern, etc. These parameters are chosen to ensure acceptable reception (or ‘coverage’) of an intended program in an area associated with, and usually surrounding, the transmitter location. However, the desired coverage of the assignment is not explicitly taken into account during the development of the plan and, in principle, can not be determined until the plan had been finalised.

Because more attention is now being placed upon the need for a plan to achieve protection of a known coverage area and because digital techniques offer greater potential for planning approaches, the concept of assignment planning, has come under close examination, and has evolved into a related, but more flexible concept termed ‘allotment planning’. An allotment is defined in RR1.17 as:

> ***“Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more administrations for a terrestrial or space radiocommunication service in one or more identified countries or geographical area and under specified conditions.”***

However, in order to avoid difficulties with regard to the competence of administrations in territories other than their own, in the context of planning for terrestrial broadcasting services, this definition can be taken to mean:

> ***“Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by an administration for a terrestrial broadcasting service within its own territory, or geographic areas within its territory, and under specific conditions.”***

The following sections describe basic principles of the technical and other criteria which can be used to identify required coverage areas and be used in allotment planning. These methods and ideas were used successfully during the Wiesbaden T-DAB Planning meeting held in 1995 (the WI’95 Plan) and again during the Maastricht T-DAB Planning meeting held in 2002 (the MA’02 Plan). It should be noted that the considerations below can be taken into account when developing suitable reference networks as well as for developing input requirements to the RRC.

It should be noted that throughout this document ‘interference limited’ planning will be assumed as this will provide a more efficient plan (i.e., more requirements will be satisfied) than would be the case for ‘noise limited’ planning. See also 3.8.

2 GENERAL

Allotment planning may be used to ensure that the area which is intended to be protected against interference is taken into account during the development of a plan. The coverage of an allotment may be achieved by using:

- A Single Frequency network (SFN) consisting of a group of transmitters whose precise site locations and other technical characteristics are known at the time when the plan is made because the transmitter infrastructure has already been determined. In this case, the interference potential of the network can be represented by the set of assignments forming the SFN;
- A single transmitter with known characteristics at a pre-determined site. The interference potential is represented by the assignment;
- A Single Frequency network (SFN) consisting of a group of transmitters whose precise site locations and other technical characteristics have not been determined at the time when the plan is made. In this case, the interference potential of the network must be represented by means of a reference network;

- In the case where a small area is to be covered but where there have been no decisions regarding the choice of transmitter site or other characteristics, the interference potential may be represented by a single transmitter (see **Annex 3**).

In all of the above cases, the outer boundary, or boundaries, represented by test points as described in section 3.6, is used in the calculation of potential interference *to* the allotment. Calculations of the interference potential of the allotment are made using:

- The characteristics of the transmitter or set of transmitters defined with the allotment; or
- The relevant reference network placed at each of the boundary test points in turn.

SFNs are particularly suited to provide coverage of medium to large areas within which it is intended to provide a common set of programmes with all transmitters synchronised on a single frequency.

Implementation of an allotment (see section 4.2 below) can be carried out, "stepwise" if desired, at a time after the planning has been finished.

In order to be of use to the service provider, an allotment must be designed to suit the purpose of the required coverage. Although this document is primarily intended to deal with technical criteria, it is useful to have at least an overview of non-technical aspects of designing an allotment. Some of these general aspects are indicated briefly below:

- <u>Demographic aspects</u>

  One important consideration when designing an allotment is 'where are the people'. Allotments may be often focused on the main population centres. In particular, the existing transmitter sites may in general be situated to efficiently reach 'the people'.

- <u>Programming Requirements</u>

  Allotments may be shaped according to requirements to provide regional programming (for example, because of linguistic diversity within a country or to reflect regional sub-divisions of a country).

- <u>Size</u>

  The size of an allotment may be based in part on political considerations, such as boundaries, either between countries, or within countries. National or regional allotments have the advantage of more efficient spectrum usage because of their generally larger size, however, it is a requirement that the same multiplex, or set of programmes, is to be transmitted over the whole of the area.

- <u>Transmitter infrastructure</u>

  The extent of an allotment may be decided on the basis of existing transmitter infrastructure (see section 3.9 below for the technical considerations).

- <u>Existing overlap coverage</u>

  It may be the case that an existing analogue coverage area is to be replicated in size because this area already meets certain coverage requirements for the administration concerned. Under these circumstances it may also be necessary to replicate any coverage overlaps between adjacent areas. If the RRC takes any decisions regarding the total number of non-overlapping coverages within a country, it may be necessary for the concerned administration to extend the relevant coverage area by means of co-ordination.

3 TECHNICAL BASIS

A description is given below of each of the technical elements which need to be considered when designing an allotment.

It should be noted that, when developing an allotment, all of the elements below should be considered together, because of the interaction between them.

3.1 Service Type

DVB-T is to be planned in broadcasting Bands III and IV/V. T-DAB may be planned in broadcasting Band III.

In Band III, a choice between a 7 MHz and an 8 MHz bandwidth can be made for DVB-T. Usually the bandwidth chosen will be determined by the bandwidth and channel raster of any existing analogue network in the same area.

3.2 Reception Mode and Location Probability

Three different reception modes are considered here: fixed, mobile and portable (indoor and outdoor).

The desired ‘Reception Mode’ is closely related to the desired ‘Location Probability’. The usual correspondence is:

- Fixed reception : 95%
- Mobile reception : 99%
- Portable outdoor reception : 95%
- Portable indoor reception : 70% or 95%.

The reception mode chosen may dictate to a certain extent the approach needed for implementing the allotment (see section 4.2) after planning has finished, for example the choice of transmitter sites, higher or lower powers, density of transmitters, etc.

3.3 Coverage area

National, regional, or local coverage can be planned. The size of the allotment may have an impact on the number of transmitters required and their density or spacing or separation distance (see section 3.11 below). For example, some system variants (see section 3.4 below) providing a large data capacity may require a short ‘guard interval’, which in turn may limit the size of the allotment area and restrict the allowable transmitter separation distance (See also **Annex 2**).

3.4 System Variant for DVB-T

When planning DVB-T, many system variants may be considered. To ease the planning process it may be necessary to reduce the total number of possibilities to a ‘standard’ set of variants.. Of particular interest at this point are the quality of service desired, the data capacity and the ruggedness.

Many of the decisions taken at this point will determine which values of required minimum field strength, protection ratios, etc. are to be used in planning.

3.5 Terrain

Terrain can play an important role in determining the physical configuration of an allotment. For example, at one extreme, the use of larger allotments may be favourable for a very large flat landscape. At the other extreme, the use of smaller allotments may be favourable for a very rugged mountainous terrain where areas are isolated or ‘cut off’.

Terrain ‘shielding’ can sometimes also play a role in solving a compatibility problem between two allotments considered by the planning process as not-compatible if the terrain is not taken into account.

3.6 Allotment Test Points

Once the coverage area for an allotment has been decided, its boundary must be explicitly defined by means of test points. These test points will serve several purposes.

First of all, the allotment test points will define the geographical position, shape, and size of the allotment, that is, the 'allotment boundary':

- For this purpose, the test points are to be specified using, where appropriate, points contained in IDWB, in terms of degrees, minutes, and seconds of longitude and latitude.
- An allotment area will be represented by the polygon (or polygons) defined by the specified test points (which will be the vertices of each polygon). Because only a limited number of test points can be usefully treated, the match between the polygon (or polygons) and the desired coverage may not be exact; therefore the choice of test points must be made carefully to demarcate the allotment area to a sufficient degree of accuracy.
- The test points for a given polygon should be ordered so that, when straight lines are drawn between consecutive points, a closed polygon is formed with no sides intersecting and containing the intended coverage area. This means that the coordinates of the first test point and the last test point in the sequence for the polygon must be identical (i.e., they represent the same physical point) so that the polygon 'closes'.

Secondly, for calculations during planning in those cases where the interference potential of the allotment is represented by means of reference networks rather than by actual assignments, the test points will be used for the locations of the source of the interference that is associated with the allotment. In this way the interference potential of the allotment can be assessed. Rules for this procedure are described in section 3.8.

Thirdly, for calculations during planning, the interference level due to other allotments or assignments will be calculated for the allotment test points. For this reason they should be 'reasonably' spaced. This means that they should give a 'good' approximation to the intended coverage area, the idea being that any potential interference within the polygon (i.e., the coverage area) will be no more than that occurring at the test points; too large a spacing may not assure this aim. On the other hand, too small a spacing may be 'overkill' and only lead to superfluous calculations.

More specific guidelines on the construction of allotment areas are given in **Annex 1**.

3.6.1 National Boundaries and Coastlines

On the land boundary of a country, the test points should be chosen sequentially so that no overlap arises with an allotment from the other side of the mutual country border.

Enhanced propagation across warm- or cold-water seas can aggravate the interference situation to or from other allotments. This effectively reduces the total number of coverages that may be generally obtainable in coastal areas. For this reason particular care must be taken when defining the allotment boundaries along the coasts. However, some administrations may have a need to take account of the complete national territory.

A common allotment boundary for a group of closely located small islands should be specified using relevant IDWM coastline points to create a perimeter line passing through the outer coastline points of the outer islands. Suitable criteria for such allotments should be considered (for example, a specification of the maximum distances between the nearest islands, beyond which the integration of islands within a common allotment would be unreasonable).

If an allotment is to include an island or group of islands off the coast of a country, it may also be unavoidable having boundary test points which intrude seaward.

3.7 Interference Potential

The interference potential of an allotment has two components, one used during the frequency planning stage and one used during the implementation stage.

3.7.1 Frequency planning stage

The interference potential of an allotment is used to determine the compatibility of all the allotments or assignments that are being planned. Two allotments or assignments are compatible if they can use the same frequency without causing harmful interference to one another.

In those cases where the interference potential of an allotment is to be represented by means of reference networks an appropriate reference network (see section 5) must be chosen for the allotment in order to provide a model for the interference potential of the allotment during the planning stages. The interference potential of the reference network is determined by its structure and its reference parameters (transmitter locations, e.r.p.s, effective antenna heights, etc.). The necessary calculations should be based on an agreed propagation model.

3.7.2 Implementation stage

When implementing an allotment (see section 4.2) the interference potential of the allotment is calculated on the basis of the transmitters that are brought into operation. Each new transmitter will be a potential source of interference. The sum of all interference from all the transmitters in the allotment is calculated on the basis of the characteristics of each transmitter. The total interference is calculated at the calculation test points (see section 4.1) and must not exceed a reference level that is agreed during the planning stages, otherwise co-ordination is required.

3.8 Power margin

A power margin should be introduced in order to improve the efficiency of spectrum usage. This entails the addition of a margin (e.g 3 dB) to the transmitter radiated power required to provide the minimum field strength needed to overcome the effects of receiver and man-made noise. This additional power margin gives rise to what is termed ‘interference limited’ planning, in contrast to ‘noise limited’ planning.

It should be noted that if BSS is introduced in the band 620 to 790 MHz, it may be necessary to increase the power margin for fixed antenna reception, in this band, to 5 dB. This is because the maximum limiting BSS signal levels have been established on the basis of increasing the noise level of DVB-T reception by 3 dB in the case of fixed antenna reception.

3.9 Existing Infrastructure

A transmitter network infrastructure for an existing analogue service will often serve as the basis for constructing a new digital allotment. In this way costs can be saved and it may facilitate the changeover during the analogue-to digital transition period.

In order to derive an allotment from an assignment, the characteristic features of the assignment have to be transformed into allotment characteristics. The intention is to keep the properties of the planning object as they are, but describe them now in terms of allotment features.

The simplest way to do this is to take the interference limited coverage contour, of the existing analogue transmitter that is associated with the assignment, as the boundary of the allotment, with appropriately chosen test points, and identify the actual interference that is produced by the converted transmitter as the interference potential of the allotment.

In those cases where an allotment is to be created from a set of assignments (which could be a number of main stations or could also include the associated relay or fill-in stations), the outer boundary of the allotment can be created from the combination of the outer boundaries of the individual assignments.

Existing analogue precision offset working may require additional agreement between the concerned administrations.

Other procedures may be thought of and have to be studied.

3.10 Size

It should be kept in mind that, all other things being equal, the smaller an allotment is, the more ‘spectrum hungry’ the planned network is. This means that if initial planning considerations have led to a large number of ‘small’ allotments it may be desirable to consider if some of the small contiguous allotments might not be ‘fused’ into larger allotments.

If an allotment exceeds a certain size the allotment area can no longer be served by a single transmitter and the implementation of an SFN is necessary. This would also allow network gain (see **Annex 2**) to aid in increasing the coverage potential. SFNs encounter the intrinsic self-limiting mechanism of self-interference, (see **Annex 2**). Self interference depends on the DVB-T variant, the length of the guard interval, the density of the transmitter network and the size of the coverage area. It may be possible to use allotments having large areas when a large guard interval and a sufficiently rugged DVB-T system variant, which would reduce the occurrence of self-interference, can be foreseen.

4 FURTHER CONSIDERATIONS ON ALLOTMENTS

Section 3 describes aspects, which must be taken into account when defining an allotment for planning purposes. For completeness, the following two subsections indicate aspects, which need to be taken into account after planning has finished.

4.1 'Calculation' Test Points

In order to enable an allotment to be turned into a useful coverage (a process called 'implementation', which is described in the following subsection), some rules must be established so that the implementation does not cause unacceptable interference to its neighbours.

One method serving for such a control uses the concept of 'calculation test points. These could be the boundary test points of neighbouring co-channel allotments or some other test points specifically defined for this purpose.

4.2 Allotment Implementation

In general, an allotment will be implemented, totally or in part, after planning has been finished and a frequency has been attributed. The implementation can be carried out stepwise, specifying one transmitter installation after another within the allotment. At each point in the implementation process, it is necessary to ensure that the transmitter considered will not lead to an interference potential at the calculation test points (see preceding subsection) exceeding an agreed reference value. It must be kept in mind that after the planning is finished and implementation has begun, it may be possible to exploit terrain shielding to reduce interference. The interference potential of each individual (real) transmitter is used in the calculation. The agreed method to sum multiple interferences is the power sum method. The total real interference occurring at the calculation test points would not be allowed to exceed a given reference value, unless co-ordinated.

It must be noted that there is no implication that there is any defined relationship between the locations of the 'artificial' transmitters of a reference network and the 'real' transmitters, which are to be implemented.

5 REFERENCE NETWORKS

It must be emphasized once more that a RN does not dictate how the implementation of an allotment is realised, other than by providing the reference value of the interference potential which must be respected during the implementation process.

Reference networks are needed to represent the outgoing interference potential in those cases where the details of the assignments which will form the network are not known at the planning stage.

Reference networks (RN) are theoretical network structures designed to be used as a tool during the planning stage.

A typical RN usually has a regular geometric structure, for example a hexagon or a square. Reference transmitters are located at the vertices, and sometimes at the centre of the structure. These reference transmitters have specified values for reference parameters, such as e.r.p., effective antenna height, etc. These parameters are chosen so that coverage would be possible everywhere inside the network, meeting the expected quality, data rate, location probability, etc. Network gain is taken into account and the parameters are chosen to ensure that an efficient network can be constructed with respect to e.r.p.s, transmitting antenna heights and wanted field strength.

RNs are constructed to allow a reasonable compromise between the density of the transmitters required to support the desired coverage and the potential to re-use the same frequency block with different programme content in other areas, in other words. In particular, the design of an RN ought to accommodate the desired system variant and reception mode.

Because of the multiplicity of possible system variants, reception modes, existing transmitter network structures, etc., it is possible that a multitude of distinct reference networks could be required. While this would give the planner greater freedom in designing an allotment that would fit with specific needs, It is desirable that the number of RNs should not be too large, in order to simplify the choices which may be needed.

Once the complete RN structure and parameters are defined it is possible to calculate its interference potential. A propagation model is needed for this purpose, as well as a method for combining the multiple interfering contributions. The interference potential is used as described in section 3.7 above.

Examples for possible DVB-T modes to be used for planning are given in **Annex 3**. Note that a subset of these examples (or similar parameter configurations) could be used to define appropriate corresponding RN structures, as has been done in **Annex 3**. A possible approach for development of DVB-T RNs is also described in **Annex 3**.

Annex 4 includes similar considerations for T-DAB mobile and portable indoor reception.

6 GENERAL DISCUSSION

As can be inferred from the foregoing text, the construction of a suitable allotment to meet an administration's needs will require much study. All considerations must take account of many or all of the elements described in this document.

It is true that an allotment which satisfies specific coverage demands, for example portable indoor reception, will also 'automatically' satisfy other coverage situations, for example fixed reception, over all of the allotment area, or perhaps even beyond. In this sense an allotment can serve a multi-purpose function. However, because of the close interconnection of the parameters defining allotments (and reference networks as well) for specific service type, reception mode, etc., it is not considered practically feasible to develop reference networks which will provide distinct 'custom made reception' modes in specific sub-areas within an allotment according to an arbitrarily predetermined design.

7 CONCLUSION

Allotment planning can be very efficient and convenient. However, due the large number of parameters, service requirements, national aspirations, etc, it is appropriate to reduce the number of reference networks available for the planning process in order to provide some simplification. The reference networks described in the annexes have been developed with this goal in mind.

ANNEX 1

STEPS FOR THE CONSTRUCTION OF POLYGONS REPRESENTING AN ALLOTMENT AREA

In order to deal with the variety of input requirements it is necessary to represent the area over which coverage of a service is required. The principle of equitable access demands that all input requirements are expressed in a comparable fashion. To satisfy this, it is proposed that each service area could be defined as a set of polygons, as set out in the steps below. Each polygon would then represent the coverage of a single service (an allotment) in an area.

Step 1

A set of polygons is defined as one or more two-dimensional objects. Each polygon must have a minimum of 3 vertices.

Any allotment which is split into distinct geographical areas should be represented as multiple polygons.

Step 2

The use of boundary test points taken from the IDWM will ensure that a polygon will not extend beyond a country's boundary, and that adjacent polygons from neighbouring countries will not overlap.

Taken together, Steps 1 and 2 imply that each polygon represents a single portion (or maybe the whole) of a country's territory.

Step 3

The boundary test points should be chosen so that consecutive points are not separated by more than about 20 km. In those cases where consecutive points in the IDWM are separated by more than 20 km, the great circle path between the consecutive points should be subdivided equally into segments of no more than 20 km.

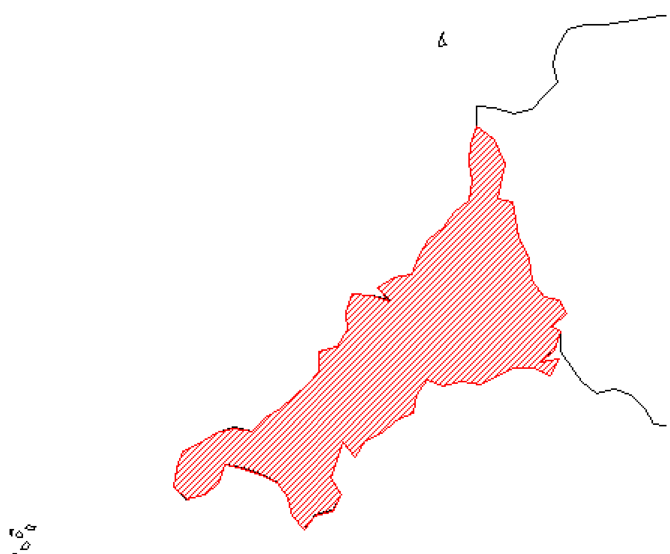

Figure 1: Notional allotment polygon, using coastline data extracted from IDWM dataset. The land boundary shown is constructed to represent the edge of a regional service requirement

Step 4

A common allotment boundary for a group of closely located small islands may be specified using relevant IDWM coastline points to create a perimeter line passing through the outer coastline points of the outer islands.

Suitable criteria for such allotments should be considered (for example, a specification of the maximum distances between the nearest islands, beyond which the integration of islands within a common allotment would be unreasonable).

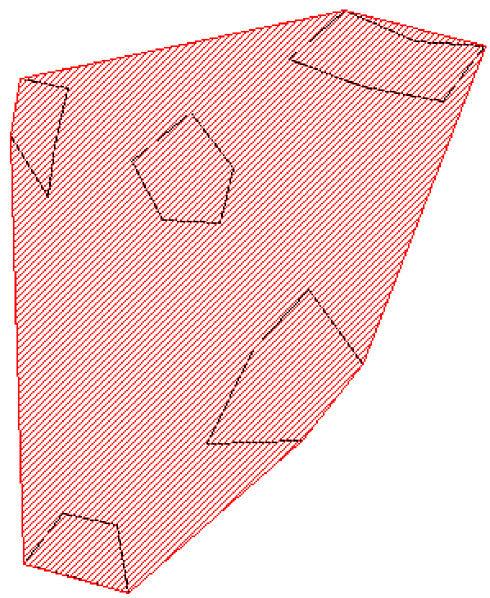

Figure 2: Notional allotment area showing coverage of group of offshore islands by one polygon (IDWM data in black, constructed polygon in red).

Step 5

The collection of polygons defined by a country may cover as much or as little of the country's territory as the administration wishes.

This leaves open the possibility that a country may elect to define parts of its territory as “unserved”. This does not necessarily preclude the later addition of assignments that fall within suitable co-ordination rules However, the size of an allotment may be limited by self-interference, see **Annex 2**.

ANNEX 2

NETWORK GAIN AND SELF INTERFERENCE IN OFDM NETWORKS

Multipath Capacity

An OFDM receiver has to cope with the adverse conditions of the broadcast transmission channel. In general, signals arriving at a receiver by different paths have different time delays which results in the effect of inter-symbol interference, a degradation in reception. An OFDM system with a multipath capability allows for the constructive combination of these signals. This is achieved by employing a guard interval, i.e. a cyclic prolongation of the useful symbol duration of the signal.

Network Gain

Due to this multipath tolerance there exists, within delay limits, mutual addition of the signal powers from a number of transmitters in a network when operated as a single frequency network. This effect is termed the network gain of the SFN, at the reception location under consideration, and consists of an additive part and a statistical component.

The additive part is simply a result of the fact that there is more than one useful signal and hence the signal powers are added in the receiver. The statistical part is due to the location variation distributions of the different fields. The field strength from a single transmitter shows statistical variations due to the presence of reflections and obstacles on the propagation path, particularly for portable and mobile reception. The adverse effect of these field strength variations is reduced by the presence of several transmitters, located at different bearings as seen from the receiver, since when one source is shadowed, others may be easily receivable.

Self-Interference

The power of all signals in an SFN received within the time width of the guard interval is treated as useful, and contributes to the total available signal power. Outside the guard interval, only a part of the echo power is associated with the same OFDM symbol as the primary signal, and therefore contributes positively to the total useful signal power.

The other part of the echo power is associated with the previous or subsequent OFDM symbol and produces inter-symbol interference. Therefore, as the signal delay is progressively increased beyond the guard interval, the useful contribution decreases and the inter-symbol interference increases.

Maximum transmitter separation distance and maximum allotment area size

This gives rise to two restrictions imposed on SFNs. Firstly, for a given receiving location, the main contributing signals in an SFN come from the nearby transmitters. In order to keep these contributions constructive the time delay between them must not exceed the guard interval to any significant extend, which means that neighbouring transmitters have to keep a certain upper limit for the distance between them.

Secondly, even if the maximum separation distance for neighbouring transmitters is kept, more distant transmitters in the network may contribute destructively in such a way that a maximum size of the SFN service area must not be exceeded in order to keep the number of relevant self-interfering transmitters small.

The significance of self-interference, the resulting maximum separation distance between neighbouring transmitters and whether there is an overall maximum size of the SFN service area depends on the chosen guard interval, the sensitivity of the system with regard to self-interference (indicated by the relevant C/N value) and the density of the transmitters in the network.

ANNEX 3

PLANNING CONFIGURATIONS AND REFERENCE NETWORKS FOR DVB-T

1 PLANNING CONFIGURATIONS

1.1 General considerations

The DVB-T system gives the freedom to implement a large variety of broadcast service options. Several thousand planning configurations could be thought of by combining the various possible modulation schemes, code rates, FFT modes, guard intervals, reception modes, coverage quality classes, network approaches etc. However, a large number of these theoretically possible combinations make no or little sense, either from an economical, a technical or a frequency management point of view. Moreover, seen within the context of the RRC04/06, where compatibility aspects are the major issue for the aim to produce a frequency plan, also a large number of the realistic and meaningful planning configurations could be treated as equivalent, since they do not or not very much differ with regard to compatibility aspects.

It is the aim of this section to show that for frequency planning purposes a massive reduction of planning configurations is possible and adequate – in the end a reduction to three reference planning configurations is possible, which then are abstract in the sense that they do no longer correspond to particular real planning configurations. But before formulating these abstract planning configurations in section 3.2 of this Annex, a selection of typical and representative real planning configurations is presented. Section 1.1 of this Annex is dedicated to the discussion of the various aspects of this choice.

Frequency bands

At the RRC04/06 the frequency range to be covered is that of the broadcasting bands III, IV and V. Since propagation characteristics change considerably over this frequency range, it is reasonable to describe planning configurations for all three of these bands.

Reception modes

DVB-T allows for the implementation of broadcasting services for all interesting reception modes – fixed roof-level, portable outdoor, portable indoor and mobile reception -, and it is to be expected that across the planning area of the RRC04/06 all of these reception modes will be requested by administrations. Therefore, in the selection of typical planning configurations in chapter 1.2 each of these reception modes is represented by two instances.

System ruggedness and broadcast transmission channel characteristics

Terrestrial broadcasting is, in general, faced with a more difficult transmission channel than cable or satellite transmission. In addition, even between the various terrestrial transmission channels exists, there are considerable differences. Portable indoor and outdoor reception is confronted with a much more hostile environment than is fixed roof-level reception, and mobile reception is even more difficult because of the additional Doppler degradation. Therefore, usually, for broadcast services for portable reception more rugged DVB-T system variants are chosen, typically with the modulation scheme 16QAM, than for fixed roof-level reception, where often the modulation scheme 64QAM is chosen or planned. For mobile reception even more rugged system variants seem to be reasonable.

Code rates

The code rate indicates the amount of redundancy that is introduced into the data stream in order to overcome the adverse effects of the broadcast transmission channel. Since the terrestrial broadcast transmission channel is particularly hostile – even in the case of fixed roof-level reception – for terrestrial broadcasting code rates providing high protection, e.g., 1/2, 2/3 or 3/4 are normally chosen. Therefore, the selection of typical planning configurations is restricted here to these high protection code rates.

Location coverage probability

Digital broadcasting systems have a rather abrupt degradation behaviour when passing from receiving conditions with perfect audio and picture quality to conditions with no reception at all. In order to provide a satisfactory coverage it is therefore necessary to guarantee good reception conditions with a high probability. The natural statistical variation of field strengths with location is described by the quantity location coverage probability which is a measure for the coverage quality. Normally, to achieve a satisfactory coverage, a location coverage probability of 95% is required for fixed and portable reception and 99% for mobile reception. Sometimes the value of 70% is requested for a lower coverage quality target.

Choice of Transmitter power and power restrictions

In general, for a point-to-area service as it is represented by broadcasting, high power modes are superior to low power modes in an economical sense. This means, e.g., that for broadcasting purposes it is more advantageous operating a service with one network at a higher power than operating two networks at lower power with each network providing half of the data capacity. On the other hand, there are upper limits for the transmitter powers given by technical and environmental considerations and restrictions. There is, e.g., the tendency in the planning of digital broadcasting networks to keep powers below the existing analogue transmitter powers, or at least not to exceed these powers. As a consequence, for fixed roof-level reception higher DVB-T modulation schemes and lower protection code rates will be chosen than for portable or mobile reception.

Guard interval and Data capacity

Large service area SFNs need a large guard interval of 1/4 of the useful symbol time T_u in order to cope with the large delay times in a large scale SFN. Small service area SFNs and dense SFNs can be operated with 1/8 T_u – in advantageous cases even 1/16 T_u may be possible. A single transmitter may be operated with a guard interval of 1/16 or 1/32 T_u. Since in the DVB-T system self-interference immunity is paid for by data capacity, single transmitter or small SFN implementations with smaller guard intervals have a higher data capacity for the same DVB-T planning configuration than large area SFNs have. In Tables 3 to 5 the range for the possible data capacity of particular planning configurations is given.

Diversity and non-diversity receivers

Diversity reception is an appropriate means to cope with the adverse effects of a time-variant multipath broadcast channel which is encountered in mobile and portable reception. For mobile reception it is expected that receivers will employ diversity techniques in any case, whereas for portable reception it is still an open question whether this technique will be established as a standard. The difference in C/N figures between diversity and non-diversity receivers amounts to about 6 dB.

2k/8k FFT

Compatibility aspects are not affected by the choice of a 2k or 8k FFT. However, the 2k FFT is not able to cope with SFN signal configurations with large time delays unless a dense network approach is chosen. The reason is that the guard interval length of a 2k FFT amounts to only 1/4 of that of an 8k FFT.

The various aspects of a planning configuration are summarized in Table 1. Obviously not all of the elements of these aspects are independent; some of the elements only make sense in combination with a subset of the elements of another aspect.

Aspect	Element	Comment
Reception mode	Fixed roof-level portable outdoor portable indoor mobile	
Coverage quality	70% 95% 99%	in terms of percentage of location
Network structure	Single transmitter SFN Dense SFN	adequate for MFN coverage adequate for large area SFN coverage adequate for small and large area SFN coverage
DVB-T system variant	from QPSK-1/2 to 64QAM-7/8	in principle all variants are available
Frequency band	Band III (200 MHz) Band IV (500 MHz) Band V (800 MHz)	

Table 1: Aspects of planning configurations

The selection of eight representative planning configurations in the next chapter 1.2 may be understood as an intermediate step in the derivation of the restricted set of reference planning configurations, as a means of explaining and justifying the particular choice of the final, abstract reference planning configurations.

1.2 Eight Representative Planning Configurations

According to the above described criteria, eight planning configurations have been chosen and the minimum field strengths for each of them have been calculated for the three frequencies 200 MHz, 500 MHz and 800 MHz. Minimum field strengths and protection ratios are the basic quantities to characterize a planning configuration in the context of a compatibility analysis. In this chapter the eight representative planning configurations are characterized and the parameters that are used in the description of these planning configurations are given. At this stage they are formulated independently of the network structure. This aspect will be dealt with in section 3.

All C/N values for fixed and portable antenna reception are taken from the ITU-R TG 6/8 report (Document RRC(04)07). Also C/N values for mobile reception are based on the ITU-R TG 6/8 report. Height loss values for the cases of portable and mobile reception are taken from Recommendation ITU-R P-1546. Figures for building penetration loss and man made noise are used as adopted by PT24/Gothenburg in February 2004 (see Document FM(04)061).

The detailed information about these parameters may be taken from the cited references. The following table highlights a small selection of the parameters.

				Comment
Receiver noise figure		7 dB		
Minimum receiver signal input power (at C/N = 0dB)	(7 MHz band width)	-128.8 dBW		
	(8 MHz band width)	-128.2 dBW		
Building penetration loss	Band III	9 dB		
	Band IV/V	8 dB		
Standard deviation of building penetration loss	Band III	3 dB		
	Band IV/V	5.5 dB		
Man made noise	Band III	2 dB		
	Band IV/V	0 dB		
Receiving antenna height loss		suburban	urban	
	(200 MHz)	12 dB	17 dB	Receiving antenna height loss is applied in the portable and mobile reception cases only.
	(500 MHz)	16 dB	22 dB	
	(800 MHz)	18 dB	24 dB	

Table 2: Selected planning parameters

The minimum median equivalent field strengths E_{med} for the eight representative planning configurations are calculated as defined in the TG 6/8 report and given in Tables 3 to 5. The relevant explanations from the TG 6/8 report (see Document RRC(04)07) can be found in Appendix 1. In the Tables the following abbreviations are used:

fix: fixed roof-level reception

po: portable outdoor reception

pi: portable indoor reception

mob: mobile reception

MMEFS: Minimum median equivalent field strength

		fix	fix	po	po	mob	mob	pi	pi
Planning configu-ration	**Reception mode**	**fix**	**fix**	**po**	**po**	**mob**	**mob**	**pi**	**pi**
	Modulation	**64QAM**	**64QAM**	**16QAM**	**64QAM**	**QPSK**	**16QAM**	**16QAM**	**16QAM**
	Code rate	**2/3**	**¾**	**2/3**	**2/3**	**2/3**	**1/2**	**2/3**	**2/3**
	Loc probability	**95%**	**95%**	**95%**	**95%**	**99%**	**99%**	**70%**	**95%**
Required C/N (dB)		**20.1**	**21.6**	**17.2**	**22.3**	**13.0**	**15.5**	**17.2**	**17.2**
Data capacity (MBit/s)	**From:**	**19.9**	**22.4**	**13.3**	**19.9**	**6.6**	**10.0**	**13.3**	**13.3**
	To:	**24.1**	**27.1**	**16.1**	**24.1**	**8.0**	**12.1**	**16.1**	**16.1**
MMEFS	**E_{med} (dBµV/m)**	**49.0**	**50.5**	**65.3**	**70.4**	**64.9**	**67.4**	**68.6**	**75.6**

For 7 MHz bandwidth E_{med} is reduced by 0.6 dB and the data capacity is reduced by a factor 7/8

Table 3: Planning Configurations for Band III (200 MHz) (Bandwidth = 8 MHz)

Planning configuration	Reception mode	fix	fix	po	po	mob	mob	pi	pi
	Modulation	64QAM	64QAM	16QAM	64QAM	QPSK	16QAM	16QAM	16QAM
	Code rate	2/3	3/4	2/3	2/3	2/3	1/2	2/3	2/3
	Loc probability	95%	95%	95%	95%	99%	99%	70%	95%
Required C/N (dB)		20.1	21.6	17.2	22.3	13.0	15.5	17.2	17.2
Data capacity (MBit/s)	From:	19.9	22.4	13.3	19.9	6.6	10.0	13.3	13.3
	To:	24.1	27.1	16.1	24.1	8.0	12.1	16.1	16.1
MMEFS, E_{med} (dBµV/m)		53.0	54.5	73.1	78.2	72.7	75.2	76.1	84.8

Table 4: Planning Configurations for Band IV (500 MHz) (Bandwidth = 8 MHz)

Planning configuration	Reception mode	fix	fix	po	po	mob	mob	pi	pi
	Modulation	64QAM	64QAM	16QAM	64QAM	QPSK	16QAM	16QAM	16QAM
	Code rate	2/3	3/4	2/3	2/3	2/3	1/2	2/3	2/3
	Loc probability	95%	95%	95%	95%	99%	99%	70%	95%
Required C/N (dB)		20.1	21.6	17.2	22.3	13.0	15.5	17.2	17.2
Data capacity (MBit/s)	From:	19.9	22.4	13.3	19.9	6.6	10.0	13.3	13.3
	To:	24.1	27.1	16.1	24.1	8.0	12.1	16.1	16.1
MMEFS, E_{med} (dBµV/m)		57.1	58.6	79.2	84.3	78.8	81.3	82.2	90.9

Table 5: Planning Configurations for Band V (800 MHz) (Bandwidth = 8 MHz)

2 REFERENCE PLANNING CONFIGURATIONS

2.1 Grouping of planning configurations

Reference planning configurations are intended to represent DVB-T implementations with typical planning configurations. Since it can be expected that a variety of DVB-T planning configurations will be implemented in the future, it seems reasonable to represent them not by a single reference configuration but by a number of different reference planning configurations.

Tables 3 to 5 show that the planning configurations can be grouped into sets with similar minimum median equivalent field strengths, which is the relevant quantity for the required power budget of a network as well as a basic quantity for the assessment of compatibility. This grouping is done in Tables 6 and 7 which are an extract of the Tables of the previous chapter. Three groups can be formed:

- fixed reception
- portable outdoor reception and mobile reception and lower coverage quality portable indoor reception
- higher coverage quality portable indoor reception.

An average value is calculated for each of the groups and given in the last row of the Tables.

A further observation can be made. There are consistent differences in the minimum field strengths across the frequency range 500 to 800 MHz throughout the planning configurations. The difference amounts to about 4 dB for the fixed roof-level reception case and about 6 dB for the portable and mobile reception cases. This gives the possibility to unify band IV and band V planning configurations by choosing average values and to extrapolate from these values to lower or higher frequencies in band IV/V if needed. This unification is done in Table 7.

Group	Fix		mob, po, pi					pi
Planning configuration	**64QAM-2/3 – fix 95%loc**	**64QAM-3/4 – fix 95%loc**	**QPSK-2/3 – mob 99%loc**	**16QAM-1/2 – mob 99%loc**	**64QAM-2/3 – po 95%loc**	**16QAM-2/3 – po 95%loc**	**16QAM-2/3 – pi 70%loc**	**16QAM-2/3 – pi 95%loc**
C/N (dB)	**20.1**	**21.6**	**13.0**	**15.5**	**22.3**	**17.2**	**17.2**	**17.2**
E_{med} (dBµV/m)	**49.0**	**50.5**	**64.9**	**67.4**	**70.4**	**65.3**	**68.6**	**75.6**
Average E_{med} (dBµV/m) Band III	**49.8**		**67.3**					**75.6**

For 7 MHz bandwidth E_{med} is reduced by 0.6 dB

Table 6: Grouping of Planning Configurations, Band III, Band width = 8 MHz

Group	Fix		mob, po, pi					pi
Planning configuration	**64QAM-2/3 – fix 95%loc**	**64QAM-3/4 – fix 95%loc**	**QPSK-2/3 – mob 99%loc**	**16QAM-1/2 – mob 99%loc**	**64QAM-2/3 – po 95%loc**	**16QAM-2/3 – po 95%loc**	**16QAM-2/3 – pi 70%loc**	**16QAM-2/3 – pi 95%loc**
C/N (dB)	**20.1**	**21.6**	**13.0**	**15.5**	**22.3**	**17.2**	**17.2**	**17.2**
E_{med} (dBµV/m) (500 MHz)	**53.0**	**54.5**	**72.7**	**75.2**	**78.2**	**73.1**	**76.1**	**84.8**
E_{med} (dBµV/m) (800 MHz)	**57.1**	**58.6**	**78.8**	**81.3**	**84.3**	**79.2**	**82.2**	**90.9**
Average E_{med} (dBµV/m) Band IV/V	**55.8**		**78.1**					**87.9**

Table 7: Grouping of Planning Configurations, Band IV and V, Band width = 8 MHz

The grouping and the average E_{med} values of the Tables 6 and 7 may now serve for the definition of the reference planning configurations in the next chapter.

2.2 Planning parameters for the reference planning configurations

In the previous chapter, three groups of planning configurations with corresponding average minimum field strength values have been identified as representative. They are now used to define three reference planning configurations (RPC) which are associated with the following reception modes:

RPC1: fixed roof-level reception

RPC2: portable outdoor reception,
mobile reception,
lower coverage quality portable indoor reception

RPC3: higher coverage quality portable indoor reception.

The reference planning configurations are no longer associated with a particular DVB-T system variant.

The E_{med} values (rounded to integer) of the reference planning configurations are summarized in Table 8.

Reference planning configuration	RPC1	RPC2	RPC3
Reception modes	**Fixed roof-level**	**Portable outdoor, mobile, portable indoor (lower coverage quality)**	**portable indoor (higher coverage quality)**
$(E_{med})_{ref}$ (dBµV/m) **Band III**	**50**	**67**	**76**
$(E_{med})_{ref}$ (dBµV/m) **Band IV/V**	**56**	**78**	**88**

Table 8: $(E_{med})_{ref}$ for the three reference planning configurations (RPC)

Since $(E_{med})_{ref}$ do not correspond to E_{med} of particular planning configurations, also the corresponding C/N values are different from those of the particular planning configurations. They have to be re-derived from the $(E_{med})_{ref}$ and are given in Table 9. They are to be regarded as artificial and are only to be used in the context of compatibility calculations and reference network calculations relating to the RPCs. With respect to reception mode and envisaged coverage probability – for a calculation, definite figures are needed – the values given in the row entitled with "Representative of the RPC" should be used.

Reference planning configuration	RPC1	RPC2	RPC3
C/N (dB)	**21**	**19**	**17**
Representative of the RPC	**Fix, 95%**	**po, 95%**	**pi, 95%**

Table 9: C/N for the three reference planning configurations (RPC)

$(E_{med})_{ref}$ from Table 8 and C/N from Table 9 may be used in the definition and description of reference networks in the next section. In the process of establishing a frequency plan they may also serve for compatibility calculations between DVB-T service areas to which the particular RPCs are attributed.

3 REFERENCE NETWORKS

3.1 General considerations

A basic task when establishing a frequency plan is to perform compatibility analyses between transmitters and/or networks. For such a calculation the characteristics of the transmitters have to be known. However, there will be cases where the exact transmitter characteristics of a network will not yet be known at the time when a frequency plan is to be established. This will in particular be true for the case of SFN implementations where the service area may be already known but not yet the exact number, positions and powers of the SFN transmitters. Despite this lack of knowledge it is necessary to perform the compatibility calculations in order to establish the plan. For this purpose it is useful to define generic network structures which may act as representatives of the yet unknown real networks in a compatibility analysis. Such generic networks are called reference networks.

In section 2 three reference planning configurations have been selected for each of the two bands III and IV/V. For each of them a reference network has to be developed, and the properties of these reference networks will be different according to the characteristics of the associated reference planning configurations.

There are further aspects that have to be considered with the design of reference networks. Firstly, the type of network operation has to be taken into account: Will the network be operated in MFN or in SFN mode? In the MFN case a single transmitter will be the reference, whereas in the SFN case a set of transmitters has to be grouped together to form a reference network. Secondly, the size of the intended service has to be taken into account. This is true for both a single transmitter, where a large service area will be served by a high power transmitter and a small area by a low power transmitter, as well as for an SFN, for which – in principle – there is no restriction on the size of the service area, from local/small to very large extensions. It is obvious that reference networks which represent reasonable implementations of these various cases will significantly differ in their properties. As a third element, the ground cover of the intended service area may have an important impact on the network implementation. A network for urban or dense urban areas will need significantly higher powers than a network for rural areas of the same size. Finally, also the case is to be considered when increased implementation efforts regarding transmitter locations and antenna patterns are undertaken in order to reduce the outgoing interference of the network, i.e. whether an open or a (semi)closed network type is implemented

Reference networks are regarded as ideal representatives of real network implementations. They exhibit a high degree of geometrical symmetry and homogeneity with regard to transmitter characteristics. They can be characterized by the following parameters:

- Transmitter number
- Transmitter distance
- Transmitter geometry
- Transmitter power
- Transmitter antenna height
- Transmitter antenna pattern
- Service area (area to be covered).

In the design of the reference networks, transmitter characteristics are assumed to be the same for all SFN transmitters, i.e. all transmitters have the same power, antenna height and antenna pattern.

Reference networks are auxiliary means in order to facilitate the compatibility analysis and plan synthesis in frequency planning. Their main purpose is to determine interference potentials and interference susceptibilities of typical DVB-T implementations, which are the basic input for a compatibility calculation between service areas and by this fundamental for the production of a frequency plan.

According to the considerations given above, it seems reasonable to establish reference networks for the six reference planning configurations of section 2, and further to distinguish between the network operation approach – MFN or SFN - between small and large service areas, between urban/dense-urban and rural /sub-urban ground cover type and to add a reference network type with a very low outgoing interference.

Single reference transmitter

A single artificial reference transmitter, in the case of an MFN approach, would be the simplest representative of a reference “network”. However, in the majority of the cases of a one-transmitter requirement, the characteristics of the transmitter are already known - and if not, they can easily be calculated from the intended service area properties. Therefore, in the one-transmitter case, there seems to be no need to define an artificial “reference transmitter”, rather the “real” transmitter properties can be used in the compatibility analysis. This case is dealt with in section 3.2 of this Annex.

Reference SFN

The SFN case is more complex. SFN are intended to cover larger service areas, and in general not all of the SFN transmitters and their characteristics will be known at the stage of the establishment of the frequency plan. Moreover, these transmitter characteristics are actually not needed in an allotment planning approach at the stage of the establishment of the frequency plan. Compatibility calculations may be performed by means of reference networks as described above. This case is dealt with in section 3.3 of this Annex. Of course, where the real transmitter locations and other characteristics are known, these should be used in compatibility calculations also in the SFN case.

Interference Potential

The interference potential of a transmitter or a transmitter network is the outgoing interference that is produced by the transmitter or the transmitter network. If in the planning process the real interference potential of a network is not known, the interference potential of a reference network may be taken as a representative of the real interference potential. For this purpose, the characteristics of the reference network and a procedure how to calculate the representative interference potential have to be defined.

The interference potential of a reference network may be represented by a field strength curve which is calculated by summing the interfering field strengths of the transmitters of the reference network along a line directing outwards of the reference network and starting at the border of the service area of the reference network. An example which is valid for land-only paths is given in section 3.2 of this Annex. The summation can be performed by means of the power sum method or a statistical summation method.

In a compatibility analysis the interference potential curve may be used to calculate the hypothetical interference at a certain location by assuming that the test points on the border of the service area of the network under consideration are – one by one -the source of interference. The highest interfering field strength value is then taken as the representative of the interference at that location. Of course, a direct evaluation of the interference produced by the reference network transmitters at that location is also possible in a compatibility analysis, after having defined the exact position of the reference network with regard to the boundary test point.

3.2 One transmitter case

For the single transmitter case it is proposed to take the real required power of the transmitter as the interference potential and the calculated coverage area for the intended reception mode, coverage quality and DVB-T system variant as the service area. In this way to each single transmitter an individual interference potential and an individual service area will be assigned.

Two cases can be distinguished:

1. If the allotment is derived from an assignment requirement, the characteristics of the transmission will be available and may be used for the calculation of the interference potential. The characteristics of the assignment requirement may be taken from an existing analogue plan assignment or an existing transmitter site or may be newly designed for the digital plan.

2. If the allotment is to be implemented by an assignment whose characteristics are as yet completely unknown, it is necessary to calculate the required e.r.p. It is reasonable to assume that the effective height of the transmitting antenna is 150 m. The basic steps might be:

    a) Determine the centre point of the allotment area by selecting a point with a longitude mid way between the longitudes of the eastern-most and western-most test points, and a latitude mid way between the latitudes of the northern-most and southern-most test points.

    b) For each test point, calculate the e.r.p. required to give the give E_{med}. The largest calculated e.r.p is then selected as the value for the requirement. It is necessary to add a 3 dB power margin to allow for interference-limited planning, as described above and in section 3.8 of the main text.

As a conclusion it can be stated that, on the one hand, the one-transmitter case can easily be treated by using the real transmitter characteristics as described above, and that on the other hand this is the most precise way of handling the compatibility analysis since the exact requirement is input to the analysis.

3.3 Single frequency networks

3.3.1 General considerations

For the determination of the power budget of the reference networks, antenna heights and powers are adjusted in such a way, that the envisaged coverage probability is achieved at each location of the service area. Full account is taken of network gain and self-interference aspects in the calculation of the coverage probability within the service area. Recommendation ITU-R P-1546 is used as the field strength prediction model. Statistical field strength summation is performed by means of the k-LNM method. The basic (theoretical) minimum median field strength values were derived in section 1 and 2 and the considerations taken in to account are given in these sections.

The k-LNM statistical field strength summation method uses the calibration factor k to adjust the summation process of the wanted field strengths to varying standard deviations of the involved fields. In the power budget calculations of this section the following values have been used:

$k = 0.5$ for UHF, portable indoor reception cases

$k = 0.7$ for VHF, portable indoor reception cases

$k = 0.8$ for VHF/UHF, fixed, portable outdoor and mobile reception

$k = 1.0$ for all unwanted signal summations.

The approach of adjusting the power budget of the network described above uses a noise limited basis, which is known to be not very frequency efficient. To overcome this drawback, the powers of the transmitters in the reference networks have to be increased by a value of 3 dB. This additional amount of power is indicated in the respective tables by the symbol Δ to ensure that there is no confusion about the various elements which enter into the power budget.

For the effective antenna heights of the transmitter in the reference networks 150 m has been regarded as a reasonable average value. It is clear that in real network implementations effective antenna heights may differ considerably from this average value. However, it should be kept in mind that there is a trade-off between effective antenna heights and transmitter powers. If in an SFN a transmitter has a significantly larger effective antenna height than the other transmitters, its power will normally be reduced, since in an SFN it is not desirable to have strong inhomogeneities with regard to transmitter characteristics because self-interference would then become dominant.

An open network structure has been chosen for the reference networks since it is assumed that real network implementations will more often resemble this network type. The service area is defined as a hexagon about 15% larger than the hexagon formed by the peripheral transmitters. However, in order to allow for network implementations with very low interference potentials, also a reference network with a semi-closed network structure is introduced.

The remaining section describes the various reference networks for the RPCs as listed in the previous section. Each chapter consists of a table with the parameters of the reference networks, a figure describing the geometry and figures giving insight into the power budget determination. The table and figures are explained in more detail in the first chapter dealing with Reference Network 1. For convenience, "Reference Network" will be abbreviated by RN.

3.3.2 Reference Network 1

(Large service area SFN)

RN 1 consists of a set of 6 individual RNs: for fixed, outdoor/mobile and indoor reception, each for Band III and for Band IV/V. RN1 is intended for large service area SFN coverage. It is assumed that main transmitter sites with a reasonable effective antenna height are used as a backbone for this type of network. At least for portable and mobile reception the size of the real service areas for this type of SFN coverage will be restricted to 150 to 200 km in diameter because of self-interference degradation, unless very rugged DVB-T system variants are used or the concept of dense networks is employed.

The network consists of seven transmitters situated at the vertices of a hexagonal lattice. An open network type has been chosen, i.e. the transmitters have non-directional antenna patterns and the service area is assumed to exceed the transmitter hexagon by about 15%. The geometry of the network is given in Figure 1.

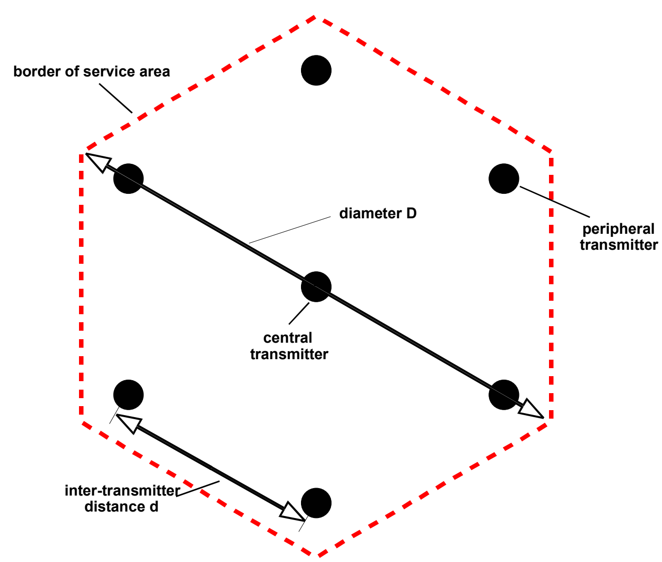

Figure 1: RN 1 (Large service area SFN)

As the guard interval length the maximum value 1/4 T_u of the 8k FFT mode has been chosen. The inter-transmitter distance in an SFN should not exceed by too much the distance equivalent to the guard interval length. In this case the guard interval length amounts to 224 µs which corresponds to 67 km. The inter-transmitter distance for RPC 1 has been chosen to be 70 km. For the RPC 2 and 3, 70 km seems to be too large a distance from a power budget point of view. The powers of the transmitters would have to be up to several hundred kW in the case of RPC 3 which seems not to be reasonable. Therefore, smaller values for the inter-transmitter distance have been selected, 50 km for RPC 2 and 40 km for RPC 3.

Table 10 gives the parameters and the power budgets of the reference networks RN 1.

Reference planning configuration		**RPC 1**	**RPC 2**	**RPC 3**
Type of network		**open**	**open**	**open**
Geometry of service area		**Hexagon**	**Hexagon**	**Hexagon**
Number of transmitters		**7**	**7**	**7**
geometry of transmitter lattice		**Hexagon**	**Hexagon**	**hexagon**
Inter-transmitter distance d(km)		**70**	**50**	**40**
Service area diameter D(km)		**161**	**115**	**92**
Tx antenna height (m)		**150**	**150**	**150**
Tx antenna pattern		**non-directional**	**non-directional**	**non-directional**
ERP (dBW)	**Band III**	**31.1 + Δ**	**33.2 + Δ**	**37.0 + Δ**
	Band IV/V	**39.8 + Δ**	**46.7 + Δ**	**49.4 + Δ**

The interference margin Δ is chosen to be 3 dB

Table 10: Parameters of RN 1 (Large service area SFN)

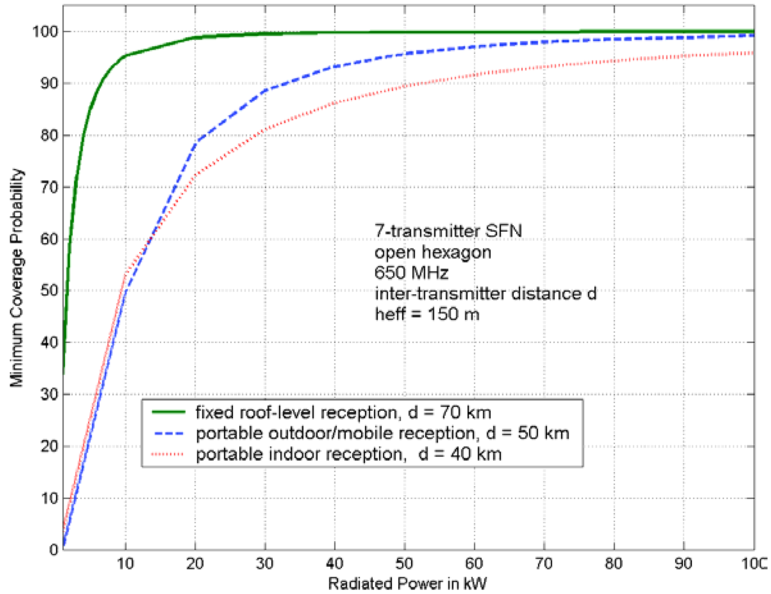

Figure 2: Determination of the power budget for RN 1, Band IV/V

As an example Figure 2 gives the coverage probability of the least covered pixel in the service area as a function of the radiated power in the network for the portable outdoor reception case in Band IV/V. The indicated power is that of one transmitter. The curves serve as a means of determining the necessary power budget in order to achieve everywhere across the service area the intended coverage probability.

Figure 3 shows a coverage plot of the RN 1 for portable indoor reception and Band IV/V. The position of the 7 transmitters can clearly be identified. The pattern of the coverage probability exhibits the hexagonal symmetry of the network. The coverage probability does not fall below 95% across the whole service area.

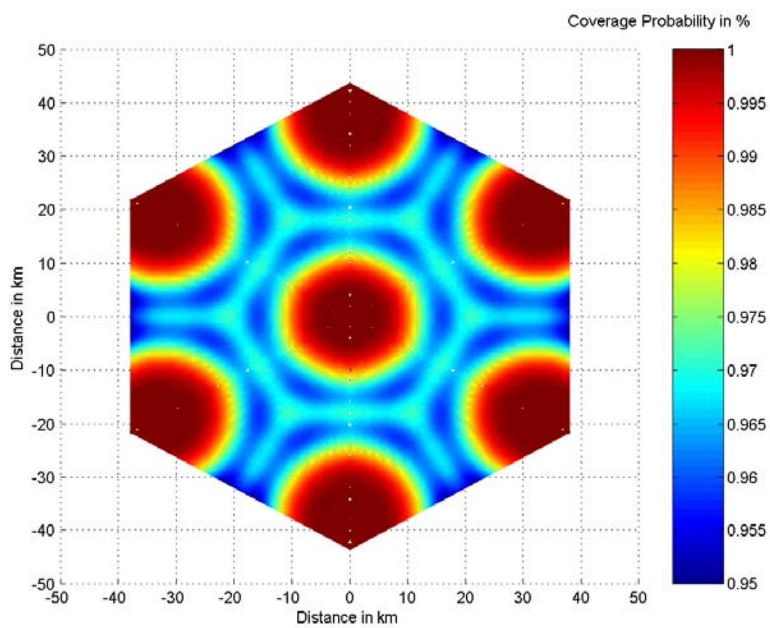

Figure 3: Coverage probability plot for RN 1, portable indoor reception, Band IV/V

Figure 4 gives as an example the corresponding interference potential of the reference network in Band IV/V.

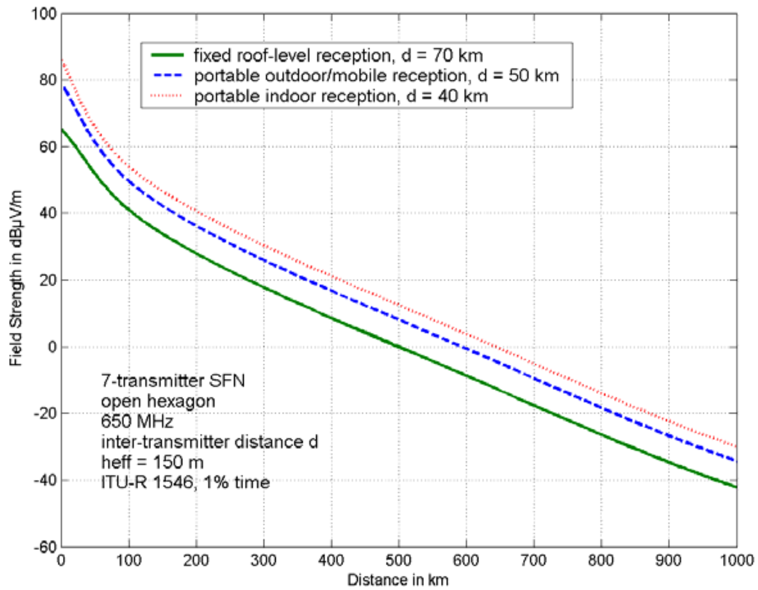

Figure 4: Interference Potential RN 1, Band IV/V, land path

Figure 5 shows the geometry for the interference potential calculation, see also section 3.1.

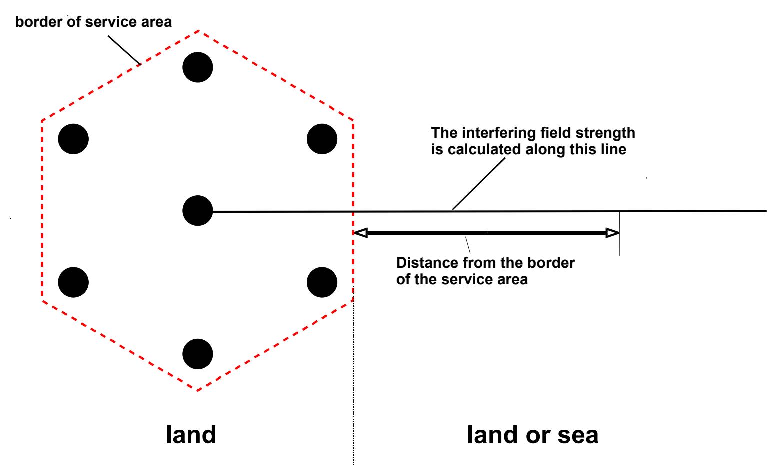

Figure 5: Geometry used in the calculation of interference potential, RN 1

3.3.3 Reference Network 2

(Small service area SFNs, dense SFNs)

RN 2 consists of a set of 6 individual RNs: for fixed, outdoor/mobile and indoor reception, each for Band III and for Band IV/V. RN 2 is intended for small service area SFN coverage. Transmitter sites with reasonable effective antenna heights are assumed to be available for this type of network and self-interference restrictions are expected to be small. Typical service area diameters may be 30 to 50 km.

It is also possible to cover large service areas with this kind of dense SFN. However, a very large number of transmitters is then necessary. It therefore seems to be reasonable to choose RN 1 for large service areas in any case, even if a dense network structure is envisaged.

The network consists of three transmitters situated at the vertices of an equilateral triangle. An open network type has been chosen, i.e. the transmitters have non-directional antenna patterns. The service area is assumed to be hexagonal as indicated in Figure 6.

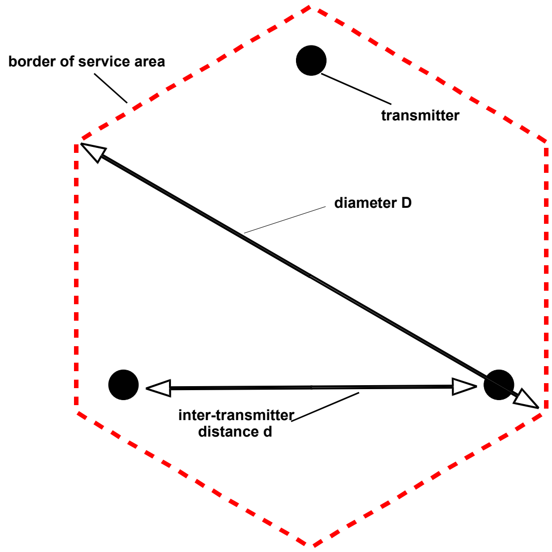

Figure 6: RN 2 (Small service area SFN)

In RN 2 the inter-transmitter distance is 25 km in the case of RPCs 2 and 3. It is therefore possible to use a value of 1/8 T_u (8k FFT) for the guard interval, which would increase the available data capacity as compared to RN 1. The same guard interval value might also be feasible for the RPC 1 with its higher inter-transmitter distance of 40 km, since fixed roof-level reception is less sensitive to self-interference because of the directional properties of the receiving antenna.

Table 11 gives the parameters and the power budgets of the reference networks RN 2.

Reference planning configuration		RPC 1	RPC 2	RPC 3
Type of network		Open	Open	Open
Geometry of service area		Hexagon	Hexagon	Hexagon
Number of transmitters		3	3	3
Geometry of transmitter lattice		Triangle	Triangle	Triangle
Inter-transmitter distance d(km)		40	25	25
Service area diameter D(km)		53	33	33
Tx antenna height(m)		150	150	150
Tx antenna pattern		non-directional	non-directional	non-directional
ERP (dBW)	Band III	21.1 + Δ	23.6 + Δ	31.1 + Δ
	Band IV/V	28.8 + Δ	36.0 + Δ	43.3 + Δ

The interference margin Δ is chosen to be 3 dB

Table 11: Parameters of RN 2 (Small service area SFN)

Figure 7 shows the geometry below for the interference potential calculation.

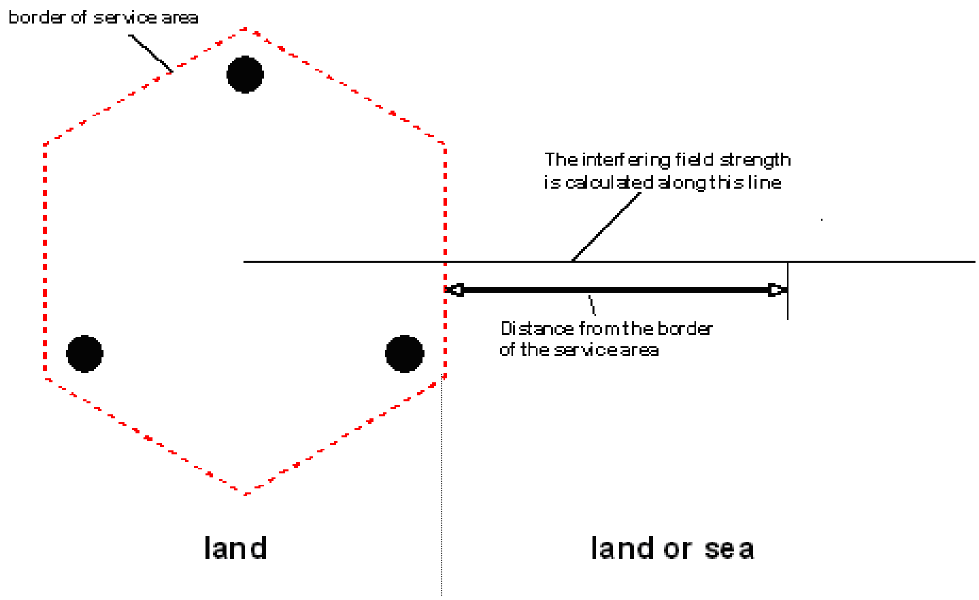

Figure 7: Geometry for the calculation of interference potential, RN 2

3.3.4 Reference Network 3

(Small service area SFNs for urban environment)

RN 3 consists of a set of 6 individual RNs: for fixed, outdoor/mobile and indoor reception, each for Band III and for Band IV/V. RN 3 is intended for small service area SFN coverage in an urban environment. It is identical with RN 2 apart from the fact that now urban type height loss figures are used, see Table 2. This increases the required powers of the SFN transmitters by about 5 dB.

The geometry of the transmitter lattice and the service area is identical with that of RN 2, it is therefore not necessary to repeat the figures.

Reference planning configuration		RPC 1	RPC 2	RPC 3
Type of network		Open	Open	Open
Geometry of service area		Hexagon	Hexagon	Hexagon
Number of transmitters		3	3	3
Geometry of transmitter lattice		Triangle	Triangle	Triangle
Inter-transmitter distance d/km		40	25	25
Service area diameter D/km		53	33	33
Tx antenna height/m		150	150	150
Tx antenna pattern		non-directional	non-directional	non-directional
ERP / dBW	Band III	21.1 + Δ	29.5 + Δ	37.1 + Δ
	Band IV/V	28.8 + Δ	41.9 + Δ	49.2 + Δ

The interference margin Δ is chosen to be 3 dB

Table 12: Parameters of RN 3 (Small service area SFN for urban environment)

3.3.5 Reference Network 4

(Semi-closed small service area SFN)

The geometry for RN 4 is identical to that for RN 2, except for the antenna patterns of the transmitters, which have a reduction of the outgoing field strength of 6 dB over 240 degrees (i.e. it is a semi-closed RN). The service area of this RN is shown in Figure 8.

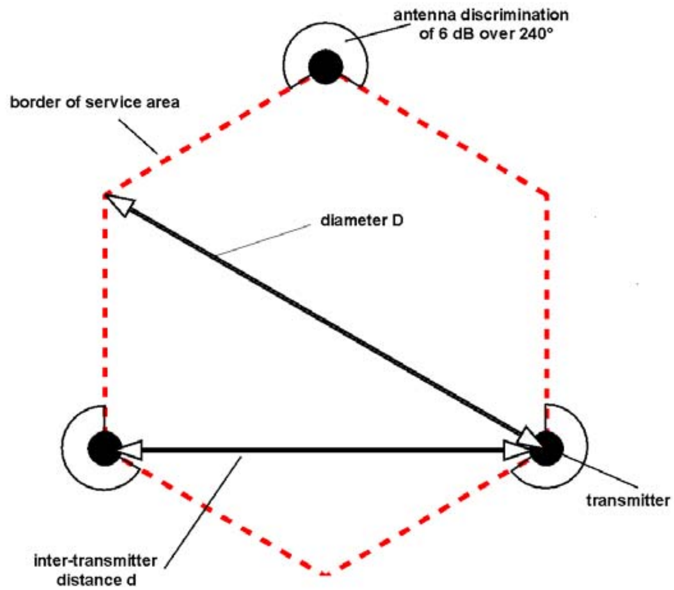

Figure 8: RN 4 (Semi-closed small service area SFN)

The difference between RN 4 and RN 2 is the outgoing interference (interference potential). RN 4 has a lower interference potential, compared to the other RNs. Because of this, the distance at which the same frequency can be re-used, is smaller when two allotments are both planned with RN 4.

There is a trade-off between this lower interference potential and the increased implementation costs to achieve the directional antennas. This should be kept in mind when choosing this RN for planning. There is also a reduction in the diameter of the service area compared with those for RN2.

Table 13 gives the parameters and the power budgets of the reference networks RN 4.

Reference planning configuration		**RPC 1**	**RPC 2**	**RPC 3**
Type of network		**Semi-closed**	**Semi-closed**	**Semi-closed**
Geometry of service area		**Hexagon**	**Hexagon**	**Hexagon**
Number of transmitters		**3**	**3**	**3**
Geometry of transmitter lattice		**Triangle**	**Triangle**	**Triangle**
Inter-transmitter distance d/km		**40**	**25**	**25**
Service area diameter D/km		**46**	**29**	**29**
Tx antenna height/m		**150**	**150**	**150**
Tx antenna pattern		**directional 6 dB reduction over 240 degrees**	**directional 6 dB reduction over 240 degrees**	**directional 6 dB reduction over 240 degrees**
ERP / dBW	**Band III**	**19.0+ Δ**	**21.0+ Δ**	**29.5 + Δ**
	Band IV/V	**26.4+ Δ**	**34.2+ Δ**	**41.8+ Δ**

The interference margin Δ is chosen to be 3 dB

Table 13: Parameters of RN 4 (Semi-closed small service area SFN)

Figure 9 shows the geometry for the interference potential calculation.

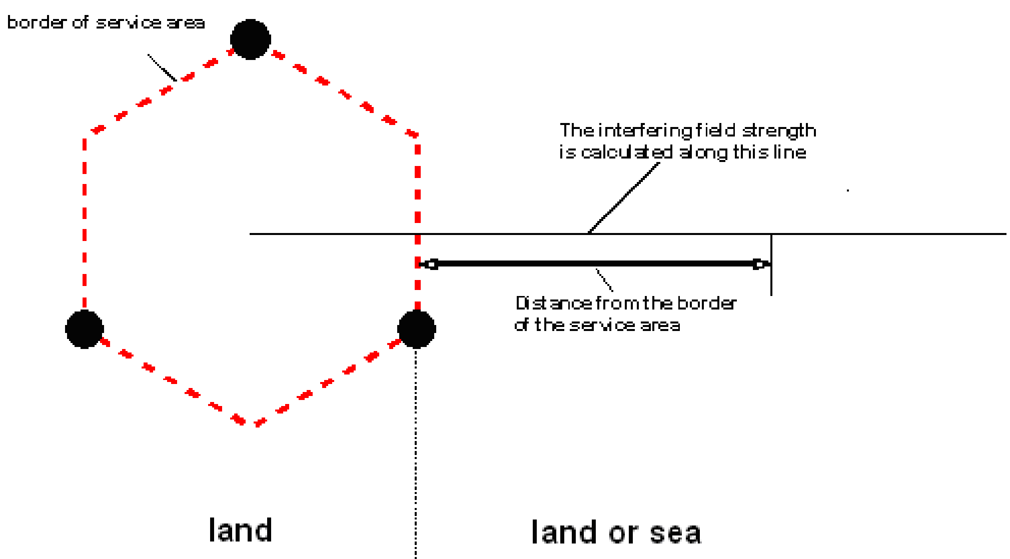

Figure 9: Geometry for the calculation of the interference potential, RN 4

Appendix 1 to Annex 3

Excerpt from ITU-R TG 6/8 report, chapter 5 (Document RRC(04)07)

Calculation of minimum median equivalent field strength

The minimum median equivalent field strength can be calculated using the following formulas:

P_n	$= F + 10 \log_{10} (k\, T_0\, B)$	
$P_{s\,min}$	$= C/N + P_n$	
A_a	$= G + 10 \log_{10} (1.64\lambda^2/4\pi)$	
ϕ_{min}	$= P_{s\,min} - A_a + L_f$	for fixed antenna reception
ϕ_{min}	$= P_{s\,min} - A_a$	for portable reception
E_{min}	$= \phi_{min} + 120 + 10 \log_{10} (120\pi)$	
	$= \phi_{min} + 145.8$	
E_{med}	$= E_{min} + P_{mmn} + C_l$	for fixed antenna reception
E_{med}	$= E_{min} + P_{mmn} + C_l + L_h$	for portable outdoor reception
E_{med}	$= E_{min} + P_{mmn} + C_l + L_h + L_b$	for portable indoor reception

where:

P_n : Receiver noise input power {dBW}
F : Receiver noise figure {dB}
k : Boltzmann's Constant ($k = 1.38\ 10^{-23}$ {Ws/K})
T_0 : Absolute temperature ($T_0 = 290$ {K})
B : Receiver noise bandwidth ($B=7.61\ 10^{6}$ {Hz})
$P_{s\,min}$: Minimum receiver input power {dBW}
C/N : RF signal to noise ratio at the receiver input required by the system {dB}
A_a : Effective antenna aperture {dBm^2}
G : Antenna gain related to half dipole {dB}
λ : Wavelength of the signal {m}
ϕ_{min} : Minimum power flux density at receiving place {dBW/m^2}
L_f : Feeder loss {dB}
E_{min} : Equivalent minimum field strength at receiving place {dBμV/m}
E_{med} : Minimum median equivalent field strength, planning value {dBμV/m}
P_{mmn} : Allowance for man made noise {dB}
C_l : Location correction factor {dB}
L_h : Height loss (10 m agl to 1.5 m agl) {dB}
L_b : Building penetration loss {dB}

ANNEX 4

PLANNING CONFIGURATIONS AND REFERENCE NETWORKS FOR T-DAB

1 INTRODUCTION

Digital terrestrial audio broadcasting T-DAB is the second broadcasting service that will be planned at the RRC04/06, in addition to DVB-T. The planning of T-DAB will be restricted to Band III. Similar to DVB-T, also T-DAB needs an agreed set of planning parameters and procedures in order to be incorporated in the future RRC frequency plan. Different from the DVB-T case, for T-DAB there already exists a planning framework that was developed for the Wiesbaden-95 T-DAB plan. This framework was designed for mobile reception. It seems reasonable to take it as a basis for the RRC planning, brought in line with the corresponding DVB-T planning parameters and procedures and supplemented by an additional reference planning configuration for portable indoor reception.

This Annex is to be seen in the context of the corresponding **Annex 3** relating to DVB-T planning. All general aspects and explanations regarding reference planning configurations and reference networks are dealt with in this **Annex 3**.

2 REFERENCE PLANNING CONFIGURATIONS

For T-DAB in Band III two reference planning configurations (RPC) may be considered which take account of mobile reception on one hand and portable indoor reception on the other hand. It is expected that with a coverage for mobile reception also portable outdoor reception is ensured and thus no separate planning configuration is needed for portable outdoor reception. Regarding fixed roof-level reception, it seems very unlikely that a T-DAB service will be implemented that is designed only for this reception type. Therefore, specific T-DAB planning configurations for fixed roof-level reception are not proposed.

The C/N values for the two RPCs are assumed to be equal and are taken from Recommendation ITU-R Rec. IS.1660, height loss values are taken from Recommendation ITU-R P-1546 and the figures for building penetration loss and man made noise as adopted by PT24/Gothenburg are used (see Document FM(04)061), see Table 1.

Receiver noise figure	**7 dB**
Minimum receiver signal input power (at C/N = 0dB)	**-135.1 dBW**
Man made noise (dB)	**2**
Height loss suburban/ rural (dB)	**12**
building penetration loss (dB)	**9**
Standard deviation of building penetration loss (dB)	**3**
Standard deviation of field strength distribution (dB)	**5.5**

Table 1: Planning parameters for T-DAB in Band III

Table 2 gives the required C/N and minimum median equivalent field strengths of the two reference planning configurations.. The reference networks are described in the next section.

		RPC 1	RPC 2
Reference planning configuration	**Reception mode**	**mobile**	**portable indoor**
	Loc probability	**99%**	**95%**
required C/N (dB)		**15.0**	**15.0**
MMEFS	**E_{med} (dBµV/**	**60.0**	**66.5**

MMEFS: minimum median equivalent field strength

Table 2: Reference Planning Configurations for T-DAB in Band III (200 MHz)

Since the height loss value of 12 dB, taken from Recommendation ITU-R P.1546, is 2 dB higher than that assumed in WI95 and also man made noise is increased by 1 dB, the minimum median equivalent field strength for RPC1 is higher than that used in WI95. The increases, however, is not 3dB as might be expected, but only 2 dB since the WI 95 value was calculated for 230 MHz /and not 200 MHz as assume here) which results in a 1 dB smaller effective antenna aperture.

3 REFERENCE NETWORK

For RPC 1, which corresponds to the mobile reception case as planned in WI95, the reference network of the WI95 agreement is taken. This reference network consists of 7 transmitters located at the centre and the vertices of a hexagon and is of the closed network type. The power of the central transmitter is reduced by 10dB with respect to the peripheral transmitters, which have a power of 1 kW.

As a consequence of the slightly higher minimum median equivalent field strength for RPC 1 as compared to WI95, the original WI95 reference network now exhibits a small coverage deficit for a restricted number of locations in the inner part of the service area. It amounts to few % in location coverage probability. This deficit is regarded as not essential with regard to the overall properties of the reference network and in particular with regard to the resulting interference potential, which justifies the choice of the original WI95 reference network for RPC 1.

For RPC 2 which is associated with portable indoor reception the same reference network geometry is chosen as for RPC 1, and the transmitter powers are increased by 9 dB corresponding to the higher minimum field strength needed for this reception mode.

Table 3 gives the parameters and the power budgets of the RN for the two RPCs; Figure 1 shows the geometry of the RN and Figure 2 provides information related to the geometry used in the calculation of the interference potential.

Reference planning configuration	**RPC 1**	**RPC 2**
Type of network	**Closed**	**Closed**
Geometry of service area	**Hexagon**	**Hexagon**
Number of transmitters	**7**	**7**
Geometry of transmitter lattice	**Hexagon**	**Hexagon**
Inter-transmitter distance d(km)	**60**	**60**
Service area diameter D(km)	**120**	**120**
Tx antenna height(m)	**150**	**150**
peripheral Tx antenna pattern	**directional 12 dB reduction over 240°**	**directional 12 dB reduction over 240°**
central Tx antenna pattern	**non-directional**	**non-directional**
peripheral Tx ERP(dBW)	**30.0**	**39.0**
central Tx ERP(dBW)	**20.0**	**29.0**

Table 3: Parameters of the RN for RPC 1 and RPC 2

In **Annex 3**, an increase of the transmitter ERP by an interference margin of 3 dB, denoted by Δ, is proposed in the case of DVB-T reference networks. For T-DAB however, in order to keep the planning philosophy of the WI95 Agreement, it is proposed to set Δ equal to 0 dB and use the values given in Table 3. As a consequence, the distance at which a T-DAB frequency block can be re-used is increased to a certain extent, but on the other hand an equal treatment is ensured for new RPC1 and already existing WI95 network implementations.

When a new T-DAB requirement is formulated for portable indoor reception, it is normally expected that mobile reception is also possible for the envisaged service area. This is ensured when only the wanted network is taken into consideration. Regarding external interference, however, account has to be taken of the fact that a mobile reception mode has a lower interference susceptibility than a portable indoor reception mode. This aspect has to be taken into account in a compatibility analysis.

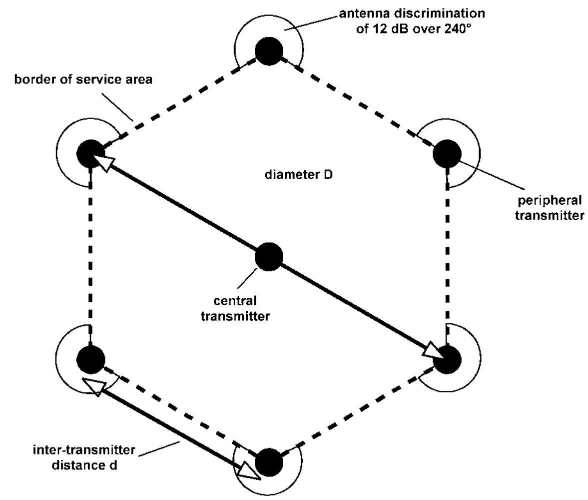

Figure 1: Geometry of the RN

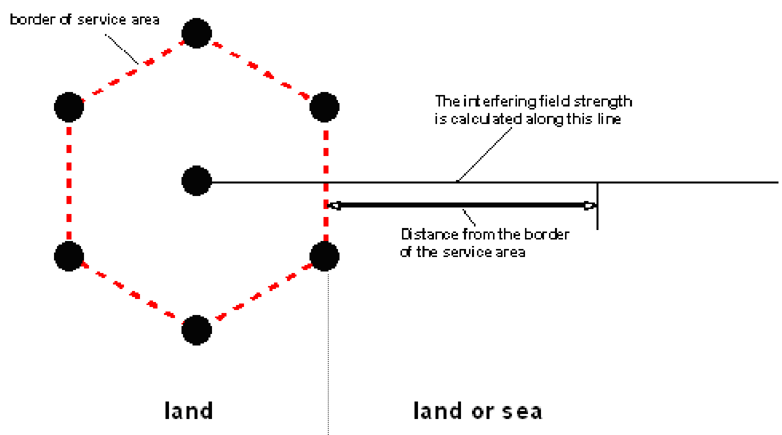

Figure 2: Geometry used in the calculation of the interference potential