RRC-06 — technical basis and planning configurations for T-DAB and DVB-T

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One fundamental part of the RRC planning process is to carry out a compatibility analysis. To facilitate this procedure, a reduction in the large number of possible transmitter configurations, down to just a few reference planning configurations, is useful. For compatibility calculations, SFNs may be represented by generic reference networks, whereas single transmitters are described by their "real" characteristics.

This article describes various planning configurations and reference networks for T-DAB and DVB-T, while keeping an eye on DVB-H requirements as well.

The new digital terrestrial broadcasting systems (DVB-T, DVB-H and T-DAB) allow an efficient use of the frequency spectrum. To take advantage of this, it is essential to revise the Stockholm 1961 (ST61) and Geneva 1989 (GE89) frequency plans. To this end, the ITU established a Regional Radio Conference (RRC-04/06) to be held in two parts. At the first part, RRC-04 in 2004, the planning criteria and parameters were defined. Based on these agreements, planning exercises are now being carried out during the intersessional period. The results of these exercises will then be presented at RRC-06 and will act as an input for the establishment of the new digital plan.

One important element of the planning process is the treatment of ***assignments*** and ***allotments*** at RRC-04/06. Assignments and allotments are fundamental tools for making a frequency plan.

Planning and network concepts

For the RRC planning process, it is important that every ITU Administration feels mirrored in the planning options. Therefore, it is made possible to choose between assignments and allotments as well as between a ***Multiple-Frequency Network*** (MFN) and a ***Single-Frequency Network*** (SFN) approach. Some examples are shown in *Figs 1* to *4*.

In the assignment approach, each planned transmitter – together with its characteristic properties – is specified. In the allotment approach, the planned service areas – together with a set of general network implementation rules – are given. Assignments and allotments describe the same planning objects in different ways, and they can be transformed into one another. Both planning concepts give the same rights to ITU Administrations. There is a natural correspondence between planning and network concepts. Assignment planning is primarily dedicated to the MFN approach, while allotment planning serves the SFN approach. But the RRC rules also allow for any other combination.

ST61 Assignments
ZDF national network in Germany
UHF

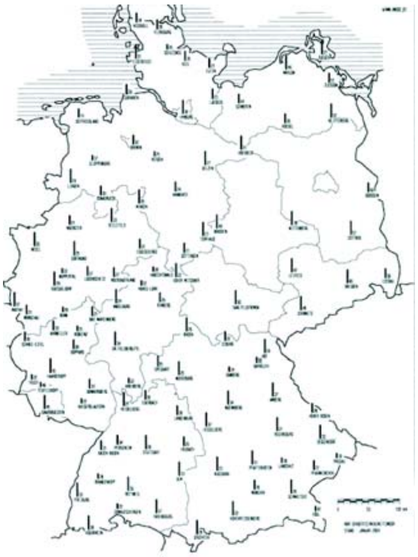


Figure 1
Assignment planning

Wi95 Allotments
Central Europe
VHF, Layer 1

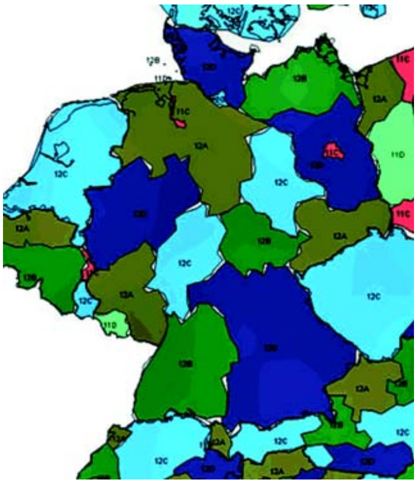


Figure 2
Allotment planning

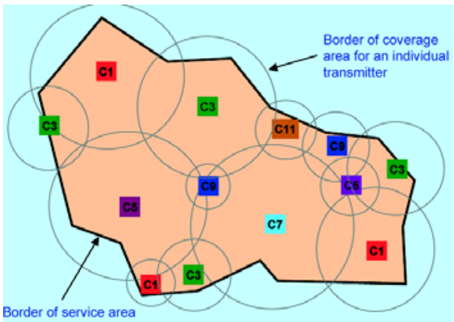


Figure 3
Multiple-frequency network

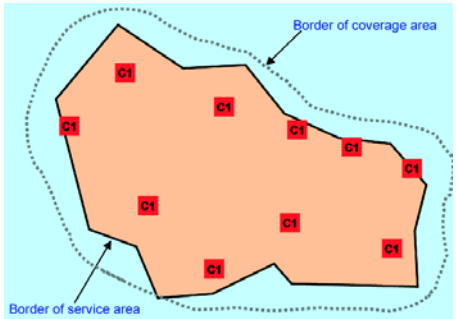


Figure 4
Single-frequency network

Planning configurations

One fundamental component of the planning process is the assessment of compatibility between co-channel service areas in the phase of establishing the plan, and in the subsequent update phase.

As shown in *Table 1*, there are many variants for planning configurations and, due to this, there are also a large number of possible combinations for which a compatibility analysis would have to be performed in the establishment of the plan. A planning configuration is composed of various aspects, each with further options concerning the implementation variants. To simplify the planning process it is useful to reduce the number of possible planning configurations to just a few that are expected to be used often. These representative network implementations of typical planning configurations are called Reference Planning Configurations (RPCs). They are not identical with "real" network implementations, but they are helpful for the compatibility analysis. RPCs are formulated for T-DAB and DVB-T, but they may also be applied to other systems, e.g. DVB-H, as long as the compatibility criteria are retained.

Some common DVB-T planning configurations – characterized by their reception mode, DVB-T variant (modulation and code rate) and coverage quality – are shown in *Table 2*.

Table 1 – Example of DVB-T planning configurations

Aspect	Element	Comment
Reception mode	Fixed roof-level Portable outdoor Portable indoor Mobile	
Coverage quality	70% 95% 99%	In terms of percentage of locations
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 64-QAM-7/8	In principle, all variants are available
Frequency band	Band III (200 MHz) Band IV (500 MHz) Band V (800MHz)	

Fixed roof-level reception

Portable outdoor reception

Table 2 – Common DVB-T planning configurations

DVB-T planning configuration	**Reception mode**	Fixed	Fixed	Portable outdoor	Portable outdoor
	Modulation	64-QAM	64-QAM	16-QAM	64-QAM
	Code rate	2/3	3/4	2/3	2/3
	Location probability	95%	95%	95%	95%
DVB-T planning configuration	**Reception mode**	Mobile	Mobile	Portable indoor	Portable indoor
	Modulation	QPSK	16-QAM	16-QAM	16-QAM
	Code rate	2/3	1/2	2/3	2/3
	Location probability	99%	99%	70%	95%

Mobile reception

Portable indoor reception

RPC1

Table 3 – Representative DVB-T planning configurations

DVB-T planning configuration	**Reception mode**	Fixed	Fixed	Portable outdoor	Portable outdoor
	Modulation	64-QAM	64-QAM	16-QAM	64-QAM
	Code rate	2/3	3/4	2/3	2/3
	Location probability	95%	95%	95%	95%
DVB-T planning configuration	**Reception mode**	Mobile	Mobile	Portable indoor	Portable indoor
	Modulation	QPSK	16-QAM	16-QAM	16-QAM
	Code rate	2/3	1/2	2/3	2/3
	Location probability	99%	99%	70%	95%

RPC2

RPC3

From these frequently-used planning configurations, some representative combinations were taken to define the RPC. The combined planning configurations are shown in *Table 3*. The appropriate Reference C/N for the RPC is the average of the individual C/N values of the included planning configurations. Taking into account the building-penetration loss and the man-made noise as well, for DVB-T the following Reference minimum field strengths $(E_{med})_{ref}$ are found (*Table 4*):

Table 4 – Reference planning configurations for DVB-T

RPC	RPC1	RPC2	RPC3
Reception mode	Fixed roof-level	Portable outdoor, or lower-coverage portable indoor, or mobile	Higher-coverage portable indoor
Reference location probability	95%	95%	95%
Reference C/N (dB)	21	19	17
Reference $(E_{med})_{ref}$ [dB(μV/m)] at 200 MHz	50	67	76
Reference $(E_{med})_{ref}$ [dB(μV/m)] at 650 MHz	56	78	88

The Reference minimum field strength $(E_{med})_{ref}$ is defined at 10 m agl, for 50% of locations and 50% of the time. The height loss values are taken from ITU-R Recommendation P.1546 [1].

The system variant for a difficult reception mode, e.g. portable indoor, has to be more rugged than for a less difficult reception mode, e.g. fixed roof-level. Therefore, the Reference C/N value decreases with increasing demand on the reception mode.

RRC-04/06 also deals with T-DAB. In *Table 5* the T-DAB Reference planning configurations are shown.

Table 5 – Reference planning configurations for T-DAB

RPC	RPC4	RPC5
Reception mode	Mobile	Portable indoor
Reference location probability	99%	95%
Reference C/N (dB)	15	15
Reference $(E_{med})_{ref}$ (dB(μV/m)) at 200 MHz	60	66

For T-DAB there are two frequently-used reception modes: ***mobile*** and ***portable indoor*** reception. The Reference minimum field strength $(E_{med})_{ref}$ for mobile reception is based principally on the values from Wiesbaden 95 (WI95). Since the height loss value of 12 dB, taken from ITU-R Recommendation P.1546, is 2 dB higher than that assumed in WI95, and also man-made noise is increased by 1 dB, the Reference minimum field strength for RPC1 is higher than that used in WI95.

1. ITU-R Recommendation P.1546: **Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz**
http://www.itu.int/ITU-R/publications/rec/index.asp

Abbreviations

16-QAM	16-state Quadrature Amplitude Modulation	**ITU**	International Telecommunication Union
64-QAM	64-state Quadrature Amplitude Modulation	**ITU-R**	ITU - Radiocommunication Sector
agl	above ground level	**MFN**	Multi-Frequency Network
C/N	Carrier-to-Noise ratio	**QPSK**	Quadrature (Quaternary) Phase-Shift Keying
CEPT	European Conference of Postal and Telecommunications Administrations	**RN**	Reference Network
		RPC	Reference Planning Configuration
DAB	Digital Audio Broadcasting (Eureka-147)	**RRC**	(ITU) Regional Radiocommunication Conference
DVB	Digital Video Broadcasting		
DVB-H	DVB - Handheld	**SFN**	Single-Frequency Network
DVB-T	DVB - Terrestrial	**ST61**	Stockholm Frequency Plan of 1961
ERO	European Radio Office of the CEPT	**T-DAB**	Terrestrial - DAB
ERP	Effective Radiated Power	**Tx**	Transmitter
GE89	Geneva Frequency Plan of 1989	**WI95**	Wiesbaden Frequency Plan of 1995

The increase, however, is not 3 dB as might be expected, but only 2 dB since the RRC value was calculated for 200 MHz (and not 230 MHz as assumed at WI95) which results in a 1 dB larger effective antenna aperture. For portable indoor reception, there was no planning configuration at WI95 and, therefore, it was defined from new at RRC-04.

The RRC-04 report suggests the use of reference planning configurations for the formulation of requirements but the RRC-04 rules also allow using each individual planning configuration that is possible, for the formulation of requirements. This may be necessary in cases where particular coverage and implementation objectives are to be met.

Reference networks

An allotment plan for DVB-T or T-DAB networks is established on the basis of specific frequency allocations to well-defined geographical coverage areas. The plan itself should not be influenced by the network implementation within the allotment area. Therefore, no parameters concerning the network design are known at this stage of the planning process and a representative network structure, called a ***Reference Network*** (RN), has to be assumed. The network structure could be for large or small service areas, in suburban or urban environments. These reference networks show a high degree of geometrical symmetry and homogeneity of transmitter characteristics. They do not correspond to the transmitter pattern for real implementations but they are needed for compatibility calculations when establishing a frequency plan. They are essential for the determination of the interference potential, which describes the outgoing interfering field strength of a network.

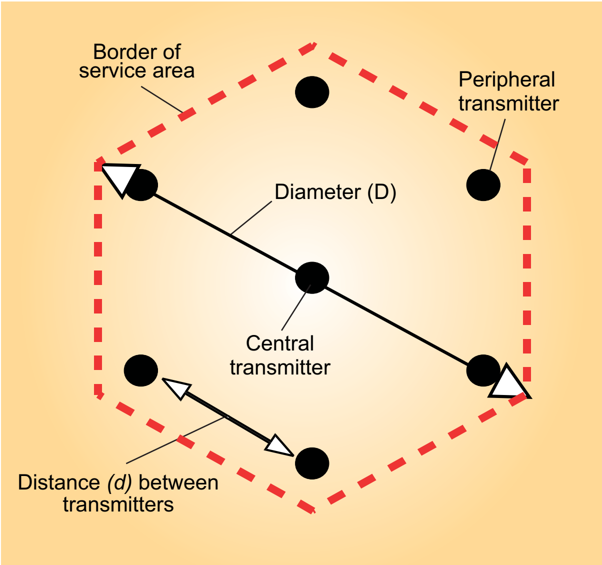


Figure 5
DVB-T reference network for large service areas (RN1)

An example of a DVB-T reference network for large service areas is shown in *Figure 5*.

The distance *(d)* between the transmitters varies depending on the reference planning configuration. As an example, the required power budget of the transmitters in RN1, for a given coverage quality in band IV/V, is depicted in *Fig. 6*. *Fig. 7* shows the coverage probability within the service area of RN1 for RPC3 in band IV/V.

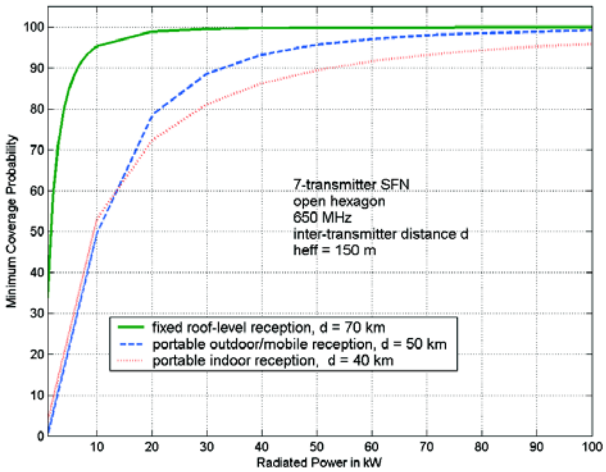


Figure 6
Power budget RN1, UHF

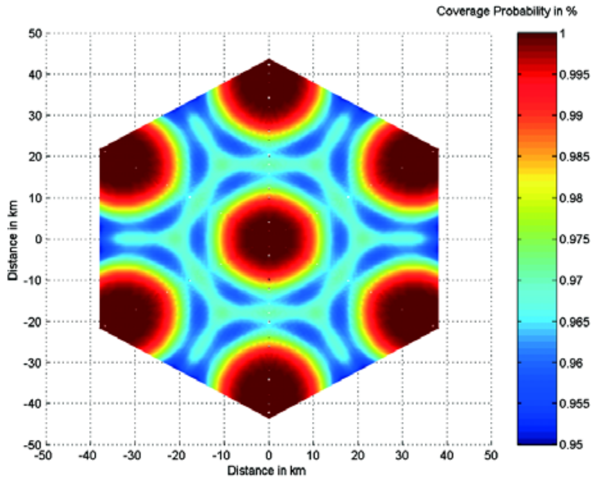


Figure 7
Coverage probability RN1, RPC 3, UHF

There are several network classes.

- **Four DVB-T reference networks:**
  - for large-area SFNs (RN1)
  - for small-area SFNs (RN2)
  - for small-area urban SFNs (RN3)
  - for small-area semi-closed SFNs (RN4)
- **One T-DAB reference network:**
  - for large-area SFNs (RN5)

The reference network (RN) classes and the reference planning configurations (RPC) are put together in a matrix, which results in 12 instances for DVB-T and two instances for T-DAB. For each instance, there results certain transmitter conditions. As an example, the antenna height and ERP for reference network RN1 (*Figure 5*) are given in *Table 6*. The power budget of the network uses a noise-limited basis: for interference-limited planning, a power margin Δ of 3 dB is adopted.

Table 6 – Transmitter conditions for DVB-T reference network RN1

RPC and reception type		RPC1 fixed antenna	RPC2 portable outdoor and mobile	RPC3 portable indoor
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
Distance between transmitters *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 power margin Δ is 3 dB				

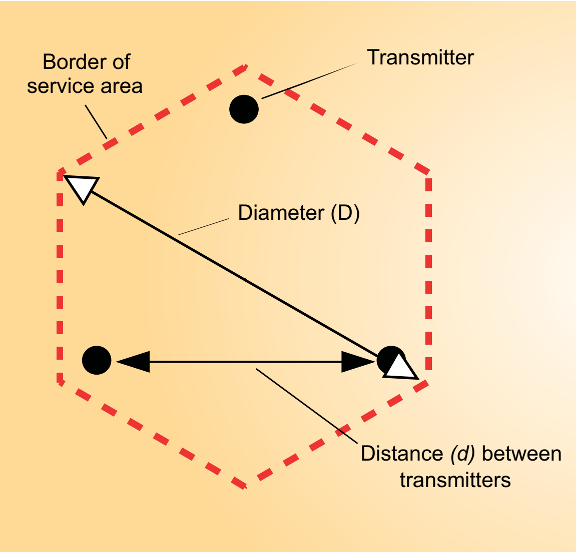


Figure 8
DVB-T small-area SFN (RN2)

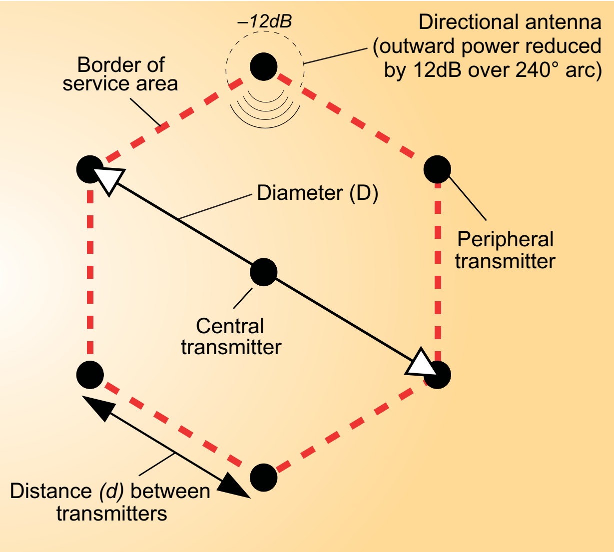


Figure 9
T-DAB large-area SFN (RN5)

Another example of a small-area SFN for DVB-T (RN2) is shown in *Fig. 8* while the T-DAB reference network (RN5) is shown in *Fig. 9*. The related transmitter conditions for different RPCs are given in *Table 7* (RN2) and *Table 8* (RN5).

Table 7 – Transmitter conditions for DVB-T reference network RN2

RPC and reception type		RPC1 Fixed antenna	RPC2 Portable outdoor and mobile	RPC3 Portable indoor
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
Distance between transmitters *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 power margin Δ is 3 dB				

The T-DAB reference network is designed using directional antennas with a front-to-back ratio of 12 dB, thus forming a closed network. Closed networks are more rugged against interference effects and, therefore, no power margin for interference-limited planning is taken into account.

For a single transmitter requirement, the individual characteristics of the transmitter are known and formulated in the requirement. Therefore, no reference network is needed. This is normally the case for an MFN approach, but the RRC-04 rules also allow us to formulate individual transmitter characteristics for an SFN in the context of an allotment requirement.

Table 8 – Transmitter conditions for the T-DAB reference network RN5

RPC and reception type		RPC4 mobile	RPC5 portable indoor
Type of network		Closed	Closed
Geometry of service area		Hexagon	Hexagon
Number of transmitters		7	7
Geometry of transmitter lattice		Hexagon	Hexagon
Distance between transmitters *d* (km)		60	60
Service area diameter *D* (km)		120	120
Tx antenna height (m)		150	150
Peripheral Tx antenna pattern		Directional (outward power reduced by 12 dB)	Directional (outward power reduced by 12 dB)
Central Tx antenna pattern		Non-directional	Non-directional
ERP (dBW)	Peripheral Tx	30.0	39.0
	Central Tx	20.0	29.0

Interference potential

One fundamental step for establishing a frequency plan is the compatibility analysis. The outgoing interfering field strength of a transmitter or transmitter network will be of substantial interest because it can impair the functionality of other co-channel service areas. The interference potential is defined by power, effective antenna height, antenna pattern and the transmitter locations. If the real network implementation is not yet known, the interference potential of a reference network may be used as a representative in the compatibility analysis.

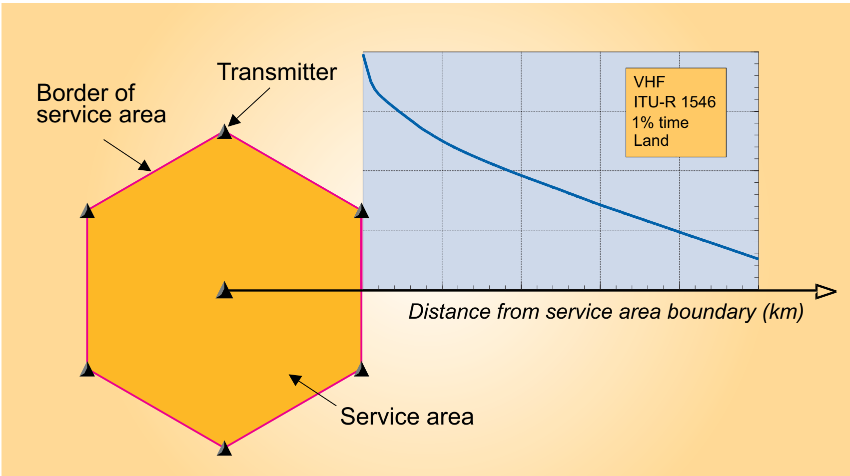


Figure 10
Example of interference potential of a 7-Transmitter SFN

An example of an interference-potential curve, caused by a 7-transmitter SFN, is given in *Fig. 10*. The test points are situated on the x-axis, starting at the border of the service area. The calculation of the interfering field strength is done with 1% time probability.

The range of the interference potential of various reference networks and different reference planning configurations is shown in *Fig. 11*. The difference between the highest and the lowest interference can be up to nearly 30 dB. The interference levels within a given reference network vary about 20 dB for different reference planning configurations.

Requirements

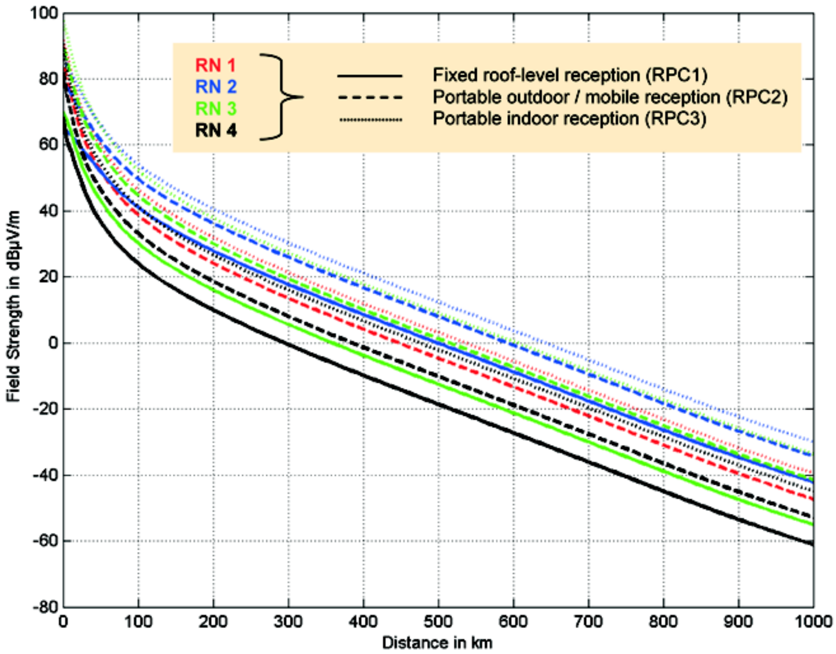
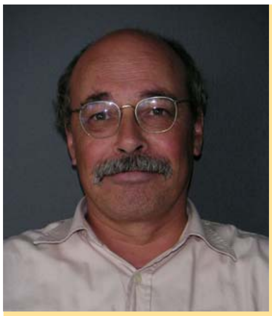


Figure 11
Range of interference levels for DVB-T reference networks

Requirements are the administrations' input to the RRC-06. The RRC rules give full flexibility in the formulation of these requirements. The administrations are allowed to choose between assignments or allotments and between single- or multiple-frequency networks. It is possible to use reference or individual planning configurations, as well as reference networks or individual transmitter characteristics. The choice depends on the specific needs of each country. Therefore, it necessitates a high responsibility for administrations to make a reasonable choice for themselves and for the planning process as a whole. There is only a restriction concerning the perimeter of the allotments, which has to be at least 30 km. The lower bound for the transmitter power of assignments is also restricted to 50 W in band III and to 250 W in band IV/V. In all cases, it would be reasonable for all participants to make pre-coordinations by bi- and multi-lateral negotiations.

Conclusions

One fundamental part of the RRC planning process is to carry out a compatibility analysis. To facilitate this procedure, a reduction in the large number of possible configurations to just a few is useful. For compatibility calculations, SFNs may be represented by generic reference networks, whereas single transmitters are described by their "real" characteristics. The planning process of RRC-04/06 is intended for T-DAB and DVB-T, but the mask concept allows extensions, e.g. for DVB-H. The



Dr Roland Brugger received a PhD in physics. In 1987 he joined the Frequency Management Section of the *Institut für Rundfunktechnik* (IRT) in Munich, where he worked on statistical and combinatorial optimisation problems in the frequency planning field. Since 1992, he has been involved in frequency and network planning for digital terrestrial broadcasting services. In 2004, he became head of the Frequency Management Section of the IRT.

Dr Brugger participated in the T-DAB and DVB-T Planning Meetings in Wiesbaden 1995, Chester 1997 and Maastricht 2002, and in the ITU-R conference RRC-04. Presently he is engaged in the preparations for RRC-06. He is project manager of EBU project group B/BCP and a member of ITU-R IPG and CEPT WG-RRC06 and PT2.

Kerstin Mayer studied electrical engineering, with the main focus on Audiovisual Communication, at the University of Karlsruhe, Germany. Since 2002, she has been a member of the scientific staff of the *Institut für Rundfunktechnik* (IRT) in Munich.

In preparing for the ITU Regional Radio Conference, RRC-04/06, she has been involved in the development of frequency planning methods and planning configurations for DVB-T and T-DAB.

RRC rules offer great flexibility in the formulation of requirements. Therefore, it is most desirable that the administrations show a high degree of responsibility when making their choices (i.e. presenting their demands). Pre-coordinations, by bi- and multi-lateral negotiations, are advisable.

Further information

Further information concerning the technical basis of the planning process at RRC-04/06 are given in the following reports:

[1] ECC Report 49: **Technical Criteria of Digital Video Broadcasting Terrestrial (DVB-T) and Terrestrial Digital Audio Broadcasting (T-DAB) allotment planning**
CEPT/ERO, Copenhagen, 2004 < **http://www.ero.dk/ecc** >

[2] RRC-04 Report – **Annex to Resolution 1 of the First Session of the Regional Radiocommunications Conference for planning of the digital terrestrial broadcasting services in parts of regions 1 and 3 in the frequency bands 170 – 230 MHz and 470 – 862 MHz** (in particular: chapter 3)
ITU-R, Geneva, 2004 < **http://www.itu.int/ITU-R/conferences/rrc/rrc-04/index.asp** >