

Computer-Based Software Frequency Planning Tools for Digital TV Broadcasting Service

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Introduction

There are two main groups involved in frequency planning:

- **Regulators** who pursue the national task of spectrum administration to ensure the economic assignment of the spectrum, and to observe the compliance with national spectrum users and users in adjacent countries.
- **Network Providers** who have to have their transmitters coordinated, which implies an administrative task with their governmental office and - which is the primary task from the network provider's point of view - a network planning that ensures most economic coverage of the target area or population, resp.

Regulators focus on the compatibility aspect and the avoidance of interference, while operators focus mainly on coverage aspects.

Transmitter Databases / Frequency "Plans"

Even for network operators it is of great importance not only to keep the data of their "own" transmitters in a database, but to have a reference of officially released data of transmitters that are in operation or represent "plan positions" requiring protection.

Examples of such databases are:

- IFL (ITU)
- WIC (ITU) (now both contained in the BR IFIC)
- regional plans (as maintained by ERO for CEPT in Europe for DAB [1],[2] and DVB [3],[4])
- national plans (mainly the regulator's plan)
- sub-national plans (within federal states)

Technically, the most important attributes related to a plan position are:

- geographic position
- frequency
- power
- antenna diagram
- antenna height plus site height above sea level
- transmission mode (e.g. TV system for analog TV)

GIS

Modern frequency planning software can be considered a Geographic Information System (GIS). Most of the data has a strong geographic connection and there are different types of data such as raster data, vector data, and technical and administrative attributes of the sites.

Raster Data

Common "terrain databases" are in raster format, i.e. the terrain is divided into pixels. This requires a certain scheme in projecting the curved surface of the earth on a plane grid; thus the "geodetic datum" used in the terrain model and details of the projection need to be known.

There are different types of raster data:

- topography (elevation height)
- morphology (clutter classes, land use)
- conductivity maps for LF/MF use
- population data
- topological maps (showing cities, roads, etc.)

Vector Data

Vector data is said to be a more "intelligent" type of data, for example it is more suitable when changing the scale; the individual entities can be addressed in a better way.

Examples of data in vector format are:

- country contours
- contours consisting of test points (as in the allotment database for DAB maintained by ERO)

Propagation Calculation Models

One of the main distinction criteria for calculation models is whether or not the models are terrain based or non-terrain based.

Although this does not reflect today's performance of "personal computers" (that have computing power even mainframes could not offer at the time), calculation models not using any terrain data are still widely applied. One of the main reasons for this is that - to obtain the same results at different locations (broadcasting network providers, regulators, the ITU, etc.) - it would not only be necessary to use the same algorithms in the computer programs but also the same terrain database. "The same" not only implies to have databases using the same

raster size (e.g. 100 m times 100 m) and geodetic datum (e.g. WGS84 geodetic), but also that they actually have to come from the same source, otherwise the precise reproduction of results would not be possible.

The quantity applied to account for terrain effects even if no terrain database is used at one's own site is the "effective antenna height" as it is called - a digital terrain model (DTM) is used once for the transmitters in a plan to calculate the "effective antenna heights" in 36 directions around the site [8]. The software for field strength prediction then uses these values to calculate different field strengths. For rays of an angle between two of these directions, the software interpolates between the two "effective antenna heights" stored.

Calculation of the actual effective antenna height supplies the height of the center of the antenna above the average ground level at distances between 3 and 15 km from the transmitter in the direction of the receiver.

The effective antenna heights are distributed in plans as part of the transmitter data, and were thus accessible even to network providers or authorities who were not capable of calculations using a real DTM.

Nevertheless, if regulators and network providers in one region would combine their efforts to establish a common DTM that is accessible to all (and paid for by all parties involved), this would be a great benefit for them and, as it is shared, would be available at bearable cost.

The use of a real DTM has proved a greater necessity for network providers than for regulators. This is due to the fact that the network provider is interested to know how many listeners/viewers he can reach with his programs.

In general, terrain-based models together with a terrain database with a good resolution allow for more detailed results.

Propagation models not using a real DTM mostly refer to curves, as in the ITU-R Recommendation 370 [8].

Most of the models using a real DTM use "knife-edge diffraction". This means that lacking a direct line of sight due to an obstacle, the obstacle is treated as if it were a conducting half plane.

The Digital Challenge

Starting with the transmitter database, the entries for digital transmitters have some special features analog ones do not have.

With a digital site, fields should be available for:

- The **transmission mode**. For DVB-T, the mode does the coding of
 - the safeguard time,
 - the modulation, which may be more (QPSK) or less robust (16-QAM or even 64-QAM),
 - the code rate or redundancy, which is a measure for "digital protection" and results in different field strengths and protection ratios required.

- An "**SFN ID**", i.e. an identifier for transmitters that do transmit exactly the same bit stream. Together with the safeguard time, as it is called, within which reflected signals or signals from other transmitters belonging to the same SFN may be "collected", this results in the "network gain". Network gain exists in SFN's using COFDM type modulations, such as DVB-T [6], T-DAB [5] and ISDB-T [7].
- A **delay**: A transmitter may be switched to a delay either on purpose to adjust for the area of maximum network gain, or the delay may result from a delay in the feeder link (satellite link), or the transmitter might be a gap filler merely used for re-broadcasting.

With DVB-T in Europe, a decision has been made to distribute "**transmitter-related test points**" with each record. The test points consist of a geographic location and a field strength value that must not be exceeded by signals from other transmitters. This reflects a new method in planning rather than a specific "digital" feature.

Single Frequency Network (SFN) Planning

Single frequency networks offer new ways of planning. The conventional planning used to be transmitter site-based. With T-DAB, "allotment planning" [1] has been introduced in Europe.

The allotment defines a whole area (defined by boundary points) to be used by the same SFN frequency block.

The protection is extended to the whole area to be tested at the boundary points (also called "required test points"). As long as the network provider does not exceed certain restrictions (field strength values tested on a more distant set of test points, called "calculated test points"), he is rather free as to how to configure his single frequency network within his "allotment". (There is still an assignment procedure, however, a rather simplified one).

The European DVB-T and the Japanese ISDB-Tw are systems capable of SFN operation. However, due to the migration scenario (no channels are cleared for digital service nationwide or region-wide but single sites are switched from analog to digital, in most cases MFN's (multifrequency networks as in the analog case) are built up.

The time of arrival of the signals at the receiver antenna becomes a new parameter to be handled by coverage prediction software if it comes to SFN's using COFDM modulation schemes such as DAB, DVB, and ISDB.

From the radio frequency aspect, the network gain of single frequency networks and the lower transmitter powers in the SFN are benefits (in addition to the more economic source coding and the new multimedia possibilities with digital systems).

Statistical Aspects

If a network provider wishes to know about the "network gain", the software must have a type of model to combine the different signals into a resulting signal (both for the wanted and interfering signals). For example "LNM", the log-normal method, assuming that the level (in dB μ V/m) of the field strength of each signal follows a normal distribution.

In view of the fact that the field strength prediction models provide a prediction for 50% of time and 50% of the locations (in the pixels), it may become rather critical to make any conclusions for the high percentages required for digital services.

With digital services, there is a rather sharp cutoff from good reception to none at all, not showing a "graceful degradation" as with analog services.

Software Requirements

Being able to handle the GIS data mentioned above is state of the art. The user should be offered several methods for field strength prediction and for combination of signals.

The transmitter database should be prepared to contain the new data types that are typical for digital services.

Data import and export formats for exchange with other authorities should be available, as well as possibilities to obtain lists and graphical results.

The user interface should be intuitive and built on standards; the requirements to hardware and the operating system environment should be affordable.

As such software is no "off-the-shelf product", it has to be customized to national requirements in some respects.

An integrated solution must be preferred to a solution consisting of a series of "standalone" tools.

Integration of a pure planning tool into an environment offering additional administrative support is a benefit; for authorities it is desirable for their daily work to

- include services other than broadcast (mobile phones, land mobile, microwave links,...)
- have reminder functions and deadline management,
- have more automation in bookkeeping, reporting, and billing,
- have a link to radio monitoring stations.

References :

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- [2] ERO DACAN CD-ROM, European Radiocommunications Office, Copenhagen, Denmark
- [3] The Chester 1997 Multilateral Coordination Agreement, relating to Technical Criteria, Coordination Principles and Procedures for the Introduction of Terrestrial Digital Video Broadcasting, DVB-T, Chester, Great Britain, 1997
- [4] ERO COCOT CD-ROM, European Radiocommunications Office, Copenhagen, Denmark
- [5] ETSI 300401 (DAB), European Telecommunications Standards Institute, Sophia Antipolis, France
- [6] ETSI 300744 (DVB), European Telecommunications Standards Institute, Sophia Antipolis, France
- [7] M. Takada/M. Sasaki/T. Ikeda: "Draft Standard for Digital Terrestrial Sound Broadcasting in Japan", Proceedings of the NAB 1999
- [8] ITU-R P.370-7, International Telecommunications Union, Geneva, Switzerland

Abbreviations Used:

BR	Radiocommunications Bureau of the ITU
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications
COCOT	Compatibility Computation for Digital Television
COST	European Cooperation in the Field of Science and Technology
DAB	Digital Audio Broadcasting, here used to denote DAB conforming ETSI 300401 (T-DAB: terrestrial DAB)
DACAN	DAB Computer Analysis
DTM	Digital Terrain Model
DVB	Digital Video Broadcasting, here used to denote DVB conforming ETSI 300744 (DVB-T: terrestrial DVB)
ERO	European Radiocommunications Office
ETSI	European Telecommunications Standards Institute
IFIC	International Frequency Information Circular
IFL	International Frequency List
ISDB	Integrated Services Digital Broadcasting (ISDB-Tn: terrestrial, narrow-band ISDB)
ITU	International Telecommunications Union
LF/MF	Low Frequency/Medium Frequency
LNM	Log-Normal Method
NAB	National Association of Broadcasters
COFDM	Coded Orthogonal Frequency Divided Multiplexing
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
SFN	Single Frequency Network
WGS84	World Geodetic System of 1984
WIC	Weekly International Circular