ITU-D Seminar

Kiev, 13-15 November 2000

THE TRANSITION FROM SECAM TO DIGITAL BROADCASTING

International co-ordination of DVB-T frequencies in Europe

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1. Introduction

This paper gives an overview of the aspects related to the international co-ordination of digital terrestrial television frequencies in Europe.

Planning of digital terrestrial television in Europe should take account of the following four conditions:

- Respecting equal rights of all countries
- Ensuring protection of analogue services
- Achieving satisfactory digital coverage
- Making migration to the future all digital plan possible

The four conditions will be explained in the following sections.

The content of this paper is based on work carried out in CEPT and EBU, part of the text has been presented before at the Commshere Conference in January 1999 [1].
The text of the Chester agreement [2], background information regarding the Chester agreement [3], a report on the implementation of the Chester agreement [4] and the latest information on DVB-T implementation can be found on the web site of the European Radio Office (ERO) of the CEPT (www.ero.dk). More information on the planning aspects of DVB-T can be found in EBU report BPN 005 on planning and implementation of digital terrestrial television [5].

2. Equal rights of all countries

2.1 General

To ensure equal rights of all countries international agreements have been made for the use of the broadcasting bands. For the introduction of digital terrestrial television in Europe the most important agreements are the Stockholm agreement of 1961 (ST61) made under the auspices of the ITU and the Chester agreement of 1997 (CH97). The Chester agreement was done at Chester (UK) at a conference organised by the CEPT. Furthermore the Wiesbaden arrangement of 1995 (WI95) regarding DAB (also CEPT agreement) is of importance for introduction of digital terrestrial television in Band III.

The table 1 below shows the relationship between these agreements in case a new or modified television is requested or needs to be protected.

To protect ⇓ From⇒	Analogue tv	DVB-T	Conversion from analogue tv	T-DAB	Other service
Analogue tv	ST61	CH97	CH97	WI95	ST61
DVB-T	CH97	CH97	CH97	WI95*	CH97
Conversion from analogue tv	CH97	CH97	CH97	WI95 *	CH97
T-DAB	WI95	WI95 *	WI95 *	WI95	WI95
Other service	ST61	CH97	CH97	WI95	RR

* protection criteria in CH97

table 1 Agreements of that are of relevance for the introduction of DVB-T

2.2 The Stockholm Agreement (ST61)

All analogue television assignments are made under the rules of the Stockholm agreement of 1961. The Stockholm Plan contains television assignments in:

- Band I, about 45 to 68 MHz ;
- Band II (television), 84 to 100 MHz;
- Band III, 174 to 230 MHz.
- Band IV, starting at 470 MHz;
- Band V, ending at 862 MHz.

(There is no real physical boundary between Bands IV and V and it is thus not necessary to quote any internal boundary frequency here.)

There are nine different analogue television systems in use in different parts of Europe. In addition since 1961 a number of enhancements of the television system have been introduced such as colour and a second sound channel. These enhancements increased the number of different standards.
An overview of the main characteristics of the different analogue systems in Band III IV/V, the bands of interest for the introduction of digital television (see section 2.3), is given in the table 2 below.

Item	Band III	Band IV/V
Frequency range	174 –230 MHz	470-826 MHz
System	B, B(I), B1, D, D1, I, L	C, K, I, L
Video	5, 5.5, 6 MHz	5, 5.5, 6 MHz
Sound	FM, AM	FM, AM
Colour	PAL, SECAM	PAL, SECAM
2nd sound channel	Dual FM, digital	Dual FM, digital
Bandwidth	7, 8 MHz	7, 8 MHz
Channel spacing	7, 8 MHz	8 MHz
Raster	Overlapping	Uniform

Table 2 Characteristics of the different television systems in Europe

In the UHF bands, it was decided at the Stockholm Conference to have a uniform channel width and spacing of 8 MHz, the channels not being completely filled in the case of systems using 7 MHz bandwidth. In the VHF bands, there was no such agreement and the result is that there are overlapping 7 and 8 MHz channel rasters with several versions of each.

It must be remembered that when planning for radio or television services, interference from a given station extends well beyond the coverage boundary of that station. When a new or modified station is required the administration concerned shall therefore consult the administration of potentially affected

countries. Potentially effected countries are identified by means of co-ordination distances. (See annex 7 of the Chester agreement).

In general terms, for a high power transmitting station, in the VHF and UHF bands, it is necessary to consider interference effects at up to 500 km from the station site and in some cases, for instance when a sea path is involved, even greater distances. Some countries in Europe are less than 500 km across and thus interference is not necessarily limited to only geographically adjacent countries.
For example: a 10 kW television station (heff 150 m) in Band IV in the centre of the Netherlands has to be co-ordinated with seven countries; even a 10W station (heff 150 m, Band IV) has to be co-ordinated with two countries in this example. (see figure 1)

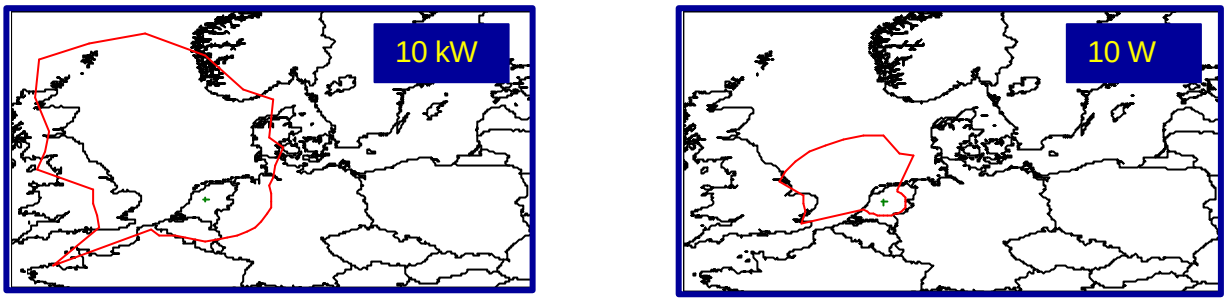


Figure 1; example of the co-ordination distance of a 10 kW and a 10 W station (heff 150m, Band IV) respectively

2.3 The Wiesbaden Arrangement 1995 (WI95)

In order to facilitate the introduction of T-DAB in Europe the CEPT organised a planning meeting in Wiesbaden (Germany) in 1995. At this meeting each CEPT country achieved two national coverages (consisting out of one or more coverage areas) in Band III and/or the frequency range 1464 to 1495 MHz.
In Europe the introduction of digital terrestrial television should take account of the T-DAB plans in Band III.

2.4 The Chester agreement 1997 (CH97)

When digital television was developed in first part of the last decade of the last century it became clear that in principle is possible to use the Stockholm Plan for international co-ordination of digital television. However it was felt that technical criteria, calculation methods and administrative procedures in addition to the Stockholm agreement would be very helpful.

For that reason the CEPT organised a conference in July 1997 in Chester (UK).
The Chester agreement gives a set of rules and procedures to be applied in addition to the Stockholm Agreement. The actual assignment of digital television station takes place by means of bi-lateral agreements between administrations.
These bi-lateral agreements must clearly have an equitable basis and must also take into account that different countries in Europe would need to implement digital services with very different time scales.
Thus it was necessary to consider:

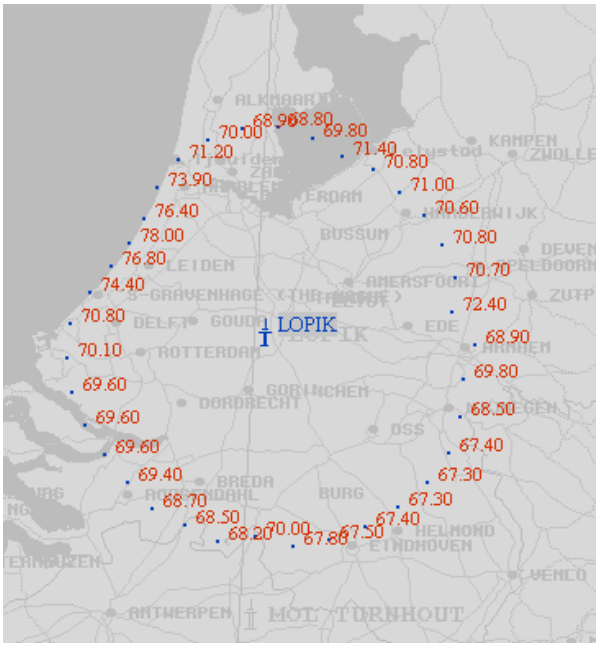
- the impact of new digital stations;
- the impact of the conversion of an existing analogue station to a digital station;
- and even the impact of introducing new analogue stations which could later be converted to digital.

To put the latter point in perspective it must be noted that the interference potential of a digital station can be greater than that of an analogue station. The conversion of a station from analogue to digital is thus a matter of particular concern.
The CEPT decided that digital television should take place in Band III and IV/V only. This means that television in Band I will cease to exist in future. Most countries use Band IV/V for the implementation of digital television. However some countries foresee that also Band III will be used.

As part of the general process of implementing digital television transmissions, the Chester conference considered that it would be important to establish an internationally agreed reference situation which

describes the existing analogue coverages. The achievement at Chester was to get agreement on a set of conditions which could be applied to all stations and all coverage areas in Europe. The particular task of calculating all of the coverage areas on a common basis is still in hand because of the long time scales involved in setting up an agreed database of the analogue transmitting station characteristics needed for these calculations. These characteristics are significantly more detailed than those contained in the Stockholm Plan.

The coverage areas themselves are established in a reasonably conventional manner as a series of radial distances (36) around each transmitter site. Each radial distance is determined by an iterative process which takes into account interference from all co-channel, adjacent channel or overlapping channel stations together with their characteristics, and the level of the wanted signal from the wanted station under consideration. There are complications caused when coverages cross national boundaries or overlap those of adjacent channel stations, but these are matters mainly of administrative concern.



An example of a reference situation is given in the figure 2.

A new or modified station should in principle not exceed the reference value at any test point by more than 0.3 dB. A higher increase is subject to negotiations between the administrations concerned.

Figure 2; *Example of the reference situation of the transmitter Lopik (NL). The usable field strength in dBuv/m is indicated at the test points*.

The DVB-T system has 60 different (non-hierarchical) variants ranging from very robust to very sensitive to noise and interference. The C/N ranges from about 3 dB to 27 dB and the net bit rate ranges from about 5 to 31 Mbit/sec.
In Chester it was decided to base international frequency co-ordination on a unified set of criteria including a unified C/N of 20 dB. This value corresponds more or less with the C/N value of the often used system variant of 64QAM-2/3.

In general there are no great difficulties in applying the Chester agreement. However the strict application of the protection rules leads to severe restrictions of digital terrestrial stations. Therefore many administrations agree bilaterally on more relaxed criteria.
The amount of work in dealing with co-ordination requests for digital terrestrial television stations should not be underestimated. In particular the calculations and negotiations of co-ordination requests of neighbouring countries require considerable resources.
For example the Netherlands administration received up to now about1400 co-ordination requests for digital terrestrial stations from neighbouring countries and has sent 188 request for digital terrestrial stations to its neighbours.

3. Protection of analogue services

Originally the Stockholm Plan provided for, effectively, four television coverages in all countries in Europe, although for a variety of reasons there were cases where the channels for one of these coverages was actually allocated to a non-broadcasting service. One of these coverages was usually in the VHF bands.

All countries in Europe have as a goal the provision of television coverage to all parts of their territories. This has involved the construction of a large number of lower power fill-in, or relay, transmitting stations. Most of these stations did not form part of the original Stockholm Plan but they have been co-ordinated in the context of the Stockholm Agreement and thus have the same rights to be protected from interference as the larger stations which were part of the original Plan. In addition, in many countries additional programme chains have been created requiring their own high and low power transmitting stations. Some of these additional stations form part of chains intended to provide primarily urban coverage. Others are intended for national area coverage. However, once co-ordinated, they all enjoy the same legal rights to continued existence and protection from interference.

In addition, in some countries there has been the introduction of a number (sometimes a large number) of additional non co-ordinated transmitting stations. The legal status may be unclear. The interference from such stations can be very obvious and very damaging.

In terms of the total number of transmitters which are in service or which have the right to be in service (that means that they have been co-ordinated but are not yet in operation) there are now in excess of 85,000 analogue service transmitters in Europe. Not all of the 85,000 have been co-ordinated but a large majority have been.

The radiated powers of these transmitting stations range from less than 1 watt to more than 1 megawatt. Obviously, there are more stations in the lower power ranges than in the higher power ranges but, once again, all of those which have been co-ordinated have the same rights.

There is no extra spectrum available for the introduction of digital terrestrial television. Analogue and digital television will therefore have to co-exist for many years or even decades. Some countries have indicated that switching off analogue television may take place as early as 2006. However in other countries introduction of digital television will not have started by then.

The challenge of finding any opportunities for putting digital transmitting stations in this environment is rather obvious, especially when it is considered that the digital stations must achieve reasonable coverage in order to attract viewers and to create the opportunity for a later transition to an all-digital future after the switch-off of the analogue stations.

The DVB-T system has the advantage that digital terrestrial signals are very robust against analogue interference. For example the often-used system variant 64QAM-2/3 has a protection ratio of 4 dB when the interfering signal is analogue television. A problem may arise when the interfering analogue station becomes digital in future. Then the protection ratio increases to 20 dB (system variant 64QAM-2/3). Even if the power of the interfering station is reduced by 7 dB relative to the power of the analogue station it replaces, the increase in interference is still 16 dB.
The digital signal itself is noise like and the protection ratio for analogue television interfered with by digital is 35 dB. In general digital television stations operate with less power than analogue stations. Nevertheless in practice it is often necessary to apply power restrictions to digital television stations in order to protect analogue television stations or the future digital stations resulting from a conversion of analogue stations.

4. Satisfactory digital coverage

Due to the rapid transition from near perfect to no picture it is required that the digital signal can be received at a high percentage of locations.
“Good” reception has been defined for reception at 95% of locations and “acceptable” reception for 70% locations. An extra margin on the mean signal is therefore required (see table 3 below).

Antenna location	95%	70%
Indoor	14 dB	4 dB
Outdoor	9 dB	3 dB

Table 3 location correction factors

These percentages apply to a small area of say 100 by 100 m, a so-called pixel. The coverage area is the collection of pixels where the required location percentage is reached or exceeded.

At present, the planning of analogue television station coverage in Europe makes the assumption that reception is based on nominally fixed receiving antennas mounted at or near roof level and with nominal directional characteristics. The primary benefit of the latter is to provide discrimination against interference, a process which is enhanced in some countries by considerable use of polarisation discrimination.

In many countries the possibility to receive digital terrestrial television by means of simple antennas in difficult reception conditions such as indoor or mobile reception is seen as an important feature for the introduction of digital terrestrial television.

For that reason planning criteria for digital terrestrial television include fixed and portable reception. This should be understood as:

- Fixed antenna reception; that is a directional roof top antenna
- Portable antenna reception; this can be a simple movable antenna on or near a television-set (see figure 3) or a built-in antenna on a transportable television set.
- Mobile reception; here reception takes place while moving in a car, train or boat.

Currently mobile reception criteria are not yet defined in ITU and CEPT.

Figure 3 indoor reception with simple portable antenna

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Portable reception requires a higher signal than fixed reception. The table 4 indicates several reasons for that and shows the range of values that can be expected for each of these.

Item	Fixed	Portable	Difference
Transmission channel	Ricean	Rayleigh	1.5 – 7 dB
Antenna gain minus cable loss	5 – 7 dB	0 dB	5 – 7 dB
Building penetration loss	No	7 dB	7 dB
Receiving height	10 m	1.5 m	10 – 12 dB

Table 4 Differences between fixed and portable reception

The difference in the minimum required signal for portable and fixed antenna reception depends also on the interference level. The overall difference is about 8 to19 dB for outdoor portable antenna reception and about 8 to 29 dB for indoor portable antenna reception.

Together, these effects create considerable problems in terms of achieving adequate coverage. Various solutions are being considered but the indications at present are that it will be necessary to install more transmitting stations and there will thus be a trend towards much denser transmitter networks than are currently used in broadcasting. In particular for portable and mobile reception Single Frequency Networks (SFN) are often applied. The concept of SFN in comparison to the conventional Multi Frequency Networks (MFN) is described in the appendix of this paper.

5. Migration to all digital plan

5.1 ITU Conference to revise the Stockholm Plan

CEPT countries have asked the ITU to organise a planning conference for the European Broadcasting Area to revise ST61 with regard to the Bands III, IV and V. According to the ITU rules at least 50% of the administrations in the area concerned (that is 28 in this case) should support such a request. Actually 43 administrations replied positively to the ITU.
The conference should consist of two sessions. The first session to be held in 2003 would be concerned with the technical preparation and should include the following elements:

- determination of the planning method;

- determination of protection criteria between analogue and digital television broadcasting stations and between digital television broadcasting stations and stations of other services to which the frequency bands in question are also allocated;
- equitable access to the spectrum;
- appropriate planning exercises;
- consideration of an orderly transition from analogue to digital television broadcasting.

The second session of the Conference, which would produce the required Plan, should take place sometime in the year 2005. The exact dates of the two sessions will be determined by the Council to fit into the overall schedule of ITU conferences and meetings.

5.2 Considerations for the introduction of DVB-T

The global aim is the introduction of DVB-T on a European wide scale and the closure of the less spectrum efficient analogue services – thus providing the opportunity for more or different types of service. In order to achieve this goal and to facilitate the planning the following points need to be decided upon at a national level and will probably differ from country to country:

- Coverage targets; coverage requirements for public service networks may differ from those of commercial networks. Near-universal coverage is usually required for public service networks. Furthermore, for each country the number of national, regional and local services will need to be decided.
- Capacity requirements; typically many countries are planning for six multiplexes. Additional capacity may be desired in the all-digital future.
- Spectrum availability; DVB-T will use the frequency bands currently allocated to broadcasting services, noting that the availability of frequencies varies from country to country.
- Reception target; planning may be required for fixed, portable (indoor and outdoor) or mobile reception. In those countries where a small percentage of households rely solely on terrestrial reception, portable and mobile reception may provide the market opportunity for the introduction of DVB-T.
- Service targets; in deciding what additional services might be required it should be noted that the additional services may require additional spectrum. The introduction of interactive and or data services may be considered.
- Transmission infrastructure; the selected transmission infrastructure will have an impact on cost and spectrum efficiency. Various configurations may be possible.

All of the above issues are inter-related and inter-dependent.
Furthermore decisions need to be taken about the extent of protection of existing analogue and digital services during transition. It will be very difficult to introduce digital terrestrial television if analogue television services require a high degree of protection during the whole of the transition period.

5.3 Frequency Planning Options

There are basically three options for achieving an all-digital plan for terrestrial television in Europe:

a. the conversion of existing analogue assignments into digital assignments. The analogue assignments may either be currently unused or in use for analogue television broadcasting;

b. a plan based on current digital television assignments (new frequencies not previously used or reserved for analogue television);

c. a completely new plan.

The first two option are both based on the current analogue television plan. This has some important advantages such as:

- New frequency assignments are likely to be compatible with analogue services
- Administrations retain their rights
- Smooth transition by means of bilateral agreements is possible

However there are equally important disadvantages, such as:
- The new plan may not lead to equitable access
- The new plan may not be optimised for spectrum efficiency
- The assignments may not result in adequate coverage

The third option, a complete new digital plan, could be designed to solve these disadvantages. It is however difficult to implement because the required change of frequencies and associated technical characteristics and the need to synchronise between countries

These options may be combined, for instance part of the spectrum may be re-planned but existing assignments could be retained in another part of the spectrum i.e. an in-between approach. In many countries, channels 61-69 are not included in the Stockholm plan and so a new digital plan could be devised for that part of the spectrum. Some approaches to the all-digital future (e.g. wide area SFNs) may only be achieved with a re-plan.

Given that there are likely to be different service requirements, time scales and frequency availability in the various countries of the European Broadcasting Area, a flexible approach to the planning process will be essential.

One possible option might be to agree an all-digital plan at a Regional Conference (2005) and then adopt a stepped approach via interim plans at a multilateral level (because in general no new spectrum is available for the introduction of DVB-T). This approach is based on a computerised plan synthesis and analysis for the final all-digital plan and also for intermediate steps where only a number of countries want to go fully digital. The station characteristics (analogue and digital) in each interim plan may have to change to a certain extent. The more countries in a certain area of Europe go digital the more the latest version of the interim plan could mirror the final digital plan for that area.

5.4 Band III

At present, the frequency band from 174 to 216 MHz is used for terrestrial analogue television, although there are some T-DAB allotments in this band. The spectrum from 216 to 230 MHz (240 MHz in some countries) is allocated to T-DAB in Europe although there is still widespread use of part of this band for television, particularly in Central and Eastern Europe. The general assumption is that part of Band III will continue to be used for digital television as its characteristics seem to be particularly suitable for services intended for portable and mobile reception. It is also generally assumed that more of Band III will be needed for T-DAB. Either there will need to be a complete split of Band III between digital television and T-DAB or there will need to be some form of sharing of the available channels between these two services, although some form of at least a partial split seems to be desirable. This topic will need considerable study.

It seems that in short term the continued use of 7 MHz and 8 MHz bandwidth channels is necessary because of the need of co-existence of analogue and digital services. In this case, special care should be taken to guarantee suitable rejection of adjacent channels signal. From a receiver's point of view (technical and economical) it would be better to uniform all bands to 8 MHz. However, such a move will be very difficult from a frequency planning point of view.

5.5 Spectrum requirements

In terms of amount of spectrum required, studies are on going. The number of channels required depends on: system variant, reception conditions, transmit antenna height, distance between transmitters, target coverage and network structure among others. First results for MFN network structure, show that 16 QAM 2/3 and 64 QAM 2/3 generally require fewer channels than QPSK to provide a given data capacity. For fixed reception, for example, for 95% location coverage and an antenna height of 150 m or greater, between 4 and 9 channels are needed to provide a given data capacity and one complete coverage.

For portable reception, 70% coverage seems to be a more feasible option than 95%. However, even in that case, it could require around twice channels than fixed reception. These results are for Multi Frequency Networks (MFN). Some studies indicate that for portable reception and Single Frequency Networks (SFN) the required number of channels are comparable with the figures given above for fixed reception and MFN.
The indications are that most countries will require 6 coverages (sometimes called multiplexes). In order to determine the complete spectrum requirement the figures given above should therefore be multiplied by 6.

The results shown above are only initial conclusions based on purely theoretical studies. Studies are still going on and further conclusions will be taken based on practical situations. It is too early to take any firm conclusion.

6. Conclusion

This paper describes the challenges for frequency planning of digital terrestrial television stations in Europe in frequency bands that are already heavily used by analogue television stations.
Currently the Chester Agreement of 1997 gives the framework for co-ordination of digital terrestrial television stations in Europe.
It is expected that the ITU will organise a conference for the revision of the Stockholm Plan for an all-digital terrestrial television plan in the European Broadcasting Area in 2005.

This seminar may help broadcasters, network operators and administrations to make up their mind with regard to their future requirements.

References

[1] COHABITATION (BETWEEN SYSTEMS; BETWEEN COUNTRIES); DIGITAL TELEVISION PLANNING CHALLENGES IN EUROPE. K.J. HUNT *(EBU)*, J. DOEVEN *(Nozema*). Presentation at Commshere conference, Toulouse, January 1999.

[2] 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, 25 July 1997

[3] ERC/EBU REPORT on planning and introduction of terrestrial digital television (DVB-T) in Europe. December 1997. (also EBU BPN 018).

[4] ERC REPORT 079; Implementation of the Chester Agreement. Naples 2000.

[5] EBU BPN 005; Terrestrial Television Planning and implementation considerations.

Appendix 1

Network structures

A wide range of DVB-T network structures has been identified. There are two basic DVB-T network structures: Multi Frequency Networks (MFNs) and Single Frequency Networks (SFNs).

Multi Frequency Network

In a multi frequency network (MFN), each transmitter operates independently (using a different channel) and has its own coverage area. The same channel is re-used only in regions separated by a sufficient distance, to avoid harmful co-channel interference.

MFNs can provide for large coverage where the individual transmitters carry different multiplexes and can thus allow for regional or local programming. In addition, MFNs can be designed to reproduce, approximately, the coverage of the existing analogue networks and this may be of importance when it is considered necessary to maintain an existing coverage pattern for political or commercial reasons.

Single Frequency Network

In a single frequency network (SFN), all transmitters of a network use the same channel. They possess a common coverage area and cannot operate independently. They require a high degree of synchronicity (in time, frequency and data stream): the emitted signal from different transmitters must be identical in content, signal emissions must take place at the same time (or with precisely controlled delays) and the RF carriers must comply with stringent frequency precision requirements.

Several types of SFN can be envisaged and some examples are given below.

Types of SFN

National SFN
It seems that a real national network using the same frequency (SFN) will be difficult to achieve in any but the smaller countries because of self-interference effects, unless a low data capacity DVB-T variant were to be adopted.

Regional SFN
It is assumed that a medium or small SFN corresponds in Europe to a cultural or administrative region of up to [200] km diameter. The sizes of the European regions are very different from one country to another, even for countries of comparable size. Clearly, there is also a major impact from the size of the country and any internal linguistic or cultural conditions.

Local area SFN
Such SFNs are assumed to be needed to provide for local programme coverage. Normally a local SFN covers a single part of a town or city.

In addition, SFN gap-fillers can be used to enhance the coverage of a network.

Mixed MFN-SFN environments

There could be an interest in having a MFN, which consists of higher power main stations that do not provide complete coverage and in which the coverage is completed by lower power relay stations using the same frequency as the associated main station.