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TERRESTRIAL DIGITAL TELEVISION PLANNING AND IMPLEMENTATION CONSIDERATIONS

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FOREWORD

This is the third version of the EBU handbook giving planning and implementation considerations for terrestrial digital television. The second version of this handbook was issued in July 1997 in order to assist the work of the Chester Conference. Since then, more work has been undertaken by a number of European groups active in the terrestrial digital television field and the results of this additional work has been included here.

This third version of the EBU handbook has taken material available from several relevant groups and used it, where appropriate, to update or to modify the text previously issued. At the same time, a number of editorial improvements have been made. However, the opportunity has been taken to remove some of the material contained in the second issue but which can be found in a more complete form in other documents. In particular:

most of the material dealing with the DVB-T system has been removed as it can be found in a more complete form through the DVB project http://www.dvb.org;

most of the material dealing with national studies and implementation has been removed as more up-to date versions may be found through the DigiTAG organisation http://ww.digitag.org;

Although information on protection ratios can be found in an ITU-R Recommendation (BT.1368) (see http://www.itu.int), this information has been included in this handbook as it is so closely linked with the planning process.

In this version, a major concern has been to collect together as much as possible of the material relevant to planning so that the decisions which need to be taken, with regard to the initial co-ordination and introduction of terrestrial digital television and the preparations for a revision of the Stockholm Plan, can be made with all of the people involved having access to a full set of information.

However, there are many other relevant studies being undertaken and the EBU is publishing a number of documents dealing with various aspects of planning.

Terrestrial Digital Television
Planning and Implementation Considerations

1. INTRODUCTION

1.1 General

Over the next few years the world of terrestrial television broadcasting will see a revolution: the word is not too strong. The changes which will be brought about by the introduction of digital transmissions, and the subsequent closure of the analogue transmissions which have provided television services within the European Broadcasting Area (EBA) for some 40 years, will be by more far-reaching than those which have resulted up until now from the introduction of cable and satellite services. Of course, cable and satellite systems will also experience the digital revolution, indeed in some parts of the world this has already started.

Why should the advent of digital transmissions be described as revolutionary? The primary reason is that digital television will free us from some of the constraints associated with the current analogue systems. The major constraints are the lack of spectrum capacity for broadcasting and the high demands which analogue television systems make in terms of protection against interference. The combination of these two elements means that only a limited number of television programmes can be transmitted into a given area: at least, the number is limited if high quality reception is to be obtained.

In the EBA, where the usual target has been the provision of television on a national, or near-national, basis, there are 3 or 4 programme chains available to virtually the whole population of all countries. In some countries, one or more of these chains may have a regional basis, but this does not significantly affect the general concept. In some countries there are additional services in the more densely populated areas. Such services cannot be extended to the whole country because to do so would create additional interference and thus reduce the number of services, or their quality, available to some viewers.

The broadcasters recognise that it is not possible to increase the number of analogue programme chains available for terrestrial services because of spectrum limitations. At the same time, however they are faced with continual demands from the audience for an increasing diversity of programme material. These demands cannot be satisfied by means of terrestrial broadcasts. To some extent, satellite and cable systems have been able to respond to these demands by providing more thematic programme chains or simply more hours devoted to a given topic within a more generalist chain because there are more such chains available.

Digital television systems provide for a “step function” change in the situation because they allow for:

- multiple programmes in a given radio-frequency channel;
- a more rugged system which can provide a better use of the limited spectrum available.

To some extent these two advantages of digital systems are mutually exclusive. The greater the capacity of a system (which is better expressed in terms of bit rate than number of programmes per channel), the higher is the minimum required C/N ratio (which is equivalent to a greater susceptibility to interference).

Of course, to make use of a digital television broadcasting system, it is necessary to be able to introduce it. Because it is unrealistic to seek additional spectrum, this means that the new digital system must co-exist with the existing analogue television services without undue mutual interference. This co-existence will need to continue for some considerable time because of the large number of analogue receivers in the hands of the public. To persuade all viewers to change to digital receivers or to persuade them to equip themselves with converter equipment, to permit display of the digital programme material, will take several years.

To achieve a satisfactory co-existence between analogue and digital services will take very careful planning. This planning is complicated by the fact that some of the characteristics of digital broadcasting systems are very different from those of analogue systems. For example, analogue systems exhibit a large amount of "graceful degradation". As the wanted signal level decreases over a range of many dB, the picture quality will degrade but will remain usable. Digital systems usually exhibit a very rapid failure characteristic; often a reduction in signal level of 1 or 2 dB corresponds to a transition from near perfection to no picture. Such a difference brings with it the need to adopt new planning techniques.

The purpose of this current document is to provide a guide for the planning and introduction of terrestrial digital television services. This is an ambitious target. While based on known techniques, many of the ideas needed in the planning of digital services are still being developed. It is to be expected that there will be changes needed over the next few years and new editions of this guide will be produced to meet those needs.

1.2 Scope of document

The document which follows this introductory chapter starts with a description of the DVB system developed in Europe and the target is to provide a basis for the planning of such a system within the 8 MHz wide channels used at UHF and the 7 and 8 MHz wide channels in Band III in Region 1. Much of the document is general and could be applied to other digital television systems including the case of DVB in channel widths other than 7 or 8 MHz. Some of the numeric examples would need to be extended in such a case. A special case which will need to be considered is that of the introduction of DVB into the VHF bands. In the EBA, there are channel widths of 7 and 8 MHz in Band III leading to overlapping channel rasters. This will need careful attention.

The DVB system is particularly flexible in that it offers a very wide range of implementation possibilities and it was considered unrealistic (and potentially very confusing) to try to provide numeric example related to all of the possibilities available. For that reason, only representative cases are treated; results for a specific system variant can generally be obtained by interpolation between the examples given. However, because of the very marked influence of the receiving environment, several quite specific examples are treated in detail. These range from reception using a fixed antenna mounted externally at, or near, roof-level to reception using a portable receiver with a built-in or attached antenna in a ground-floor room.

The impact of propagation is considered, with special attention being given to the influence of the statistical variation of field strength with location. This is especially important in view of the rapid failure characteristics of digital systems. Special attention is also given to network planning and the benefits of Single Frequency Networks (SFNs), a technique for which the DVB system is particularly well suited.

It seems likely that in many countries the early introduction of digital broadcasting will be by using any “gaps” which exist in the spectrum. The scope for nation-wide or even sub-national regional use of SFNs may be rather limited in the short term. Nonetheless, in the longer term it is to be expected that the benefits of SFNs will lead to their much more general use, perhaps especially in those cases where portable reception is a primary target.

Considerable attention is given to the continued protection of the analogue television services. This is a topic which is seen by all broadcasters as being of primary importance. To assist in this process, database formats for analogue and digital television stations have been developed. These contain considerably more information than is available, for example, from Stockholm Plan records. This additional information is needed in order to be able to carry out calculations which examine the compatibility between analogue and digital services.

However, it is also recognised that there are some “other services”, which use the spectrum allocated for terrestrial television. Compatibility with these services will need to be examined. At present, only an outline of this latter process can be given as there is insufficient detail available about such other services. It is recognised that it is a high-priority task to obtain such information and process it in such a way that methods for evaluating compatibility can be developed.

1.3 Looking to the future

As noted earlier, many of the ideas about planning for digital television are still being developed. This development process will continue for some time. After all, in most countries there is little or no equipment in the market place for terrestrial digital television services and, in addition, there has not been sufficient time to develop ideas on the best ways of using the considerable flexibility of the DVB system. One of the main reasons for producing a new version of this guide is to provide a firm basis for the many planning studies which will be needed before widespread implementation takes place. Such studies will not only form an essential part of the development process they will also lay down the basis for a plan for the all-digital future which will result when it has been possible to turn off the analogue transmissions.

Progress towards a new plan, expected to be the result of a revision of the Stockholm Plan, is likely to change the direction of planning work over the next few years. There will be less emphasis on the implementation of digital television stations and networks and more emphasis on moving towards the all-digital future. In most countries this will involve two separate transition periods. The first period will involve a change from analogue-only to a mixed analogue a digital broadcasting environment. A mechanism for doing this was developed within the CEPT and resulted in the Chester 97 Agreement. While designed for CEPT countries, the guidelines it developed (it did not involve the production of a plan) could be used by any other countries to help in the initial implementation process.

The second transition period will involve the change from a mixed scenario to an all-digital one. There is little doubt that this will represent a considerable challenge for all of those involved as it will be important to find solutions which are seen to be equitable between administrations and which are also seen not to be disruptive for the viewing public. A discussion of this aspect is beyond the scope of this handbook but some initial thoughts on the topic may be found in the EBU publication BPN 033.

1.4 Terminology

While many of the terms used in this handbook will be familiar to those who have been involved in the planning of analogue television services, there are other terms which will not be so familiar. In order to help the reader, the Annex 1 to this chapter provides a glossary of terms, both familiar and unfamiliar.

ANNEX 1

Definition of terms

A1.1. Acronyms

ACTS	Advanced Communications Technologies and Services (EC research programme)
BPN	EBU Technical Document
CEPT	European Conference of Postal and Telecommunications Administrations
CH97	Chester 1997 Multilateral Co-ordination Agreement
DigiTAG	Digital Terrestrial Television Action Group
dTTb	Digital Terrestrial Television Broadcasting (RACE project)
DVB-T	Digital Video Broadcasting - Terrestrial
EACEM	European Association of Consumer Electronics Manufacturers
EBA	European Broadcasting Area
EBU	European Broadcasting Union
EC	European Commission
ERO	European Radiocommunications Office
ITU-R	International Telecommunication Union, Radiocommunication Sector
Motivate	Mobile Television and Innovative Receivers (ACTS project)
MPEG	Moving Picture Experts Group
RACE	R&D for Advanced Communications for Europe (EC research programme)
ST61	Regional Agreement for the European Broadcasting Area concerning the use of Frequencies by the Broadcasting Service in the VHF and UHF Bands (Stockholm 1961)
Validate	Verification and Launch of Integrated Digital Advanced Television in Europe (ACTS project)

A1.2. Abbreviations[1]

ACI	adjacent channel interference
AM	amplitude modulation
BER	bit error ratio
CCI	co-channel interference
CIR	channel impulse response
COFDM	coded orthogonal frequency division multiplex
C/I	carrier to interference ratio
C/N	carrier to noise ratio
DAC	digital-to-analogue converter
DII	delayed image interference
EPT	effective protection target
ERP	effective radiated power
FEC	forward error correction
FFT	fast Fourier transform
FM	frequency modulation
IF	intermediate frequency
IFFT	inverse fast Fourier transform
ISI	inter symbol interference
LNM	log-normal method
MCP	motion-compensated prediction
MFN	multiple frequency network
NICAM	near-instantaneous companded audio multiplex

[1] It must be noted that many of these abbreviations may appear in print as lower-case letters and some of them also appear with the symbol ’,’ separating the individual letters.

OFDM	orthogonal frequency division multiplex

PAL	phase alternation line (colour TV system)
PR	protection ratio
PSM	power sum method
QAM	quadrature amplitude modulation
QPSK	quadrature phase shift keying
RF	radio frequency
RMS	root mean square
SAB/SAP	services ancillary to broadcasting/programme making
SECAM	sequentielle couleur avec memoire (colour TV system)
SFN	single frequency network
SMM	simplified multiplication method
T-DAB	terrestrial digital audio broadcasting
UHF	ultra high frequency (470 to 960 MHz when applied to broadcasting)
VHF	very high frequency (47 to 240 MHz when applied to broadcasting)

A1.3. Terms and Definitions

Allotment planning

In allotment planning, a channel is 'given' to an administration to provide coverage over all or part of its territory or its service area in the cast of non-territorial services such as maritime mobile. In general nothing is known of the actual location of the transmitter site nor of the transmissions characteristics to be used. The only parameters available are a definition of the area to be covered and the channel to be used (and in some cases, the transmission times). (See also 7.1.2)

Antenna aperture

The vertical aperture of an antenna which consists of *n* tiers of elements (e.g. dipoles, slots, etc.) is defined as *n* multiplied by the element spacing in wavelength (λ) at its nominal operating frequency.

Antenna gain (dB)

The ratio G_d, usually expressed in decibels, of the power required at the input of a loss free reference antenna (normally considered to be a half-wave dipole in the case of broadcasting) to the power supplied to the input of a given antenna to produce, in a given direction, the same field strength or the same power flux-density at the same distance.

Assignment planning

In assignment planning, a specific channel is assigned to an individual transmitter site location with defined transmission characteristics (for example, radiated power, antenna height, etc). At the completion of the assignment plan, the locations and characteristics of all transmitters are known and the transmitters can be brought into service without further co-ordination. (See also 7.1.1)

Band I

Frequency range: 47 - 68 MHz (in the EBA)

Band III

Frequency range: 174 - 230 MHz (in the EBA)

Band IV

Frequency range: 470 - 582 MHz (in the EBA)

Band V

Frequency range: 582 - 862 MHz (in the EBA)

Carrier to interference ratio (dB)

The ratio (C/I), expressed in decibels, of the power of the wanted signal to the total power of the interfering signals, evaluated for specified conditions at the receiver input. In practice, there is some confusion between ‘carrier to interference’ ratio and ‘carrier to interference plus noise’ ratio. In most cases, it is the latter which is the more important and is what is really intended. However, the abbreviation C/(N+I) should be avoided as it implies a numerical addition of noise and interference powers and in many cases a statistical addition is what is needed.

Carrier to noise ratio (dB)

The ratio (C/N), expressed in decibels, of the power of the wanted signal to the noise power, evaluated for specified conditions at the receiver input.

Coarse offset

A relatively large frequency offset that can be used to improve adjacent channel protection. (See also 2.5.3)

Coverage area

The area within which the field-strength of a transmitter is equal to or greater than the usable field-strength.

Echo delay spread

Echo delay spread is a characteristic of the propagation channel. 'Natural echoes' are caused by the presence of obstacles and reflections in the propagation environment while 'artificial echoes' are introduced by other transmitters mainly in SFNs. The delay spread of the echoes is important in the specification of the guard interval duration. (See also 6.3.3)

Effective antenna aperture

The ratio of power available at the antenna terminals to the power per unit area of the appropriately polarised incident wave. It is defined in terms of the directive gain of the antenna through the relationship $A = (\lambda^2/4\pi)\ G_d$.

Effective transmitting antenna height (m)

The height of the electrical centre of the transmitting antenna above the mean level of the ground between 3 and 15 km from the transmitter in the direction of the receiver.

Effective protection target

System parameter which represents the ratio between the power of the wanted signals and the sum of the powers of noise and effective interference at the system thresholds. (See also 2.6)

Effective radiated power (ERP)

The product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction.

Equivalent noise bandwidth (Hz)

The bandwidth of an ideal rectangular filter that gives the same noise power as the actual system.

Fine offset

A relatively small frequency offset that can be used to improve co-channel protection. (See also 2.5.2)

Fixed antenna reception

Reception where a fixed roof level (10 m above ground level) directional receiving antenna is used.

Frequency offset
Change of the characteristic frequency of a radio-frequency channel in relation to its nominal frequency, used as a means of reducing protection ratios.

Gaussian channel
Reception of the wanted signal with no delayed signals, but taking account of the gaussian noise only. (See also 2.1.4)

Height loss
A correction in decibels applied to the predicted signal strength at roof level when making a prediction for lower reception heights. (See also 5.3.2.2)

Location correction factor
The ratio, expressed in decibels, of the field strength for a given percentage of the receiving locations to the field strength for 50% of the receiving locations.

Location distribution
The statistical distribution (typically log normal) over a specified area of the more or less random variation of the received signal level with location due to terrain irregularities and the effect of obstacles in the near vicinity of the receiver location.

Location probability
Percentage of receiving locations where a given field strength is achieved or exceeded.

Mean building penetration loss (dB)
The mean building penetration loss is the ratio between the mean field strength inside a building at a given height above ground level and the mean field strength outside the same building at the same height above ground level. (See also 5.3.2.3)

Minimum equivalent receiver input voltage
The minimum voltage required at the receiver input to overcome receiver noise.

Minimum power flux density f_{min} (dBW/m^2)

f_{min} = *minimum required receiver input power – effective antenna aperture + feeder loss*

at a particular receiver location.

Minimum median power flux density f_{med} (dBW/m^2)
The power per unit area at the receiving antenna for a given % location and % time for a receiver to successfully decode a signal.

f_{med} = f_{min} + *Allowance for man-made noise* (P_{mm}) + *location correction factor* (C_l) *for a specified % location*

Minimum equivalent field strength E_{min} (dBmV/m)

$E_{min} = f_{min} + 145.8$

Minimum median equivalent field strength E_{med} (dBmV/m)
The minimum field strength required for a given % location and % time to ensure the minimum signal level at the receiver is achieved for a receiver to successfully decode a signal.

$E_{med} = f_{med} + 145.8$

Minimum receiver signal input power (dB)

The minimum power required at the receiver input to overcome receiver noise. Defined as the sum of the receiver noise input power and the RF signal to noise ratio required by the system, measured at the receiver input.

Minimum usable field-strength

Minimum value of field-strength necessary to permit a desired reception quality, under specified receiving conditions, in the presence of natural and man-made noise, but in the absence of interference from other transmitters.

Note l - The desired quality is determined in particular by the protection ratio against noise, and for fluctuating signal levels, by the percentage of time during which this protection ratio must be ensured.

Note 2 - The conditions include, amongst others:
- *the type of transmission and frequency band used;*
- *the equipment characteristics (antenna gain, receiver characteristics, siting);*
- *receiver operating conditions, particularly the geographical zone, the time and the season.*

Minimum wanted field strength

Minimum field strength at the receiving antenna required for the receiver to successfully decode a signal in the presence of interference.

Mobile reception

Reception while in motion, using a non-directional antenna situated at no less than 1.5 metres above ground level.

Network gain

Increase of the wanted signal level at a specific receiving location due to simultaneous reception of multiple useful signals. This is a characteristic of OFDM systems operating in an SFN. (See also 6.3.4)

Nuisance field strength

The field strength of an interfering transmitter to which is added the relevant protection ratio.

Portable antenna reception

Reception where a portable receiver with an attached or built-in antenna is used outdoors at no less than 1.5 metres above ground level, or indoors at no less than 1.5 metres above a specified floor level.

Protection margin (dB)

The difference between the carrier-to-interference ratio and the protection ratio.

Protection ratio

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

Note 1: The specified conditions comprise, inter alia:

- *the nature and characteristics of the wanted signal,*
- *the nature and characteristics of the unwanted signal,*
- *the characteristics of the receiver,*
- *the propagation conditions. (continuous or time varying)*

Note 2: The expression "unwanted signal" may describe the total interfering energy.

Rayleigh channel

Situations where there are several statistically independent incoming signals with different delay times, none of which dominates, together with thermal noise. There will be rapid and severe variations (from location to location) in the received signal, caused by multipath propagation. (See also 2.1.4)

Receiver noise bandwidth (Hz)

The bandwidth over which the noise generated within the receiver is calculated.

Receiver noise factor/noise figure

The ratio of the exchangeable power spectral density of the noise appearing at a given frequency at the output of a receiver, to the spectral density which would be present at the output if the only source of noise were the thermal noise due to a one-port electrical network connected to the input and which is assumed to have at all frequencies a noise temperature equal to the reference thermodynamic temperature fixed, by convention, around 290 K.

Note 1 – The receiver noise factor, F(f), is related to the equivalent receiver noise temperature T(f) as follows:

$$F(f) = 1 + \frac{T(f)}{T_0}$$

where T_0 is the thermodynamic reference temperature.

Note 2 - A receiving antenna can be regarded as a one-port electrical network when viewed from its output port.

Note 3 – The value of the ratio F(f) may be expressed in decibels. In English, the term 'noise factor' is generally employed when the ratio is expressed arithmetically, and 'noise figure' is employed when the ratio is expressed in decibels.

Receiver noise input power (dB)

The sum of all noise sources referenced to the receiver input.

Ricean channel

Situation where there is a dominant incoming signal with lower level delayed signals and thermal noise. (See also 2.1.4)

Service area

The part of the coverage area in which the administration has the right to demand that the agreed protection conditions be provided.

Transmitting antenna height (m)

Electrical centre of the transmitting antenna above ground level.

Usable field-strength

The value of field strength necessary to permit a desired reception quality under specified receiving conditions, in the presence of natural and man-made noise and in the presence of interference from other transmitters.

A1.4. References

EBU Doc. Tech. 3236	VHF/FM planning parameters and methods
EBU Doc. Tech. 3254	Planning parameters and methods for terrestrial television broadcasting in the VHF/UHF bands
EBU BPN 003	Technical Basis for T-DAB Services Network Planning and Compatibility with existing Broadcasting Services
EBU BPN 033	Ideas on Migration from Analogue to Digital Television in the European Broadcasting Area

EBU BPN 038	Report from Ad-hoc group B/CAI-FM24 to B/MDT and FM PT24 on Spectrum Requirements for DVB-T Implementation
ETSI Standard EN 300 744	Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television
ETSI Tech. Rep. TR 101 190	Digital Video Broadcasting (DVB); Implementation guidelines for DVB terrestrial services; transmission aspects
ITU-R Recommendation P. 370	VHF and UHF propagation curves for the frequency range from 30 MHz to 1000 MHz
ITU-R Recommendation BT.417	Minimum field strength for which protection may be sought in planning a television service
ITU-R Recommendation BT.419	Directivity and polarisation discrimination of antennas in the reception of television broadcasting
ITU-R Recommendation BT.470	Characteristics of television systems
ITU-R Recommendation BT.655	Radio-frequency protection ratios for AM vestigial sideband terrestrial television systems interfered with by unwanted analogue vision signals and their associated sound signals
ITU-R Recommendation BT.1368	Planning criteria for digital terrestrial television services in the VHF/UHF bands
ITU-R Report 945	Methods for the assessment of multiple interference

The Chester 1997 Multilateral Co-ordination Agreement relating to Technical Criteria, Co-ordination Principles and Procedures for the introduction of DVB-T (CH97)

Regional Agreement for the European Broadcasting Area concerning the use of Frequencies by the Broadcasting Service in the VHF and UHF Bands (ST61)

System specification for the second dTTb demonstrator, ver.2.2. dTTb M3. February, 1996.

Validate/D03 Report	Implementation Guidelines to DVB-T, January 1997
Motivate AC106 Report	Implementation Guidelines for Mobile Reception using DVB-T
Motivate DR/06 Report	Reference Receiver Model for Planning of Mobile DVB-T Services

A5. Web sites

DigiTAG http://www.digitag.org
DVB http://www.dvb.org
EACEM http://www.eacem.be
EBU http://www.ebu.ch

ERO	http://www.ero.dk
ITU	http://www.itu.int

2. SYSTEM ASPECTS

2.1 System specification and variants

2.1.1 Introduction

A specification has been established by the DVB project to describe a system for digital terrestrial television broadcasting.

The scope of the specification is as follows:

- it gives a general description of the system for digital terrestrial television;

- it identifies the global performance requirements and features of the system, in order to meet the service quality targets;

- it specifies the digitally modulated signal in order to allow compatibility between pieces of equipment developed by different manufacturers. This is achieved by describing in detail the signal processing on the modulator side, while the processing on the receiver side is left open to different implementation solutions.

The detailed features of the system can be found in the specification but some of the information related to frequency planning is discussed in this chapter.

2.1.2 System variants

The system originally designed for terrestrial digital television was to operate in the existing UHF spectrum allocation for analogue transmissions using an 8 MHz channel spacing. The 7 MHz version intended for Band III applications was derived by scaling[1]. For both versions it is required that the system provides sufficient protection against high levels of co-channel interference (CCI) and adjacent-channel interference (ACI) emanating from existing PAL/SECAM services. This was necessary if digital television was to be introduced into the bands already heavily used for analogue television transmissions.

To achieve these requirements an OFDM system with concatenated error correction coding is specified. To allow optimal trade off between network topology and frequency efficiency, a flexible guard interval is specified. This will enable the system to support different network configurations, such as large area single frequency networks (SFN) or multiple frequency networks (MFN), consisting of individual transmitters with neighboring transmitters on different frequencies.

The system allows for QPSK and different levels of QAM modulation and different code rates to be used to trade bit rate versus ruggedness. The system also makes

[1] An adaptation of the 8 MHz specification for use in 7 MHz channels can be achieved by scaling down all system parameters by multiplying the system clock rate by a factor of 7/8. The frame structure and the rules for coding, mapping and interleaving are kept, only the data capacity of the system is reduced by a factor of 7/8 due to the reduction of signal bandwidth.

allowance for two level hierarchical channel coding and modulation, including uniform and multi-resolution constellations.

2.1.3 Spectrum characteristics

The OFDM symbols constitute a juxtaposition of equally-spaced orthogonal carriers. The amplitudes and phases of the data cell carriers vary symbol by symbol, according to the mapping process described in § 4.3.5 of the Specification pr ETS 300 744.

2.1.4 Simulated System Performance

Tables 2.1, 2.2 and 2.3 which are for the 8 MHz version give simulated performance, assuming **perfect channel estimation and without phase noise,** of channel coding and modulation combinations, and are subject to confirmation by testing. These results are given for the Gaussian channel, Ricean channel (F_1) and Rayleigh channel (P_1) (See also chapters 4 and 5). Associated useful bit rates available are also indicated as a function of the ratio of guard interval to active symbol duration for the four different values of guard interval.

Gaussian channel Reception with no delayed signals, but taking account of thermal noise;

Ricean channel Situation where there is a dominant incoming signal with lower level delayed signals and thermal noise. This will normally be the case with directional receiving antennas at roof top level. In the case of an SFN, the delayed signals may also come from other transmitter sites;

Rayleigh channel Situations where there are several statistically independent incoming signals with different delay times, none of which dominates, together with thermal noise. There will be rapid and severe variations (from location to location) in the received signal, caused by multipath propagation. This will occur at low heights, in built-up areas and inside buildings, where there will be reflections from man-made obstacles and the ground. In the case of an SFN, the delayed signals may also come from other transmitter sites.

Mobile channel Situation corresponding to a Rayleigh channel but with a moving receiver (i.e. several statistically independent incoming signals affected by Doppler shift/spread, with different delay times, none of which dominates, together with thermal noise). There will be rapid and severe variations in the received signal caused by multipath propagation. However, the main degradation to the received signal is caused by the movement of the vehicle carrying the DVB-T receiver, the speed of which corresponds to a given Doppler frequency. Reception will normally be achieved by using a non-directional antenna situated at no less than 1.5 metres above ground level, on moving vehicles or trains, where there will be reflections from man-made obstacles and the ground. In the case of an SFN, the delayed signals may also come from other transmitter sites.

The C/N values given for the Ricean channel model should be used for the fixed reception case and those for the Rayleigh model should be used for the portable and mobile reception cases.

It must be noted that the C/N values given in these Tables are based on theoretical considerations. Estimates have been made of the increase which is likely to occur in any practical implementation. These estimates, which are based on practical experience and allow for some improvement over initial results, require an overall increase of 3 to 3.5 dB in the C/N values. Studies by the EC VALIDATE project have confirmed the validity of the estimates given in these Tables (once an implementation margin has been added), with the exception of the C/N values for code rates of 5/6 and 7/8 where rather higher C/N values were found. However, although their data rates seem to be attractive, it seems unlikely that system variants with such large code rates will be much used in practice as they are rather too sensitive to interference effects. (It should be noted that the VALIDATE results were presented in a somewhat different manner to the Tables shown here. In order to compare the two sets of results it is necessary to add the relevant implementation margins to each set of results before making the comparison.)

			Required C/N for BER=2 10^{-4} after Viterbi (quasi error-free after Reed-Solomon)			Net bitrate (Mbit/s)			
System	**Modulation**	**Code Rate**	**Gaussian channel**	**Ricean channel (F_1)**	**Rayleigh channel (P_1)**	**D/T_U =1/4**	**D/T_U =1/8**	**D/T_U =1/16**	**D/T_U =1/32**
A1	QPSK	1/2	3.1	3.6	5.4	4.98	5.53	5.85	6.03
A2	QPSK	2/3	4.9	5.7	8.4	6.64	7.37	7.81	8.04
A3	QPSK	3/4	5.9	6.8	10.7	7.46	8.29	8.78	9.05
A5	QPSK	5/6	6.9	8.0	13.1	8.29	9.22	9.76	10.05
A7	QPSK	7/8	7.7	8.7	16.3	8.71	9.68	10.25	10.56
B1	16-QAM	1/2	8.8	9.6	11.2	9.95	11.06	11.71	12.06
B2	16-QAM	2/3	11.1	11.6	14.2	13.27	14.75	15.61	16.09
B3	16-QAM	3/4	12.5	13.0	16.7	14.93	16.59	17.56	18.10
B5	16-QAM	5/6	13.5	14.4	19.3	16.59	18.43	19.52	20.11
B7	16-QAM	7/8	13.9	15.0	22.8	17.42	19.35	20.49	21.11
C1	64-QAM	1/2	14.4	14.7	16.0	14.93	16.59	17.56	18.10
C2	64-QAM	2/3	16.5	17.1	19.3	19.91	22.12	23.42	24.13
C3	64-QAM	3/4	18.0	18.6	21.7	22.39	24.88	26.35	27.14
C5	64-QAM	5/6	19.3	20.0	25.3	24.88	27.65	29.27	30.16
C7	64-QAM	7/8	20.1	21.0	27.9	26.13	29.03	30.74	31.67

Note: Quasi error-free means less than one uncorrected error event per hour, corresponding to BER = 10^{-11} at the input of the MPEG-2 demultiplexer.

Table 2.1: Required C/N for non-hierarchical transmission (8 MHz version) to achieve a BER = 2 10^{-4} after the Viterbi decoder for all combinations of coding rates and modulation types. The net bit rates after the Reed-Solomon decoder are also listed.

			Required C/N for BER=2×10^{-4} after Viterbi (quasi error-free after Reed-Solomon)			Net Bit rate (Mbit/s)			
Modulation	**Code Rate**	a	**Gaussian Channel**	**Ricean Channel (F_1)**	**Rayleigh Channel (P_1)**	D/T_U **=1/4**	D/T_U **=1/8**	D/T_U **=1/16**	D/T_U **=1/32**
QPSK	1/2	2	4.8	5.4	6.9	4.98	5.53	5.85	6.03
	2/3		7.1	7.7	9.8	6.64	7.37	7.81	8.04
	3/4		8.4	9.0	11.8	7.46	8.29	8.78	9.05
in						+			
Non-Uniform	1/2		13.0	13.3	14.9	4.98	5.53	5.85	6.03
	2/3		15.1	15.3	17.9	6.64	7.37	7.81	8.04
	3/4		16.3	16.9	20.0	7.46	8.29	8.78	9.05
16-QAM	5/6		16.9	17.8	22.4	8.29	9.22	9.76	10.05
	7/8		17.9	18.7	24.1	8.71	9.68	10.25	10.56
QPSK	1/2	4	3.8	4.4	6.0	4.98	5.53	5.85	6.03
	2/3		5.9	6.6	8.6	6.64	7.37	7.81	8.04
	3/4		7.1	7.9	10.7	7.46	8.29	8.78	9.05
in						+			
Non-uniform	1/2		17.3	17.8	19.6	4.98	5.53	5.85	6.03
	2/3		19.1	19.6	22.3	6.64	7.37	7.81	8.04
	3/4		20.1	20.8	24.2	7.46	8.29	8.78	9.05
16-QAM	5/6		21.1	22.0	26.0	8.29	9.22	9.76	10.05
	7/8		21.9	22.8	28.5	8.71	9.68	10.25	10.56

Table 2.2: Required C/N for hierarchical transmission (8 MHz version) to achieve a BER = $2 \cdot 10^{-4}$ after Viterbi decoder.

			Required C/N for BER=2×10^{-4} after Viterbi (quasi error-free after Reed-Solomon)			Net Bit rate (Mbit/s)			
Modulation	**Code Rate**	a	**Gaussian Channel**	**Ricean Channel (F_1)**	**Rayleigh Channel (P_1)**	D/T_U **=1/4**	D/T_U **=1/8**	D/T_U **=1/16**	D/T_U **=1/32**
	1/2		8.9	9.5	11.4	4.98	5.53	5.85	6.03
QPSK	2/3		12.1	12.7	14.8	6.64	7.37	7.81	8.04
	3/4		13.7	14.3	17.5	7.46	8.29	8.78	9.05
in		1				+			
	1/2		14.6	14.9	16.4	9.95	11.06	11.71	12.06
Uniform	2/3		16.9	17.6	19.4	13.27	14.75	15.61	16.09
64-QAM	3/4		18.6	19.1	22.2	14.93	16.59	17.56	18.10
	5/6		20.1	20.8	25.8	16.59	18.43	19.52	20.11
	7/8		21.1	22.2	27.6	17.42	19.35	20.49	21.11
	1/2		6.5	7.1	8.7	4.98	5.53	5.85	6.03
QPSK	2/3		9.0	9.9	11.7	6.64	7.37	7.81	8.04
	3/4		10.8	11.5	14.5	7.46	8.29	8.78	9.05
in		2				+			
	1/2		16.3	16.7	18.2	9.95	11.06	11.71	12.06
Non-	2/3		18.9	19.5	21.7	13.27	14.75	15.61	16.09
Uniform	3/4		21.0	21.6	24.5	14.93	16.59	17.56	18.10
64-QAM	5/6		21.9	22.7	27.3	16.59	18.43	19.52	20.11
	7/8		22.9	23.8	29.6	17.42	19.35	20.49	21.11

Table 2.3: Required C/N for hierarchical transmission (8 MHz version) to achieve a BER = $2 \cdot 10^{-4}$ after Viterbi decoder. Results for QPSK in non-uniform 64-QAM with $\alpha = 4$ is not included due to the poor performance of the 64-QAM signal.

2.1.5 Interpretation of the C/N performance for OFDM systems

Frequency planning for the introduction of a new broadcasting service is based on two main parameters of the transmission system; the required carrier to noise ratio (C/N) and the protection ratios (PR) needed to achieve a given quality target for the delivered signal (e.g. video and audio).

The introduction of digital broadcasting television systems implies some reconsideration of the planning procedures, in order to take into account the different behaviour of these systems and requires some clarification in the interpretation of the two relevant parameters: C/N and PR.

The characteristics of the terrestrial channel are random variables depending on the receiving location, on the receiving antenna and also on time. In fact the number of echoes, their amplitudes, delays and phases vary from place to place (and from time to time). Therefore at each location the frequency response of the channel is different. Even when the echo delays are within the guard interval, the input *C/N* required by the DVB-T system ([2]) depends on the channel characteristics. The presence of echoes produces frequency selective attenuations (notches) within the signal bandwidth, whose depths depend on the echo amplitude. The reason for the system sensitivity to the channel characteristics is due to the fact that the spectrum notches heavily attenuate some OFDM carriers (while the noise level remains constant), increasing their un-coded BER. The use of powerful inner codes (e.g. coding rates 1/2, 2/3 or 3/4) allows good recovery of the information of the attenuated carriers by means of the information carried by the other carriers. Therefore the use of these coding rates reduces the system sensitivity to the channel characteristics.
The noise margin loss between the Gaussian channel and the Rayleigh channel is of the order of 2 to 9 dB, depending on the echo characteristics and on the inner coding rate.

OFDM can exploit the power of multiple echoes in the sense that the available *C/N* at the receiver input increases, due to power summation of the *C* contributions, but at the same time the receiver performance can degrade (increase of the required *C/N*). As a result of these two effects, there can be a net performance gain or loss with multipath reception and SFN contributions. Apart from the low coding rate modes (e.g., coding rate ½), a single line-of-sight contribution (Gaussian channel) can give a better global performance than two 0-dB echoes (Rayleigh channel). Conversely, when the number of 0-dB echoes is larger than two, the required C/N does not increase further, and the global performance improves according to the growth of the available C/N. In addition to the above considerations, the space diversity in the presence of multi-path propagation or SFN echoes increases the probability that at least one contribution exceeds the required threshold of the receiver. This “statistical gain” is very important in obstructed areas and in single frequency networks.

Since a statistical characterisation of the system in the various reception environments is complex, two “representative” channels have been chosen in the specification (see Tables 2.1, 2.2 and 2.3) for computer simulations, one for fixed reception with a directive antenna (F1, Ricean channel) and one for portable or mobile reception (P1, Rayleigh channel). It should be noted that these representative channels are not a worse case, since a single 0 dB echo could introduce stronger degradations. It should also be noted that these channels include only relatively short natural echoes (up to 5.4 µs), well within the guard interval, and do not represent an SFN situation. As described in § 2.6, when an echo delay exceeds the guard interval, a steep transition occurs and the echo effect becomes similar to that of an un-correlated Gaussian noise interference, or even worse. For MFN planning, the echo delay configuration usually cannot be evaluated, therefore it is assumed that all the (natural) echoes fall within the guard interval.

[2] to achieve a final signal "quality" (e.g. BER<10^{-11} after Reed-Solomon decoding).

2.2 Modulation techniques

2.2.1 Orthogonal Frequency Division Multiplexing (OFDM)

The OFDM concept is based on spreading the data to be transmitted over a large number of carriers, each being modulated at a low bit rate. In a conventional frequency division multiplex the carriers are individually filtered to ensure there is no spectral overlap. There is therefore no inter-symbol interference between carriers but the available spectrum is not used with maximum efficiency. If however, the carrier spacing is chosen so the carriers are orthogonal over the symbol period, then symbols can be recovered without interference even with a degree of spectral overlap. For maximum spectral efficiency, the carrier spacing equals the reciprocal of the symbol period. The multiplex of carriers may be conveniently generated digitally using the inverse Fast Fourier Transform (FFT) process.

Preferred implementations of the FFT tend to be based on radix 2 or radix 4 algorithms, or some combination of radix 2 and 4. This preference leads to the number of carriers generated in practical OFDM systems being some power of 2. The specified systems are based on 2048 (2k) carriers and 8192 (8k) carriers. However, the number of actual carriers transmitted is always smaller than the maximum number possible, as some carriers at either end of the spectrum are not used. These unused carriers provide a frequency guard band which allows practical IF filtering. The active carriers carry either data or synchronisation information. Any n-QAM digital modulation scheme may be used to modulate the active carriers, where n is commonly 4, 16 or 64.

OFDM, due to its multicarrier nature, exhibits relatively long symbol periods, 224µs in a 2k system. This long symbol period provides a degree of protection against inter-symbol interference caused by multipath propagation. This protection can, however, be greatly enhanced by use of a guard interval. The guard interval is a cyclic extension of the symbol, in simplistic terms a section of the start of the symbol is simply added to the end of the symbol. The guard intervals for the 2k and 8k systems, respectively, are:

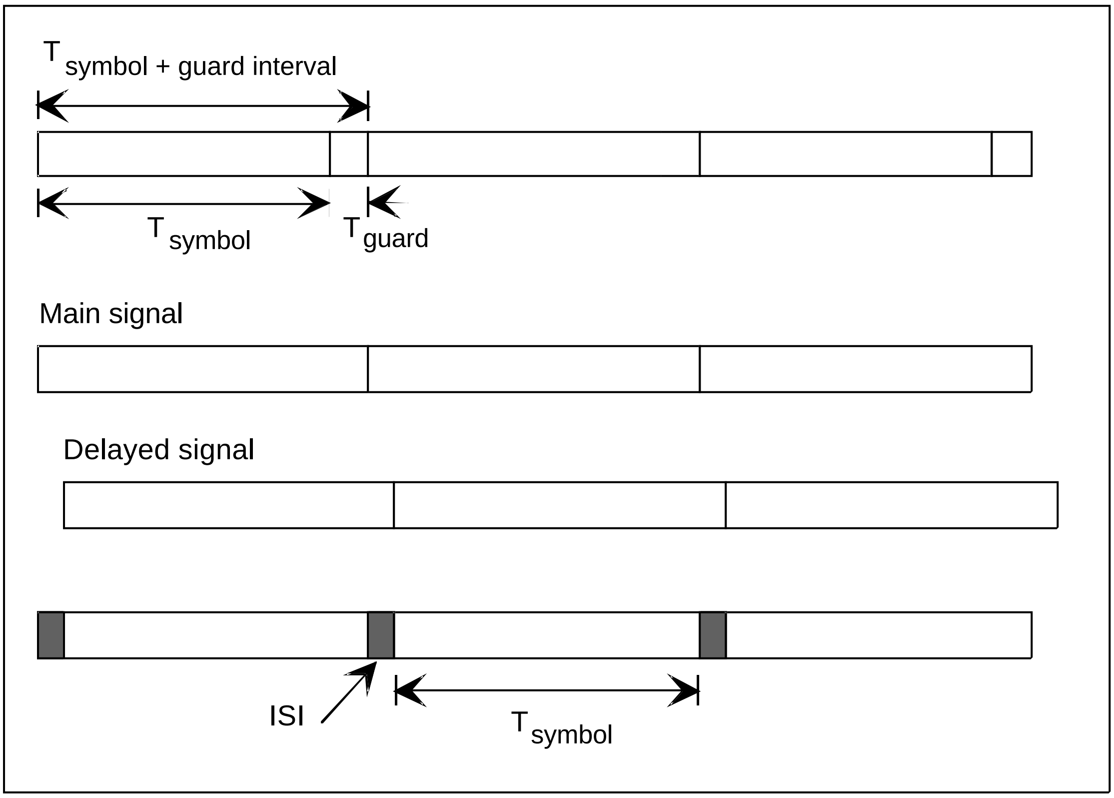
1/32 of the symbol period (7 or 28µs);
1/16 of the symbol period (14 or 56µs);
1/8 of the symbol period (28 or 112µs);
1/4 of the symbol period (56 or 224µs).

As the proportion of the symbol used to make the guard interval is increased, the transmission capacity decreases. However, if a system with a greater number of carriers were used, the symbol period would increase and therefore the same proportion of guard interval would give a greater protection in terms of absolute time. For example, the 8k system with a symbol period of 896µs and 1/4 of the symbol period guard interval results in a 224µs guard interval. Increasing the number of carriers has some drawbacks:

- higher complexity (FFT performed on a higher number of samples and more memory);
- higher sensitivity to tuner phase noise.

Therefore a trade-off is necessary. Figure 2.2 shows how the FFT sampling window, which is equivalent to the symbol period can be positioned within the symbol and guard interval to minimise inter symbol interference (ISI).

Figure 2.2: Guard Interval Utilisation



OFDM, when coupled with appropriate channel coding (error correction coding), can achieve a high level of immunity against multipath propagation and against co-channel interference e.g. PAL, SECAM, NTSC. OFDM systems also offer the broadcaster great flexibility as bit rate can be traded against level of protection depending on the nature of the service. For example, even mobile reception of the OFDM signal may be possible given due consideration to factors including vehicle speed, carrier spacing, data rate and modulation scheme, whereas, for a service with fixed reception, high order modulation schemes and consequently high bit rates could be used.

OFDM signals also allow the possibility of single frequency network (SFN) operation. This is due to OFDM's multi-path immunity. SFN operation is possible when exactly the same signal, in time and frequency, is radiated from multiple transmitters. In this case, at any reception point in the coverage overlap between transmitters, the weakest received signals will act as post or pre-echoes to the strongest signal. However, if the transmitters are far apart the time delay between the received signals will be large and the system will need a large guard interval.

The choice of the main parameters for the OFDM system is determined from the requirement for SFN operation.

2.3 Minimum receiver signal input levels

To illustrate how the C/N ratio influences the minimum signal input level to the receiver, the latter has been calculated for five representative C/N ratios, including the implementation margin, in the range 2 dB to 26 dB (see Tables 2.4a and 2.4b). For other values simple linear interpolation can be applied.

The receiver noise figure has been chosen as 7 dB for all the frequency bands I to V and thus the minimum receiver input signal level is independent of the transmitter frequency. If other noise figures are used in practice, the minimum receiver input signal level will change correspondingly by the same amount.

The minimum receiver input signal levels calculated here are used in chapter 5 to derive the minimum power flux densities and corresponding minimum median equivalent field strength values for various frequency bands.

Definitions:

- B : Receiver noise bandwidth [Hz]
- C/N : RF signal to noise ratio required by the system [dB]
- F : Receiver noise figure [dB]
- P_n : Receiver noise input power [dBW]
- $P_{s\,min}$: Minimum receiver signal input power [dBW]
- $U_{s\,min}$: Minimum equivalent receiver input voltage into Z_i [dBμV]
- Z_i : Receiver input impedance (75Ω)

Constants:

- k : Boltzmann's Constant $= 1.38 \cdot 10^{-23}$ Ws/K
- T_0 : Absolute temperature = 290 K

Formulas used:

$$P_n = F + 10 \log (k*T_0*B)$$
$$P_{s\,min} = P_n + C/N$$
$$U_{s\,min} = P_{s\,min} + 120 + 10 \log (Z_i)$$

Frequency Band I, III, IV, V – 8 MHz channels						
Equivalent noise band width	B [Hz]	$7.6*10^6$	$7.6*10^6$	$7.6*10^6$	$7.6*10^6$	$7.6*10^6$
Receiver noise figure	F [dB]	7	7	7	7	7
Receiver noise input power	P_n [dBW]	-128.2	-128.2	-128.2	-128.2	-128.2
RF signal/noise ratio	**C/N [dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\,min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\,min}$ [dBμV]	13	19	25	31	37

Table 2.4a: Minimum equivalent input signal level to receiver for 8 MHz version.

Frequency Band I, III, IV, V – 7 MHz channels						
Equivalent noise band width	B [Hz]	$6.7*10^6$	$6.7*10^6$	$6.7*10^6$	$6.7*10^6$	$6.7*10^6$
Receiver noise figure	F [dB]	7	7	7	7	7
Receiver noise input power	P_n [dBW]	-128.7	-128.7	-128.7	-128.7	-128.7
RF signal/noise ratio	**C/N [dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\,min}$ [dBW]	-126.7	-120.7	-114.7	-108.7	-102.7
Min. equivalent receiver input voltage, 75 Ω	$U_{s\,min}$ [dBμV]	12	18	24	30	36

Table 2.4b: Minimum equivalent input signal level to receiver for 7 MHz version

Note: This table provides a derivation of minimum required signal levels. §§ 5.2 and 5.3 provide information on the minimum median values of signal levels required in practical situations.

2.4 Protection ratios

Protection ratios for various interference situations related to digital television are still being studied.
In the obvious case:

- digital television interfered with by digital television,

final protection ratios are not yet available. For preliminary calculations and planning exercises, these protection ratios have been provisionally set equal to the C/N value for the system in question. However, it is expected that somewhat higher values will be applicable in SFNs because of the presence of relatively high levels of delayed signals with delays longer than those from nearby objects.

In cases where interference occurs between analogue and digital television, two sets of protection ratios are needed:
- Analogue television interfered with by digital television;
- Digital television interfered with by analogue television.

These sets of protection ratios must cover relevant analogue television systems:
- B/G PAL/A2;
- B/G PAL/NICAM;
- D/K SECAM;
- D/K PAL;
- I PAL/NICAM;
- L SECAM/NICAM.

Values adopted provisionally by the EBU for UHF are given in the tables below. The cases of overlapping channels at VHF are not yet dealt with.

In the case of digital television interfered with by analogue television the protection ratios for planning purposes are provisionally assumed to be 12 dB lower than the minimum C/N for the digital system in question.

Where digital television is the wanted signal no distinction has been made between Continuous interference and Tropospheric interference[1] because of the abrupt failure characteristic of digital television systems.

Minimum C/N requirement (dB)	Wanted digital signal in channel N; Interfering digital signal in channel:			
	N - 1	N	N + 1	Other
	C & T[1]	C & T	C & T	C & T
2	-30[1)]	2	-30[1)]	-30[1)]
8	-30[1)]	8	-30[1)]	-30[1)]
14	-30[1)]	14	-30[1)]	-30[1)]
20	-30[1)]	20	-30[1)]	-30[1)]
26	-30[1)]	26	-30[1)]	-30[1)]

Table 2.5: Protection ratios for Digital Television interfered with by Digital Television [dB]
1): Assumed value, no data available.

[1] C: Protection ratios for Continuous interference referring to impairment grade 4
T: Protection ratios for Tropospheric interference referring to impairment grade 3

Minimum C/N requirement (dB)	Wanted digital signal in channel N; Interfering analogue signal in channel:			
	N - 1	N	N + 1	Other
	C & T*	C & T	C & T	C & T
2	-30 1)	-10	-30 1)	-30 1)
8	-30 1)	0	-30 1)	-30 1)
14	-30 1)	2	-30 1)	-30 1)
20	-30 1)	8 2)	-30 1)	-30 1)
26	-30 1)	14 2)	-30 1)	-30 1)

Table 2.6: Protection ratios for Digital Television interfered with by Analogue Television [dB]
1): Assumed value, few measured results available.
2): Value taken to be 12 dB lower than for digital television interfered with by digital television. Preliminary measured results indicate that this is a reasonable assumption for planning purposes.

Analogue system	Wanted analogue signal in channel N; Interfering digital signal in channel:									
	N – 1		N		N + 1		Image		Others	
	C*	T*	C	T	C	T	C	T	C	T
G/PAL	-4	-7	40	34	-7	-9	-15	-19	1)	1)
I/PAL	-4	-9	41	37	-3	-6	1)	1)	1)	1)
K/PAL	1)	1)	1)	1)	1)	1)	1)	1)	1)	1)
K/SECAM	-1	-5	41	35	-5	-8	-11	-16	1)	1)
L/SECAM	-7	-9	42	37	-1	-1	-22	-25	-40 2)	-40 2)

Table 2.7: Protection ratios for Analogue Television interfered with by Digital Television [dB]
1): No data available.
2): For L/SECAM the protection ratios for the channels N-5 to N-2 and N+2 to N+4 are between -26 dB and -40 dB.

Wanted sound of analogue television system	unwanted DVB-T (8 MHz)	
	C	T
FM	15	5
AM	40	30
NICAM/400/400 kBut/s	12	11
NICAM/700 kBit/s		

Table 2.8: Protection ratios for analogue television sound channel interfered with by Digital Television

(Reference level for the wanted sound signal is the level of the wanted sound carrier)

2.5 Frequency offsets

The use of frequency offset as a means of reducing protection ratios is well known in analogue television planning and implementation. A similar effect may exist for digital television when interfered with by analogue television. At the time of writing (June 1997) insufficient knowledge about this subject is available although the preliminary measured results suggest that the benefits may not be large.

2.5.1 General

Two types of frequency offset can be considered for digital television. Fine offset is a shift in centre frequency of up to about 2 kHz in order to improve co-channel protection.

Coarse offset means a shift in centre frequency of about 200 kHz in order to improve compatibility with a service in an adjacent channel.

2.5.2 Fine offset

Based on the carrier spacing in the DVB-T signal, in particular in the 8k mode, it can be expected that if fine offset can be used to improve co-channel protection it will imply the use of precision offset on the analogue television transmitters involved, as well as a correspondingly high frequency stability of the DVB-T transmitter.

2.5.3 Coarse offset

The OFDM signal for the 8 MHz version of DVB-T has a bandwidth of about 7.6 MHz leaving a guard band between adjacent channels of 400 kHz. If two DVB-T transmitters are to share a common antenna this should be possible without using any coarse offset. The diplexer would then need to have characteristics similar to those of a System G sound/vision combiner, where the “cross-over band” is about 450 kHz wide.

If the DVB-T transmitter must operate on a channel adjacent to a co-sited analogue television transmitter of if an adjacent channel DVB-T service, partly covering the same geographical area, must be protected, a coarse offset of the DVB-T transmitter(s) may be considered.

Coarse offset could also be used to improve compatibility with other services in television channels adjacent to such services. Examples are channels 21 to 69, and in some countries channels 35, 37 and 39.

In order not to cause a partial overlap with an adjacent DVB-T channel, the coarse offset should not exceed the width of the guard band.

A coarse offset of 218.75 kHz is considered to be sufficient for frequency separation as described above and is also believed to be acceptable with respect to receiver synthesiser design. The value is equal to 14 times the line frequency and:

- 49 times the carrier spacing in the 2k mode; or,
- 196 times the carrier spacing in the 8k mode.

Other values of offset could be adapted but precise relationships with carrier spacings may need to be retained.

2.6 C/N ratio requirements and interpretation for SFN planning (active echoes)

In SFN planning, the statistics (levels and delays) of the "artificial" echoes from the various transmitters can be evaluated by the planner. In general, not only noise, but also delayed signals are present at the receiver input, and the echoes outside the guard interval have an important impact on the coverage achievable in SFN. The channel estimation process in the receiver, for constellation equalisation and coherent detection, is based on a frequency domain interpolation filter, which allows recovering of the channel response from the scattered pilot carriers. The pass-band T_F of this filter is designed to be larger than the guard interval ($T_g=T_u/4$) ([3]), but, because of theoretical limitations, cannot exceed $T_u/3$ (practical figures are up to $T_F= (7/24)T_u$ for a sophisticated receiver). The following cases can take place:

- the echo is within the guard interval T_g: its power adds to the "useful" signals;
- the echo is outside T_g, but within T_F: it is correctly equalised, but is split into a useful component (relevant to the actual OFDM symbol) and an interfering component (relevant to the previous OFDM symbol), as described in the formula below;
- the echo is outside T_F: it is to be considered as pure interference, with the same effect as an equal-power Gaussian noise.

The following formula describes the above considerations:

$$w_i = \begin{cases} 0 & \text{if } t \le 0 \\ 1 & t \le T_g \\ \left(\dfrac{T_u - t + T_g}{T_u}\right)^2 & \text{if } T_g < t < T_F \\ 0 & \text{if } t \ge T_F \end{cases}$$

$$C = \sum_i w_i C_i$$

$$I = \sum_i (1 - w_i) C_i$$

where:

C_i is the power contribution from the i-th transmitter

C is the total power of the effective useful signal (including natural and artificial echoes at the receiver input)

I is the total effective interfering power

w_i is the weighting coefficient for the i-th component

Instead of the required C/N ratio, a new system parameter is introduced, the **"*Effective Protection Target*"** (EPT) which represents the ratio between the power of the wanted signals (echoes within T_g and useful component of the echoes falling between T_g and T_F) and the sum of the powers of noise and effective interference (interfering component of the echoes falling between T_g and T_F echoes, and echoes outside T_F) at the system threshold.

The required *EPT* depends on the system parameters (modulation and code rate) and on the characteristics of the echoes inside T_F, which determine the *criticality* of the frequency selective channel.

For fixed reception, the channel is Ricean-type when a single transmitter dominates, while it becomes Rayleigh-type when a number of strong artificial echoes within the guard interval are present. In the case of portable reception, the channel is typically Rayleigh-type both with natural echoes and with artificial SFN echoes.

In SFN planning, it is assumed that the system can operate satisfactorily in a given location, in the presence of Gaussian noise and of echoes inside and outside the guard

[3] For smaller guard intervals (e.g. $T_g=T_u/8,\ldots, T_u/32$), it can be assumed that the interpolator filter bandwidth remains the same as for $T_u/4$.

interval, when the available aggregate C/N+I (in a bandwidth of 7.61 MHz) is larger or equal to the required *Effective Protection Target* (*EPT*):

$$\left.{}^{C}\!/_{N+I}\right|_{\text{Available}} \equiv \frac{1}{\left({}^{C}\!/_{N}\right)^{-1} + \left({}^{C}\!/_{I}\right)^{-1}} \geq EPT$$

EPT is given by the following empirical formula (proposed by RAI and derived by computer simulations), where all the items are expressed in dB:

$$EPT = \begin{cases} \left.{}^{C}\!/_{N}\right|_{F} + \left(\left.{}^{C}\!/_{N}\right|_{P} - \left.{}^{C}\!/_{N}\right|_{F}\right)\left(\dfrac{0.5}{\left(\left.{}^{C}\!/_{N}\right|_{P} - \left.{}^{C}\!/_{N}\right|_{F}\right)}\right)^{\frac{K_A}{10}} + \Delta_1 + \Delta_2 & \text{for fixed reception} \\ \left.{}^{C}\!/_{N}\right|_{P} + \Delta_1 + \Delta_2 & \text{for portable reception} \end{cases}$$

where:

EPT is the required system effective protection target in a particular SFN echo environment

C/N(F) is the carrier to noise ratio required by the system on the F1 channel as given in Annex A of the DVB-T specification (see Tables 2.1, 2.2, 2.3)

C/N(P) is the carrier to noise ratio required by the system on the P1 channel as given in Annex A of the DVB-T specification (see Tables 2.1, 2.2, 2.3)

Ka "channel criticality due to artificial echoes" is the ratio between the power received from the main transmitter and the total power of the artificial echoes inside the guard interval (but Ka < 0 dB)

D_1 is the total system implementation loss, in the range of 3 to 3.5 dB depending on the channel estimation algorithm

D_2 is an aggregate performance loss due to the echoes outside the guard interval which produce aliasing and noise increase on the channel estimation. Pending other results, D_2 should be set equal to 0 dB.

2.7 Carrier and guard interval designator

To account for the number of carriers and the guard interval ratio used in a given implementation of DVB-T, the designators given in Table 2.9 may be used. This is of particular relevance when completing the information required for data exchange purposes (see Chapter 10 and Annex 10.2).

Designator	Number of carriers	Guard interval ratio
A	2k	1/32
B	2k	1/16
C	2k	1/8
D	2k	1/4
E	8k	1/32
F	8k	1/16
G	8k	1/8
H	8k	1/4

TABLE 2.9

3. PROPAGATION

3.1 Prediction of 50% location signal levels

Propagation prediction methods using information from a terrain data bank exist in a number of countries and give significant improvements in prediction accuracy when compared with simple methods such as ITU-R Rec. PN.370[1]. However, it has been found that these newer methods cannot be applied universally due to the use of empirical correction factors within each of the computer programmes which improve results for the type of terrain found in a specific country.

Tests have been carried out within the EBU to investigate the magnitude of the differences introduced in this way (by comparing predictions with measurements) and it has been found that none of the available programmes performs consistently better than the use of a simple method such as Rec. P.370. The latter is essentially statistical in nature and its curves are intended to give reasonable results for the type of terrain met in most of Region 1. Rec. P.370 also has the advantage of having been agreed internationally, for use at conferences, for example.

It is interesting to note that some recent experiments have indicated that Rec. P.370 may provide a better propagation prediction method than some of more complex terrain databank methods as far as T-DAB signals are concerned. Because both T-DAB and terrestrial digital television are OFDM systems, it seems probable that Rec. P.370 may thus provide a reasonable propagation prediction method for the case of terrestrial digital television. However, it is necessary to remember that Rec. P.370 is a statistical method and that it cannot predict areas of poor reception due to signal level reduction caused by obstructions on the propagation path. Indeed, some experiments have indicated that the standard deviation of the difference between a 50% location measurement and a ITU-R Rec. P.370 prediction is around 13 dB. Such a high value indicates that it may not be very important for the accuracy of the prediction what is the exact value of location variation associated with OFDM signals - whether this value is 4 dB or 7 dB is not really very important. The latter topic is dealt with in more detail in § 3.2 and § 3.3.

Because of the very significant differences in propagation conditions for overland and over sea paths, a coastline (possibly in a simplified form) must be included in the propagation prediction calculations to permit account to be taken of these differences in the calculation of interference levels.

3.1.1 Prediction of wanted signal levels

There are no particular considerations to be taken into account when predicting <u>wanted</u> signal levels for an individual transmitter to receiver path in the case of predictions based on ITU-R Rec. P.370. Values for 50% of the time are appropriate in this case as this time percentage is also applicable to the 99% time requirement for wanted signals. At the short distance ranges involved, up to about 60 km, there is

[1] The ITU-R is currently considering a new Recommendation which may replace Rec. P.370. Both of these two Recs. can be described as “path general” methods as they do not take into account most of the specific features of individual propagation paths. For the purpose of the discussions in this chapter of the handbook, these two methods may be regarded as equivalent.

negligible difference in the signal level values for 50 and 99% of the time. However, there are differences in propagation over land and sea paths and it is thus necessary to take account of the nature of any individual propagation path; that is, whether it is all-land, all-sea or a mixed land-sea path.

Where the relevant information is available, Rec. P.370 allows for a correction to be made using the terrain clearance angle for the path from a specific receiving location in the direction of the transmitting site.

Signal level predictions using a terrain data bank will take into account whatever information the individual model requires. As noted above, the value predicted for a given path can be expected to be dependent upon the model used.

3.1.2 Prediction of unwanted signal levels

In the course of both a planning process and a co-ordination process it is necessary to predict the level of interference field strength produced by one transmitting station in the service area of another. When calculating the level of interfering field strength, the 1% time curves of ITU-R Rec. P.370 should be used. Other methods may, however, be used if there is agreement between the countries concerned.

Ideally, the calculation should be made to points defining the coverage area of the station to be protected. However, in some circumstances, this may not be possible or necessary. Two cases can be distinguished:

<u>Prediction to points defining the service area</u>

Predictions of interfering field strengths would normally be made to points on the periphery of the service area of the station to be protected. It is preferable that points defining the edge of the service area are specified or calculated on 36 or 12 equally-spaced radials from the transmitter site. The terrain clearance angle correction described in Rec. P.370 may be included in the calculation of interference field strengths at these points, if sufficient information concerning local terrain is available. In the case where the boundary points are specified, rather than being calculated, there is no particular requirement that they be on equally-spaced radials.

<u>Prediction to the location of the transmitting site</u>

In some cases it may not be possible or necessary to define the service area in the manner described in the preceding paragraph. An example of this would be where the station to be protected is a low power station with a very small coverage radius. To define the service area and calculate interference levels at many points would involve unnecessary computation. In this case, the location of the transmitting station can be taken as representative of the service area to be protected, and the prediction of interference field strength can be made to that point. However, since the terrain height of the transmitting site would not be representative of the area to be protected, terrain clearance angle corrections should not be applied.

3.2 Location statistics

Within a small area, say 100 m x 100 m, there will be a random variation of signal level with location which is due to local terrain irregularities. The statistics of this type of variation are generally characterised by a log-normal distribution for the signal levels. Recent measurements for digital signals have shown that the standard deviation will be about 5.5 dB depending, to some extent, on the environment surrounding the receiving location.

It cannot really be said that there is yet a large amount of measured data to fully justify any individual value of the standard deviation of location variation for digital television signals conforming (more or less, depending upon the particular experimental implementation) to the DVB specification. However, the evidence which is available indicates that this standard deviation is likely to be close to 5.5 dB, at least for outdoor paths. Any values related to outdoor coverage in the remainder of this document will be based on a standard deviation of 5.5 dB. For reception indoors, the standard deviation will be larger and this subject is treated in detail in Chapter 5. The difference between 50% and 95% of locations is thus taken to be 9 dB and that between 50% and 70% of locations is taken to be 2.9 dB. It must be stressed that such a value takes no account of the inherent inaccuracies of any propagation prediction method.

In the case that the wanted signal is composed of several individual signals from different transmitters the resulting standard deviation becomes variable, depending on the individual signal strengths. As a consequence, the difference between 50% and 70 or 95% of locations becomes variable. However, it always will be smaller than that of an individual signal. This item is dealt with in more detail in § 6.3.

3.3 Calculation of coverage area for digital television

3.3.1 Necessity for complex calculation methods

The main questions when trying to build new digital television terrestrial networks are the evaluation of the service area and the population covered. These evaluations are made through the estimation of the level of the useful signal(s) and the level of the interfering signals. As indicated in § 3.3.2, because of the rapid failure of digital reception when the level of the useful signal decreases below its "minimum" value, the target for the percentage of locations nominally at any edge[2] of the service area has to be much higher for digital systems than the 50% of locations used for analogue television systems. Values ranging from 70 to 95% are usually quoted for digital television transmissions (see Chapter 4). Under such considerations, some of the simpler tools used for analogue television coverage evaluations are not completely satisfactory and it is necessary to make more complex calculations.

3.3.2 Impact of rapid failure characteristic

In the process of evaluating the coverage area of the analogue television service using usual prediction tools, the value of the field strength specified at the edge of the coverage area is a mean value. It represents the average value of all the real values of the field strength that could be measured within a small area, usually taken to be 100 m x 100 m. That means that in this small area, about half of the real values of the field strength are under this mean value and about half are above this value. For analogue television, if the value of, say, 67 dBμV/m is specified as the lower limit of the mean value, that indicates that smaller values of the field strength can be found inside the coverage area. But, if 67 dBμV/m corresponds to grade 4 for the picture

[2] The term "edge" is taken to mean any transition between a covered area and a non-covered area. These "edges" may occur at the outer boundary of a coverage area or at the boundaries of any uncovered areas which may exist inside the overall area, usually as the result of local screening on the path of the wanted signal.

quality according to the ITU scale, a lower value of field strength will give a somewhat lower quality because of the smooth degradation of analogue reception in presence of noise or in presence of interference. A reduction of about 6 dB for the C/N or C/I will lead to a loss of one grade of picture quality. Thus, at the edge of the service area, even if the real value of the wanted field strength is below the specified limit value, a picture will still be received but with a lower quality. We can say that the inherent assumption for analogue television is that the "average" quality is grade 4 at the edge of the service area.

Concerning digital television, it is known that the behaviour of the receiver is completely different. When the level of signal decreases and the C/N or C/I falls below a given "minimum" value, the picture disappears completely with a further signal level reduction of less than about 1 dB. This behaviour is generally referred to as the "rapid failure characteristic of the digital system" and the limit value of the field strength is designated as the minimum field strength. If the same coverage definition as for analogue television were used for digital television, this would mean that 50% of the locations would not be served at or near the edge of the service area or in any other areas of reduced signal caused by local obstructions. This is due to the fact that there is no smooth degradation for digital receivers, the picture quality changes rapidly from grade 5 to grade 0, in effect without any intermediate levels of quality. This value of only 50% of locations receiving a picture is clearly unacceptable, higher values of the percentage of locations have to be selected in order to allow reception in a larger number of household, with a standard receiving installation.

The exact value chosen depends on the level of service quality which is aimed at, and that is why values can be different from one country to another or even from one company to another within a given country. Nevertheless, two values, 70% and 95% of the percentage of locations, have been chosen in the proposed coverage definitions (see Chapter 4).

3.3.3 Use of C/I and C/N

The assessment of the coverage area of a wanted digital transmitter is carried out using the parameters of the chosen system and taking into account all the transmitters operating in the vicinity of the digital transmitter on the same channel or on adjacent channels. As the DVB-T specification offers a wide range of systems, there are as many sets of parameters as systems. Most of these signals will interfere with the wanted digital signal; the exception is an SFN for which signals coming from nearby transmitters may make a positive contribution. It must be noted that the expression "in the vicinity" used in the first sentence of this paragraph may mean "within a few hundred km".

3.3.3.1 Case of one receiving location

For one receiving location to be covered by a digital television transmission, we know that the level of the wanted signal, expressed in dB, has to be higher than the level of noise by a certain value which is the minimum C/N ratio. This can be expressed in dB by the formula $C > \alpha + N$, α being here the **minimum C/N** and N the minimum signal level and C the signal level of the wanted signal. In the same way, to overcome the effect of an interferer, the level of the wanted signal must be higher than the level of this interferer by a certain value referred to as the protection ratio for this particular type of interferer. It can also be expressed in dB by $C > \beta + I$, β being the protection ratio (related to the **minimum C/I**). The sum $\beta + I$ (protection ratio + field strength of interferer) is often referred to as the nuisance field. (In practice, the receiving antenna discrimination against the interfering signal may also need to be taken into account).

Due to the different natures and bandwidths of the interferers which cause different effects on the carriers of the OFDM signal, the value of the protection ratio is very different from one type of interferer to another. Protection ratios are evaluated in laboratories with the assumption that there is only one source of interference (noise or one unwanted signal only).

In the real world, the wanted signal undergoes interference from noise and, possibly, several interferers which can be of different types. The level of the wanted signal must thus be compared with a combination of unwanted signals. It is clear that, due to the different nature of the signals, the power of the wanted signal cannot be compared directly to the power sum of the noise and the interferers.

The notation C/(N+I) should thus be avoided because the term (N+I) could be interpreted as an addition of the power of the noise and the power of each interferer, this would lead to a value that has no meaning. The only values that can be compared to the wanted signal are the nuisance fields ($\beta + I$).

Due to the fact that, in this particular case of one receiving location, the levels of the signals are real values, the condition of good reception can simply be expressed as :

$$\Sigma P_C \geq P_N + \Sigma P_{(\beta+I)}$$

where:

ΣP_C : power of the wanted signals
P_N : noise power equivalent
$\Sigma P_{(\beta+I)}$: power of the nuisance fields
and all powers are expressed arithmetically.

3.3.3.2 Case of small area

In practice, it is not possible to know the real values of the field strength for each receiving location in order to apply the previous formula and to determine precisely the coverage area. The only figures that can be evaluated are the **mean values** of the field strengths in small areas (typically 100 m x 100 m).

The problem is then to know if one given small area is inside or outside a coverage area and for that, the probability of good reception in this areas is calculated. This probability represents the percentage of receiving locations which can receive a satisfactory signal (that is, whose power is greater than or equal to the sum of the noise and nuisance powers) within the small area. A small area is found to be inside the overall coverage area if the probability is higher than a given threshold, 70% or 95% (for the coverage definitions given in Chapter 4).

The calculation of the probability is carried out using the appropriate fixed values for the level of noise and the protection ratios of each type of interferer and for the field strengths which are random variables, with prediction of the mean level of the wanted field strength and of each unwanted signal using the prediction method of the ITU-R Rec. P.370 or prediction models using terrain data banks.

But, because the wanted and nuisance powers are random variables which are only known through their means and standard deviations, the formula given above must not be applied only to the means of the wanted and nuisance powers. Therefore, it is necessary to refer to mathematical models for the distribution of field strength with locations and to use mathematical methods to obtain the result of the combination of several randomly distributed signals.

3.3.4 Calculation methods

The basic principle when evaluating a service area is to estimate mean value and standard deviation of wanted field strength and unwanted field strength in a large number of test locations in the assumed service area and with these values, to calculate the percentage of locations served. This could be done for different bearings originating from the transmitter location, for example every 10 degrees, or, in some cases, with a higher density of test locations.

For analogue television, equal values of the wanted field strength and the nuisance field strength correspond to a coverage of 50% of locations. Different methods have been developed to calculate the equivalent nuisance signal level when there are several interfering signals. These methods can be found in Rep. 945 of the ITU-R. In the case of an SFN the wanted signal may also be composed of several individual signals.

3.4 Combination of signal levels for coverage assessments

3.4.1 Introduction

One of the questions to be answered is how to combine interfering signals when there is more than one and how to take into account the effect of noise. Some of the calculation methods to deal with this question are presented below. They are all statistical methods which require computer processing and they use models of the real situation. In all the methods, except the power sum method, it is assumed that field strengths have a log normal distribution with location.

The first method is a numerical approach which is capable of providing the required accuracy but at the expense of a large amount of computer time. The remaining methods are approximations which are presented in order of growing complexity and this increasing complexity corresponds to an increasing computer processing time.

It should be noted that though there may exist some correlation between the individual signals, wanted as well as unwanted signals, none of the methods described below include the treatment of correlation in their original form. However some of them can be extended to include correlation. The effect of correlation varies with the reception situation. It can produce either an increase or a decrease of coverage depending upon the particular correlation situation.

3.4.2 The Monte-Carlo method

Apart from a deterministic (numerical integration) method, the Monte-Carlo approach is the most accurate method available to evaluate the coverage probability. With the mean value and the standard deviation of the distribution of each signal it is possible to simulate the situation for a large number of reception locations in a small area (say, 100m x 100m). This is done by generating one random value of the wanted field and one random value of each interferer. For each combination it is possible to check if the reception location is served or unserved by comparing the power of the useful signal with the sum of the powers of the noise and the nuisance fields. By repeating this simulation for a large number of combinations of wanted and unwanted signals, the coverage probability for a given small area may be derived. The higher the number of combinations, the more accurate the method becomes but this can lead to very lengthy computer processing times. In addition, the process must be repeated for a large number of small areas in order to represent the overall coverage area.

3.4.3 Power sum method

A description of the power sum method as applied to analogue television is given in EBU doc. Tech 3254. This method has been used for the assessment of multiple interference at several ITU conferences. The sum of the signal levels is calculated by a non statistical summation of the individual signal powers. For the unwanted signal, the powers of the mean values of the individual nuisance fields are added to the power of the minimum field strength (representing the noise contribution). For the wanted signal in an SFN, the powers of the individual useful fields are added. A 50% location coverage is obtained if the sum of the unwanted signal levels equals the sum of the wanted signal levels.

For digital television, a margin must be added to the resulting nuisance field in order to cover more than 50% of the locations. This margin is related to the target percentage of locations. Its value is not derived by the power sum method. Usually a value derived from the standard deviation of a single signal is used.

The method gives acceptable results for a 50% locations target but shows a poor behaviour for higher percentages due to its non-statistical character. Detailed formulas are given in Annex 3.1.

3.4.4 Simplified multiplication method

The simplified multiplication method is a statistical computation procedure which has also been used for the assessment of multiple interference, for instance at the Regional VHF/FM Broadcasting Conference (Geneva, 1984).

It gives the coverage probability in the presence of several interfering signals which are assumed to be log-normally distributed with known mean values and standard deviations. The coverage area can be determined by calculating the probability for different locations. The contour of the coverage area is made up of the set of locations where the coverage probability achieves the required value.

As the effect of noise is not taken into account in the statistical treatment, over-estimation of the coverage can be expected when the levels of the interferers are low. However, it is possible to add the effect of noise at the end of the calculation process.

This method is explained in detail in EBU doc. Tech 3254, but it must be noted that it is not applicable to SFNs since it cannot deal with multiple useful signals.

3.4.5 Log-normal method

The log-normal method is an approximation method for the statistical computation of the sum distribution of several log-normally distributed variables. In a coverage calculation it gives the coverage probability of the small area under consideration. The method is based on the assumption that the resulting sum distributions of the wanted and unwanted fields are also log-normal. It is composed of several steps. First the distributions of the composite wanted (C) and unwanted (NF) fields are calculated. Then the corresponding distributions of C/NF and C/N are evaluated. Finally, the combination of these distributions gives the coverage probability. To some extent, the LNM is able to cope with different standard deviations of the single field distributions.

To improve the accuracy of the LNM in the high probability region (that is, a high coverage value) a correction factor can be introduced. This version of the LNM is called k-LNM.

Detailed formulas of standard LNM and k-LNM are given in Appendix 3.2. A simplified version of standard LNM is described in ITU-R Rep. 945. (This is not to be confused with the so-called 'simplified log-normal method' which is applicable only for 50% coverage calculations and therefore of no use for digital television planning).

3.4.6 The t-LNM method

The t-LNM method is a numerical approximation method for the statistical computation of the sum distribution of several log-normally distributed variables. Its structure is similar to that of the standard LNM and it is based on the same idea, i.e. that the sum distribution of two log-normal variables is also log-normal. However, the parameters of the sum distribution are calculated in a different way and, as a consequence, are different from those of the standard LNM.

This approach leads to a higher accuracy in the high probability region (that is, a high coverage value) compared to the standard and k-LNM approaches but this must be paid for with higher mathematical complexity. The t-LNM method is able to process different standard deviations of the single fields with few restrictions. The specific case of noise may be regarded as an interference signal with a standard deviation of 0 dB.

A description of the method is given in Annex 3.3.

3.4.7 Schwartz and Yeh method

The Schwartz and Yeh method is an iterative method for calculation of the characteristics of the resultant of N interferers. It make the assumption that the combination of two log normal variables also has a log normal distribution (this is a common approximation) and it gives the formulas to calculate the resultant of two variables. For more than two signals an iterative process is applied. Its general approach is very similar to that of t-LNM and the accuracy of both method is comparably high; for this reason, no further details are given here.

POWER SUM METHOD

The power sum method is a procedure for the approximate calculation of the mean value of a sum field. If the mean value of the (logarithmic) field strength of a single signal is denoted by $\overline{F}$ and is expressed in dB(µV/m), its power P (in arbitrary units) is given by

$$P = 10^{\frac{\overline{F}}{10}} .$$

For n individual fields the respective powers are added:

$$P_{\Sigma} = \sum_{i=1}^{n} P_i .$$

and the mean value $\overline{F}_{\Sigma}$ of the (logarithmic) sum field strength is calculated as:

$$\overline{F}_{\Sigma} = 10 \times \log_{10}(P_{\Sigma})$$

STANDARD LNM AND k-LNM

The approach is based on the idea to describe the distribution of the sum of two log-normally distributed statistical variables by a new log-normal distribution, the parameters of which are determined by the prescription that the mean value and standard deviation of the new, approximative, distribution have to be identical with those of the true sum distribution:

$$M_{power}^{approx.} = M_{power}^{true} \quad , \quad S_{power}^{approx.} = S_{power}^{true} \quad ,$$

where M and S denote the mean value and standard deviation of the respective distributions.

Since the resulting approximative sum distribution is taken to be log-normal, it can be combined again with a third log-normal distribution, and so on, thus enabling the construction of an approximative distribution of n log-normally distributed statistical variables. This procedure can be performed analytically.

Suppose there are given:
n logarithmic fields F_i with gaussian distribution (parameters $\overline{F}_i$, σ_i, i=1...n).

The task is to find the parameters of the approximative log-normal sum distribution:

1. Transform $\overline{F}_i$, σ_i, i=1...n, from dB scale to Neper scale (this avoids nasty constants in the calculation):

$$X_{Neper} = \frac{1}{10\log_{10}(e)} * X_{dB} \quad .$$

2. Evaluate the mean values M_i and the variances S_i^2 of the n fields:

$$M_i = e^{\overline{F}_i + \frac{\sigma_i^2}{2}}, \qquad S_i^2 = e^{2\overline{F}_i + \sigma_i^2} * \left(e^{\sigma_i^2} - 1\right), \qquad i=1...n$$

3. Determine the mean value M and variance S^2 of the sum field strength distribution:

$$M = \sum_{i=1}^{n} M_i \;, \qquad S^2 = \sum_{i=1}^{n} S_i^2 \;,$$

4. Determine the distribution parameters s_Σ and $\overline{F}_\Sigma$ of the approximative log-normal sum distribution:

$$s_\Sigma^2 = \log_e\left(k\frac{S^2}{M^2} + 1\right), \qquad \overline{F}_\Sigma = \log_e(M) - \frac{s_\Sigma^2}{2}, \qquad i=1...n$$

where k is a correction factor in the range 0…1.

5. Transform $\overline{F}_\Sigma$ and σ_Σ from Neper scale to dB scale:

$$X_{dB} = 10\log_{10}(e) * X_{Neper} \ .$$

The k-LNM method suffers from the drawback that the correction factor k depends on the number, the powers and the variances of the involved fields. To obtain optimal results, an interpolation table would be necessary, but this is not suitable for an heuristic approach like k-LNM. Therefore, to keep the simple and analytic character of the approximation, only an average value of k can be chosen, extracted from a sample of representative field configurations. This simplicity has to be paid for with an inaccuracy which amounts to some dBs for the 1%-fractile for some, fairly typical, configurations. For the summation of fields with standard deviations between 6 and 10 dB the value k=0.5 seems to represent a fair compromise. For smaller standard deviations a higher value for k should be used, e.g. k = 0.7. If k is set to 1.0, k-LNM is identical with the standard LNM approach as described in ITU-R Rep. 945.

ANNEX 3.3

t-LNM (V2)

1. Introduction

This annex describes a method of computing the sum field from component field parameters (mean, variance) which provides a reduction of computational load compared to earlier versions of t-LNM. The principal structure of computing the sum field by combining the n-th component field with the sum of the fields 1 to n-1 by means of interpolation tables has been retained. By exploiting the properties of a suitably chosen analytical approximation of the expression for the sum of two fields it has become possible to compute the interpolation tables at run time and to replace the two tri-linear interpolation steps by three bilinear interpolations, which cuts down the number of necessary operations to almost ½ of the double tri-linear version t-LNM (V1).

2. The t-LNM(V2) Algorithm

Let f_1 and f_2 be the (uncorrelated and normally distributed) intensity levels of the two fields to be combined. The corresponding sum field level is given by:

$$f = \log_e (e^{f_1} + e^{f_2}), \tag{1}$$

which can be written in the form

$$f = \frac{1}{2}(f_1 + f_2) + \log_e\left(e^{\frac{x}{2}} + e^{-\frac{x}{2}}\right), \tag{2}$$

where

$$x = f_1 - f_2 \ . \tag{3}$$

From (2) it follows that the mean value <f> of the sum field level f has the form

$$\langle f \rangle = \frac{1}{2}\left(\langle f_1\rangle + \langle f_2\rangle\right) + U\left(\bar{x}, s_x\right), \tag{4}$$

where < f_1> and < f_2> are the mean values of f_1 and f_2, respectively and

$$U(\bar{x}, s_x) := \langle \log_e (e^{\frac{x}{2}} + e^{-\frac{x}{2}})\rangle \ . \tag{5}$$

For convenience, $\bar{f}$ is used in place of <f> in some of the following equations.

Clearly $U(\bar{x}, s_x)$ depends on the parameters of the distribution of x only; by proposition, x is normally distributed with mean $\bar{x} = \bar{f}_1 - \bar{f}_2$ and variance $s_x^2 = s_1^2 + s_2^2$. The variance of f can be written in the form

$$\langle f^2\rangle - \langle f\rangle^2 = \frac{1}{4}\sigma_x^2 + V(\overline{x},\sigma_x) - \left[U(\overline{x},\sigma_x)\right]^2 + \widetilde{W}(\overline{x},\sigma_1,\sigma_2), \tag{6}$$

where

$$V(\overline{x}, s_x) = \left\langle \left[\log_e(e^{\frac{x}{2}} + e^{-\frac{x}{2}})\right]^2 \right\rangle \tag{7}$$

and

$$\widetilde{W}(s_1, s_2) = \langle (f_1 - \overline{f}_1 + f_2 - \overline{f}_2) \times \log_e(e^{\frac{x}{2}} + e^{-\frac{x}{2}}) \rangle\ . \tag{8}$$

With suitably chosen coefficients A, B, and C the term $\ln(e^{\frac{x}{2}} + e^{-\frac{x}{2}})$ can be approximated by

$$\log_e(e^{\frac{x}{2}} + e^{-\frac{x}{2}}) = \frac{1}{2}|x| + Ce^{-A|x| - Bx^2}\ . \tag{9}$$

Both absolute and relative approximation errors are less than 7×10^{-3} with maximum errors occurring for x in the interval [-4, 4] when A = 0.685437037, B = 0.08198801 and C= 0.686850632. When the approximation (9) is inserted into the expressions (5), (7) and (8) the mean values can be evaluated. It turns out that

$$U(\overline{x},\sigma_x) = \overline{x}\left[\Phi(\frac{\overline{x}}{\sigma_x}) - \frac{1}{2}\right] + \frac{\sigma_x}{\sqrt{2\pi}} e^{-\frac{\overline{x}^2}{2\sigma_x^2}}$$

$$+ \frac{Ce^{-\frac{\overline{x}^2}{2\sigma_x^2}}}{\sqrt{1+2B\sigma_x^2}}\left[e^{\frac{K_+^2}{2}}\Phi(-K_+) + e^{\frac{K_-^2}{2}}\Phi(K_-)\right], \tag{10}$$

where

$$K_{\pm} = \frac{\overline{x}/s_x \pm As_x}{\sqrt{1+2Bs_x^2}} \tag{11}$$

and where $\Phi(y) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{y} dm\ e^{-\frac{m^2}{2}}$ is the cumulated normalized normal distribution.

V is given by

$$V(\bar{x},\sigma_x) = \frac{1}{4}(\bar{x}^2 + \sigma_x^2) + \frac{C\sigma_X}{1+2B\sigma_x^2} e^{-\frac{\bar{x}^2}{2\sigma_x^2}} \times$$

$$\left[\sqrt{\frac{2}{\pi}} - K_+ e^{\frac{K_+^2}{2}} \Phi(-K_+) + K_- e^{\frac{K_-^2}{2}} \Phi(K_-)\right] + \frac{C^2}{\sqrt{1+4B\sigma_x^2}} e^{\frac{-2B\bar{x}^2+2A^2\sigma_x^2}{1+4B\sigma_x^2}} \times$$

$$\left[e^{\frac{2A\bar{x}}{1+4B\sigma_x^2}} \Phi\left(-\frac{\bar{x}/\sigma_x + 2A\sigma_x}{\sqrt{1+4B\sigma_x^2}}\right) + e^{\frac{-2A\bar{x}}{1+4B\sigma_x^2}} \Phi\left(\frac{\bar{x}/\sigma_x - 2A\sigma_x}{\sqrt{1+4B\sigma_x^2}}\right)\right] . \tag{12}$$

$\tilde{W}$ finally can be written as

$$\tilde{W} = (\sigma_1^2 - \sigma_2^2)\, W(\bar{x},\sigma_x) \ , \tag{13}$$

where

$$W(\bar{x},\sigma_x) = \Phi\left(\frac{\bar{x}}{\sigma_x}\right) - \frac{1}{2} + Ce^{-\frac{\bar{x}^2}{2\sigma_x^2}} \times$$

$$\left\{\frac{1}{\sigma_x(1+2B\sigma_x^2)}\left[K_+ e^{\frac{K_+^2}{2}} \Phi(-K_+) + K_- e^{\frac{K_-^2}{2}} \Phi(K_-)\right]\right.$$

$$\left. - \frac{\bar{x}}{\sigma_x^2\sqrt{1+2B\sigma_x^2}}\left[e^{\frac{K_+^2}{2}} \Phi(-K_+) + e^{\frac{K_-^2}{2}} \Phi(K_-)\right]\right\} . \tag{14}$$

Once the functions U, V and W have been tabulated (which due to the many similarities of the terms appearing in (10), (12) and (14) consumes only a moderate amount of computing time) the combination of two fields can very simply be accomplished by first computing $\bar{x}$ and s_x, then finding the corresponding values of the functions U, V and W by bilinear interpolation in the respective tables, and finally computing the mean sum field level by formula (4) and the variance as

$$\left\langle f^2\right\rangle - \left\langle f\right\rangle^2 = \frac{1}{4}\sigma_x^2 + V(\bar{x},\sigma_x) - \left[U(\bar{x},\sigma_x)\right]^2 + \left(\sigma_1^2 - \sigma_2^2\right) W(\bar{x},\sigma_x) \ . \tag{15}$$

4. COVERAGE DEFINITIONS FOR FIXED ANTENNA, FOR PORTABLE ANTENNA AND FOR MOBILE ANTENNA RECEPTION

4.1 Introduction

It is necessary to have definitions for the coverage of a terrestrial television transmitting station or a group of such stations. Such definitions may be based primarily on technical criteria but need to be readily usable for non-technical purposes.

The above is true for analogue television transmissions as well as for digital ones. However, the case of analogue stations is relatively easy to deal with as the line defining any edge of a coverage area is rather “soft” and it is not necessary to be too precise about where the line actually lies in any given area; indeed in many cases it is not really possible to be precise.

Digital television service coverages are characterised by a very rapid transition from near perfect reception to no reception at all and it thus becomes much more critical to be able to define which areas are going to be covered and which are not. However, because of the very rapid transition described above, there is a cost penalty if the coverage target within a small area (say, 100 m x 100 m) is set too high. This occurs because it is necessary either to increase the transmitter powers or to provide a larger number of transmitters in order to guarantee coverage to the last few percent of the worst-served small areas.

For this reason, the coverage definition of “good” has been selected as the case where 95% of the locations within a small area are covered. Similarly, “acceptable” has been defined to be the case where 70% of the locations within a small area are covered.

The definitions do not aim to describe the area where coverage is achieved under worst case conditions. They provide a description of the area where "good" or "acceptable" coverage should be achieved under representative practical conditions. They may be regarded as describing the “quality” of the coverage achieved.

In practice it may also be necessary to describe and define the “quantity” of the coverage achieved in terms of some overall objective. For example, it is usually more important to define the percentage of the population covered in a country or part of a country, rather than the percentage of the area. There is usually only a loose connection between the percentage area and the percentage population. In addition, it may be desirable to consider cases where the target is to cover only specific parts of a country, for example the more densely populated areas and it may be necessary to define this in terms of the total area. Discussion of this topic is outside the scope of this handbook, but further information is given in EBU publication BPN 038, where the terminology “percentage pixels” is employed to deal with this quantification of coverage.

It should be borne in mind that in a given situation it may be possible to improve reception:

- by finding a better position for the antenna;
- by using a (more) directional antenna with a higher gain;

- by using a low-noise antenna amplifier (in the case of fixed antenna reception).

4.2 Fixed antenna reception

Fixed antenna reception is defined as:

- Reception where a directional receiving antenna mounted at roof level is used.

In calculating the equivalent field strength required for fixed antenna reception, a receiving antenna height of 10 m above ground level is considered to be representative. In the case of fixed antenna reception it is assumed that near-optimal reception conditions (for the relevant radio frequency channels) are found when the antenna is installed.

4.3 Portable antenna reception

Portable antenna reception is defined as:

- Class A (outdoor) being reception where a portable receiver with an attached or built-in antenna is used:
    - outdoors at no less than 1.5 m above ground level;

- Class B (ground floor indoor) being reception where a portable receiver with an attached or built-in antenna is used:
    - indoors at no less than 1.5 m above floor level in rooms:
    - on the ground floor;
    - with a window in an external wall.

Portable antenna reception will, in practice, take place under a great variety of conditions (outdoor, indoor, ground floor, first floor, upper floors). It could even be envisaged that a portable receiver is moved while being viewed.

It is to be expected that there will be significant variation of reception conditions for indoor portable reception, depending to some extent, on the floor-level at which reception is required. However, there will also be considerable variation of building penetration loss from one building to another and also considerable variation from one part of a room to another. Some estimates of the probable signal level requirements for different floor-levels are given in Chapter 5.

In both categories A and B, above, it is assumed that the portable receiver is not moved during reception and large objects near the receiver are also not moved. It is also assumed that extreme cases, such as reception in completely shielded rooms, are disregarded.

It is to be expected that portable coverage is mainly aimed at urban areas. In many countries most people living in urban areas live in apartment buildings. The second category, class B, is therefore probably the more common case of portable reception. It is to be expected that reception will be less difficult in rooms higher than the ground floor.

4.4 Mobile reception

Mobile reception is defined as being the reception of a DVB-T signal while in motion, where the term motion cover speeds from a walking person to a car driven on an motorway. Reception in high-speed trains could also be considered in some countries.

4.5 Coverage area

In defining the coverage area for each reception condition, a three level approach is taken:

- **Receiving location**

  The smallest unit is a receiving location with dimensions of about 0.5 x 0.5 m. In the case of portable antenna reception, it is assumed that optimal receiving conditions will be found by moving the antenna within 0.5 metre in any direction. In the case of fixed antenna reception, it is assumed that near-optimal reception conditions are found when the antenna is installed.

  Such a location is regarded as covered if the required carrier-to-noise and carrier-to-interference values are achieved for 99% of the time;

- **Small area coverage**

  The second level is a "small area" (typically 100 m by 100 m).
  In this small area the percentage of covered location is indicated.

  The coverage of a small area is classified as:

  "Good", if at least 95% of receiving locations within it are covered;
  "Acceptable", if at least 70% of locations within it are covered;

- **Coverage area**

  The third level is the coverage area.
  The coverage area of a transmitter, or a group of transmitters, is made up of the sum of the individual small areas in which a given class of coverage is achieved.

4.6 Examples of practical usage

In the case where simplified definitions of transmitter coverage are required, a phrase such as "area within which good fixed antenna reception is expected" is equivalent to:

- coverage area for a transmitter;
- at least 95% of receiving locations within every included small area are covered;
- fixed antenna reception.

In the same way "an area within which acceptable class B portable antenna reception, is expected" is equivalent to:

- coverage area for a transmitter;
- at least 70% of indoor ground floor receiving locations within every included small area are covered;
- portable antenna reception.

5. SIGNAL LEVELS FOR PLANNING

5.1 General

In § 2.3 the minimum signal levels to overcome receiver noise are given as the minimum receiver input power and the corresponding minimum equivalent receiver input voltage, assuming a receiver noise figure of 7 dB. In § 2.3, no account is taken of any propagation effects. However, it is necessary to take account of these effects when considering television reception in a practical environment.

In defining coverage (see Chapter 4) it is indicated that due to the very rapid transition from near perfect to no reception at all, it is necessary that the minimum required signal level is achieved at a high percentage of locations. These percentages have been set at 95 for "good" and 70 for "acceptable" reception. In one sense, these location coverage percentages may be thought of as defining the “quality” of the coverage.

The minimum median power flux densities are calculated for:

- 8 MHz channels. For 7 MHz channels, 0.6 dB should be subtracted from the relevant results given in Tables 5.1 to 5.12;
- 3 different receiving conditions:
    - Fixed antenna reception;
    - Portable outdoor reception;
    - Portable indoor reception at ground floor;
- 4 frequencies representing Band I, Band III, Band IV and Band V:
    - 65 MHz;
    - 200 MHz;
    - 500 MHz;
    - 800 MHz;
- 5 representative C/N ratios in the range 2 dB to 26 dB in steps of 6 dB.

As in Chapter 2, representative C/N values are used for these examples. Results for any chosen system variant may be obtained by interpolation between relevant representative values.

All minimum median equivalent field strength values presented in this chapter are for coverage by a single transmitter only, not for Single Frequency Networks. Further information on this topic is given in Chapter 6.

To calculate the minimum median power flux density or equivalent field strength needed to ensure that the minimum values of signal level can be achieved at the required percentage of locations, the following formulas are used:

$A_a = G_D + 10 \log_{10} (1.64 * \lambda^2 / 4\pi)$

$\phi_{min} = P_{s\ min} - A_a + L_f$ (in Tables 5.1 to 5.4)

$\phi_{min} = P_{s\ min} - A_a$ (in Tables 5.5 to 5.12)

$E_{min} = \phi_{min} + 120 + 10 \log_{10} (120\pi) = \phi_{min} + 145.8$

$\phi_{med} = \phi_{min} + P_{mmn} + C_l$ (in Tables 5.1 to 5.4)

$\phi_{med} = \phi_{min} + P_{mmn} + C_l + L_h$ (in Tables 5.5 to 5.8)

$\phi_{med} = \phi_{min} + P_{mmn} + C_l + L_h + L_b$ (in Tables 5.9 to 5.12)

$E_{med} = \phi_{med} + 120 + 10 \log_{10} (120\pi) = \phi_{med} + 145.8$

where:

C/N : RF signal to noise ratio required by the system [dB]
C_l : Location correction factor [dB]
E_{med} : Minimum median equivalent field strength, planning value [dBμV/m]
E_{min} : Equivalent minimum field strength at receiving place [dBμV/m]
G_D : Antenna gain relative to half wave dipole
L_b : Building penetration loss [dB]
L_f : Feeder loss [dB]
L_h : Height loss (10 m. a.g.l. to 1.5 m. a.g.l.) [dB]
P_{mmn} : Allowance for man made noise [dB]
ϕ_{min} : Minimum power flux density at receiving place [dBW/m^2]
ϕ_{med} : Minimum median power flux density, planning value [dBW/m^2]
λ : Wavelength [m]

For calculating the location correction factor C_l a log-normal distribution of the received signal is assumed. **It should be noted that this standard deviation only relates to location statistics and the inherent inaccuracies of the propagation prediction method are not taken into account.** The location correction factor will need to be re-assessed as more information becomes available.

The location correction factor can be calculated by the formula:

$$C_l = \mu * \sigma$$

where:
μ is the distribution factor, being 0.52 for 70% and 1.64 for 95%;
σ is the standard deviation taken as 5.5 dB for outdoor reception.

See § 5.3.2 for σ values appropriate for indoor reception.

While the matters dealt with in this chapter are generally applicable, additional special considerations are needed in the case of SFNs where there is more than one wanted signal contribution. This subject is treated in Chapter 6.

5.2 Fixed antenna reception

5.2.1 Antenna directivity and gain and feeder losses

The antenna diagrams (directivity) to be used for DVB-T planning are given in ITU-R Rec. 419.

The antenna gains used in the derivation of the minimum median wanted signal levels are:

65 MHz	200 MHz	500 MHz	800 MHz
3 dB	7 dB	10 dB	12 dB

These values are considered as realistic minimum values.
Within any frequency band, the variation of antenna gain with frequency may be taken into account by the addition of a correction term:

$$Corr = 10 \log_{10}(F_A/F_R)$$

where:
§§ F_A is the actual frequency being considered;
F_R is the relevant reference frequency quoted above.

The feeder losses used in the derivation of the minimum wanted signal levels in § 5.2.1 are:

65 MHz	250 MHz	500 MHz	800 MHz
1 dB	2 dB	3 dB	5 dB

5.2.2 Minimum median power flux density and equivalent field strength

The tables below give the minimum median power flux density and the equivalent minimum median field strength for 70% and 95% of location probability in Band I, III, IV and V. These values are related to the minimum power flux density and minimum equivalent field strength at the receiving location. For Bands I and III an allowance for man-made noise has been included.

Receiving condition: Fixed antenna, Band I.

Frequency	f [MHz]	65				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBµV]	13	19	25	31	37
Feeder loss	L_f [dB]	1				
Antenna gain rel. to half wave dipole	G_D [dB]	3				
Effective antenna aperture	A_a [dBm^2]	7.4				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-132.6	-126.6	-120.6	-114.6	-108.6
Min equivalent field strength at receiving place	E_{min} [dBµV/m]	13	19	25	31	37
Allowance for man made noise	P_{mmn} [dB]	6				

Location probability: 70%

Location correction factor	C_l [dB]	2.9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-123.7	-117.7	-111.7	-105.7	-99.7
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBµV/m]	22	28	34	40	46

Location probability: 95%

Location correction factor	C_l [dB]	9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-117.6	-111.6	-105.6	-99.6	-93.6
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBµV/m]	28	34	40	46	52

Table 5.1: Minimum median power flux density and equivalent minimum median field strength in Band I for 70% and 95% location probability, fixed antenna reception.

For 7 MHz channels, 0.6 dB is to be subtracted from the input signal power, the power flux density and field strength values given in the Table above.

Receiving condition: Fixed antenna, Band III.

Frequency	f [MHz]	200				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Feeder loss	L_f [dB]	2				
Antenna gain rel. to half wave dipole	G_D [dB]	7				
Effective antenna aperture	A_a [dBm^2]	1.7				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-125.9	-119.9	-113.9	-107.9	-101.9
Min equivalent field strength at receiving place	E_{min} [dBμV/m]	20	26	32	38	44
Allowance for man made noise	P_{mmn} [dB]	1				

Location probability: 70%

Location correction factor	C_l [dB]	2.9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-122	-116	-110	-104	-98
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	24	30	36	42	48

Location probability: 95%

Location correction factor	C_l [dB]	9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-115.9	-109.9	-103.9	-97.9	-91.9
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	30	36	42	48	54

Table 5.2: Minimum median power flux density and equivalent minimum median field strength in Band III for 70% and 95% location probability, fixed antenna reception.

For 7 MHz channels, 0.6 dB is to be subtracted from the input signal power, the power flux density and field strength values given in the Table above.

Receiving condition: Fixed antenna, Band IV.

Frequency	f [MHz]	500				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Feeder loss	L_f [dB]	3				
Antenna gain rel. to half wave dipole	G_D [dB]	10				
Effective antenna aperture	A_a [dBm^2]	-3.3				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-119.9	-113.9	-107.9	-101.9	-95.9
Min equivalent field strength at receiving place	E_{min} [dBμV/m]	26	32	38	44	50
Allowance for man made noise	P_{mmn} [dB]	0				

Location probability: 70%

Location correction factor	C_l [dB]	2.9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-117	-111	-105	-99	-93
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	29	35	41	47	53

Location probability: 95%

Location correction factor	C_l [dB]	9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-110.9	-104.9	-98.9	-92.9	-86.9
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	35	41	47	53	59

Table 5.3: Minimum median power flux density and equivalent minimum median field strength in Band IV for 70% and 95% location probability, fixed antenna reception.

Receiving condition: Fixed antenna, Band V.

Frequency	f [MHz]	800				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBµV]	13	19	25	31	37
Feeder loss	L_f [dB]	5				
Antenna gain rel. to half wave dipole	G_D [dB]	12				
Effective antenna aperture	A_a [dBm^2]	-5.4				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-115.8	-109.8	-103.8	-97.8	-91.8
Min equivalent field strength at receiving place	E_{min} [dBµV/m]	30	36	42	48	54
Allowance for man made noise	P_{mmn} [dB]	0				

Location probability: 70%

Location correction factor	C_l [dB]	2.9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-112.9	-106.9	-100.9	-94.9	-88.9
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBµV/m]	33	39	45	51	57

Location probability: 95%

Location correction factor	C_l [dB]	9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-106.8	-100.8	-94.8	-88.8	-82.8
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBµV/m]	39	45	51	57	63

Table 5.4: Minimum median power flux density and equivalent minimum median field strength in Band V for 70% and 95% location probability, fixed antenna reception.

5.3 Portable antenna reception

5.3.1 General

In general, most coverage studies concerning digital terrestrial television have been aimed towards fixed reception using roof-level directional receiving antennas. However the possibility of outdoor or indoor reception on a portable receiver with an in-built or set-top receiving antenna might offer substantial additional user benefits. Portable reception will take place under a great variety of conditions e.g. outdoor, indoor, ground-floor or higher-floors and with simple antennas.

The conditions for portable reception differ from fixed reception in the:

- absence of receiving antenna gain and directivity;
- reduced feeder loss;
- generally lower reception height;
- building penetration loss in the case of indoor reception.

Portable antenna reception has been defined (see chapter 4) for class A (outdoor) and class B (indoor ground floor) cases. As for fixed reception, "good" and "acceptable" coverages are defined as 95% and 70% covered locations. The variation factors will be calculated in a similar way to that indicated in § 5.1.

5.3.2 Criteria for portable reception of digital television

5.3.2.1 Signal level variations

5.3.2.1.1 General

Field strength variations can be divided into macro-scale and micro-scale variations. The macro-scale variations relate to areas with linear dimensions of 10 m to 100 m or more and are mainly caused by shadowing and multipath reflections from distant objects. The micro-scale variations relate to areas with dimensions in the order of a wavelength and are mainly caused by multipath reflections from nearby objects. As it may be assumed that for portable reception the position of the antenna can be optimized within the order of a wavelength, micro-scale variations will not be too significant for planning purposes. Another way to overcome these variations is the possibility of a receiver using antenna diversity.

Macro-scale variations of the field strength are very important for coverage assessment. In general, a high target percentage for coverage would be required to compensate for the rapid failure rate of digital television signals.

5.3.2.1.2 Micro-scale variations

Measurements carried out in Eindhoven in the Netherlands showed that the standard deviation of the micro-scale field strength distribution is about 3 dB. This value has been confirmed by measurements in the UK. The location variation for micro-scale variations is therefore:

Coverage target	Location variation
>95%	5 dB
>70%	1.5 dB

5.3.2.1.3 Macro-scale variations at outdoor locations

ITU-R Rec. P.370 gives a standard deviation for wide band signals of 5.5 dB. This value is used here for determining the location variation at outdoor locations.

This location variation for macro-scale variations is therefore:

Coverage target	Location variation
>95%	9 dB
>70%	2.9 dB

5.3.2.1.4 Signal level prediction

The signal level prediction method to be used will be based on ITU-R Rec P.370, bearing in mind that this method shows differences between predicted and measured values, as do all prediction methods. An allowance may need to be made for this inherent source of inaccuracy and the overall signal level strength prediction process should take account of this element in addition to the variation of field strength with location.

5.3.2.1.5 Macro-scale variations at indoor locations

The variation factor at indoor locations is the combined result of the outdoor variation and the variation factor due to building attenuation (see § 5.3.2.3)

5.3.2.2 Height loss

For portable reception, the antenna height of 10m above ground level generally used for planning purposes is not realistic and a correction factor needs to be introduced based on a receiving antenna near ground floor level. For this reason a receiving antenna height of 1.5 m above ground level (outdoor) or above floor level (indoor) has been assumed.

The propagation prediction method of recommendation ITU-R Rec. P. 370 uses a receiving height of 10m. To correct the predicted values for a receiving height of 1.5 m above ground level a factor called "height loss" has been introduced. Measurements in the Netherlands at UHF showed a height loss of 12 dB. For VHF, ITU-R Rep. 1203 gives a value of 10 dB.

5.3.2.3 Building penetration loss

5.3.2.3.1 General

Portable television reception will take place at outdoor and indoor locations. The field strength at indoor locations will be attenuated significantly by an amount depending on the materials and the construction of the house. A large spread of building penetration losses is to be expected.

The mean building penetration loss is the difference in dB between the mean field strength inside a building at a given height above ground level and the mean field strength outside the same building at the same height above ground level.

5.3.2.3.2 Measurements at VHF

Results of measurements carried out at VHF in the UK to investigate in-house reception of DAB have been reported in ITU-R Rep. 1203. The results indicate a median value of building penetration loss of 8 dB with a standard deviation of 3 dB.

5.3.2.3.3 Measurements at UHF

Measurements have been carried out in the Netherlands using a transmitted OFDM signal with a bandwidth of 8 MHz and containing 512 carriers. The measurements were made as samples with a receiver bandwidth of 12 kHz covering the channel in a series of steps.

The signal level was measured as a function of micro-scale variations at indoor and outdoor locations.

It is expected that the value $V_{10\%}$, which represents the received narrow band signal power exceeded at 10% of the locations, is most closely related to the wideband received signal level. Therefore, the values of $V_{10\%}$ for indoor, outdoor and 10m reference measurement sites seem the most well-suited for calculation of loss and gain figures.

It appears that the median value $M(V_{10\%}(\text{outdoor})/V_{10\%}(\text{indoor}))$, which might be a good measure for building penetration loss, is in the order of 6 dB. The standard deviation is estimated to be about 6 dB.

Further measurements carried out in the Netherlands using a transmitted noise signal of 7 MHz and receiver bandwidth of 7 MHz show a median building penetration loss of about 9 dB. However these measurements were done at a limited number of locations. The number of concrete houses was relative high. This might be the reason for the somewhat higher median value.

The influence of people walking around the receiving antenna has also been estimated. The signal level variations (10% and 90% value) ranged from +2.6 dB to
-2.6 dB. These variations are relatively small and it does not seem necessary to take them into account for planning purposes.

A number of other measurements have also been carried out in the Netherlands to determine:

- influence of a wet wall;
- time variation of the received signal in a period of 11 days over a short path.

It appeared that neither of these two conditions has a significant influence on the received signal.

Recent measurements carried out in the UK show combined building penetration and height losses for ground floor rooms between 19 dB and 34 dB with an average value of 29 dB. In upstairs rooms, losses between 16 dB and 29 dB with an average value of 22 dB were found.

5.3.2.3.4 Building penetration loss values for planning purposes

Until more consistent values become available the building penetration loss for planning purposes is taken as:

Band	Median value	Standard deviation
VHF	8 dB	3 dB
UHF	7 dB	6 dB

5.3.2.3.5 Location distribution indoors

The variation factor at indoor locations is the combined result of the outdoor variation and the variation factor due to building attenuation. These distributions are expected to be uncorrelated. The standard deviation of the indoor field strength distribution can therefore be calculated by taking the root of the sum of the squares of the individual standard deviations. At VHF, where the macro-scale standard deviations are 5.5 dB and 3 dB respectively, the combined value is 6.3 dB. At UHF, where the macro-scale standard deviations are 5.5 dB and 6.2 dB respectively, the combined value is 8.3 dB.

The location variation for macro-scale variations at indoor locations is therefore at VHF:

Coverage target	Location variation
>95%	10 dB
>70%	3 dB

and at UHF:

Coverage target	Location variation
>95%	14 dB
>70%	4 dB

As indicated in § 3.2, the overall field strength prediction process must take account of both the location variation and the difference between predicted and measured values.

5.3.2.4 Portable receiving antenna properties

5.3.2.4.1 General

A roof-level antenna as used with fixed reception can be expected to have a gain of about 10 to 12 dB at UHF. For a portable receiver the antenna will most probably be of either the built-in type of very short length and in the extreme case having -20 dB gain or at best will be a set-top orientable antenna with a few dB gain (at UHF).

For planning purposes it has been assumed that the antenna of a portable receiver is omni-directional and that the gain is 0 dB for a UHF antenna and -2.2 dB for a VHF antenna. A portable receiver can be assumed to have 0 dB feeder loss. For reference, it may be noted that a roof-level antenna will be connected to a receiver by means of a feeder cable. This is likely to have a loss of 3 to 5 dB at UHF. Such values may seem high when the relatively short feeder lengths are considered, but some allowance must be included for feeder ageing effects (for example, corrosion of the copper screening).

5.3.2.4.2 Measurements of indoor antennas

Measurements have been carried out in the Netherlands to investigate directivity of set-top antennas in practical circumstances. One "rabbit-ear" and two five element yagi antennas of moderate quality were selected. The results showed that gain and directivity depend very much on frequency and location.

The gain varied from about -15 to +3 dB for the yagi antennas and from about -10 to -4 dB for the "rabbit ear" antenna.

For directivity measurements the antennas were placed in a room close to a wall to represent practical conditions. The radiation patterns changed considerably with the frequency. In practical conditions the antenna should therefore be directed to obtain the highest signal rather than in the direction of the transmitter (assuming that this is even known). Examples of antenna patterns for two antenna types at an indoor location close to a wall, measured in the Netherlands, are shown in Figures 5.1 and 5.2.

Measurements by the BBC of two commercially available indoor antennas showed a better performance. The antennas had a gain of 5 to 6 dB throughout Band IV and V.

5.3.2.4.3 Measurements of depolarisation

Measurements carried out in the Netherlands, using test transmissions with a vertically polarized digital television signal, showed a depolarization of the signal at the receiving site and in particular for indoor reception.

The results showed that indoors the depolarisation angle ranges from 20 to 48 degrees at macro-scale.

At micro-scale level the standard deviation of the depolarisation angle ranges from 3 to 16 degrees.

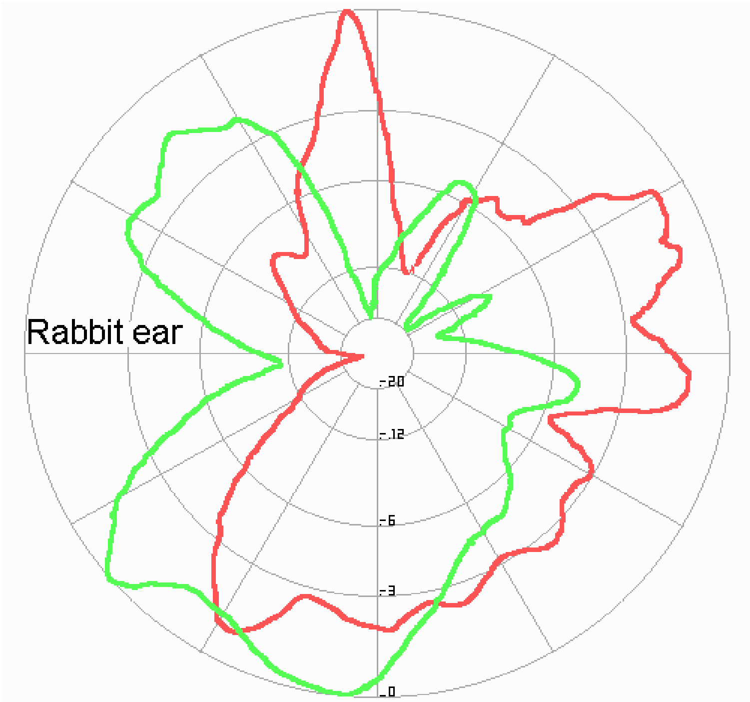
5.3.2.5 Receiver properties

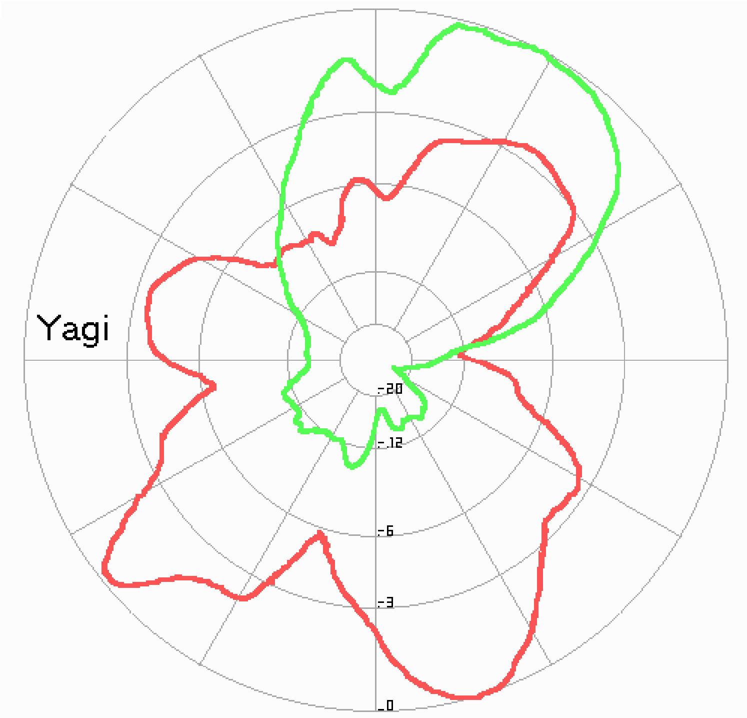
Planning studies for portable reception are based on a receiver able to handle signals of a broadband nature and the carrier to noise ratio requirement of a system will be moderate and may be as low as 2 dB in the case of a particularly rugged system. However, multi-channel services may need to be received by receivers having simple antennas. In practice, the possibilities for portable reception of signals with high bitrates and requiring a C/N of 20 to 26 dB will be very restricted due to the high signal level requirements.

For these studies it has been assumed that a portable receiver and a receiver for fixed reception have same receiver noise figure, that is 7 dB.

5.3.3 Minimum median power flux density and equivalent field strength

The tables below give the minimum median power flux density and the minimum median equivalent field strength for location probabilities of 70 and 95% in Band I, III, IV and V.





Figs. 5.1 and 5.2 - Examples of indoor antenna patterns

Receiving condition: Portable outdoor (Class A), Band I.

Frequency	f [MHz]	65				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Antenna gain rel. to half wave dipole	G_D [dB]	-2.2				
Effective antenna aperture	A_a [dBm^2]	2.2				
Min power flux density at receiving place	ϕ_{min} dBW/m^2]	-128.4	-122.4	-116.4	-110.4	-104.4
Min equivalent field strength at receiving place	E_{min} dBμV/m]	17	23	29	35	41
Allowance for man made noise	P_{mmn} [dB]	6				
Height loss	L_h [dB]	10				

Location probability: 70%

Location correction factor	C_l [dB]	2.9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-109.5	-103.5	-97.5	-91.5	-85.5
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	36	42	48	54	60

Location probability: 95%

Location correction factor	C_l [dB]	9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-103.4	-97.4	-91.4	-85.4	-79.4
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	42	48	54	60	66

Table 5.5: Minimum median power flux density and equivalent minimum median field strength in Band I for 70% and 95% location probability, portable outdoor reception.

For 7 MHz channels, 0.6 dB is to be subtracted from the input signal power, the power flux density and field strength values given in the Table above.

Receiving condition: Portable outdoor (Class A), Band III.

Frequency	f [MHz]	200				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Antenna gain rel. to half wave dipole	G_D [dB]	-2.2				
Effective antenna aperture	A_a [dBm^2]	-7.5				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-118.7	-112.7	-106.7	-100.7	-94.7
Min equivalent field strength at receiving place	E_{min} [dBμV/m]	27	33	39	45	51
Allowance for man made noise	P_{mmn} [dB]	1				
Height loss	L_h [dB]	10				

Location probability: 70%

Location correction factor	C_l [dB]	2.9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-104.8	-98.8	-92.8	-86.8	-80.8
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	41	47	53	59	65

Location probability: 95%

Location correction factor	C_l [dB]	9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-98.7	-92.7	-86.7	-80.7	-74.7
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	47	53	59	65	71

Table 5.6: Minimum median power flux density and equivalent minimum median field strength in Band III for 70% and 95% location probability, portable outdoor reception.

For 7 MHz channels, 0.6 dB is to be subtracted from the input signal power, the power flux density and field strength values given in the Table above.

Receiving condition: Portable outdoor (Class A), Band IV.

Frequency	f [MHz]	500				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Antenna gain rel. to half wave dipole	G_D [dB]	0				
Effective antenna aperture	A_a [dBm^2]	-13,3				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-112.9	-106.9	-100.9	-94.9	-88.9
Min equivalent field strength at receiving place	E_{min} [dBμV/m]	33	39	45	51	57
Allowance for man made noise	P_{mmn} [dB]	0				
Height loss	L_h [dB]	12				

Location probability: 70%

Location correction factor	C_{lc} [dB]	2.9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-98	-92	-86	-80	-74
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	48	54	60	66	72

Location probability: 95%

Location correction factor	C_{lc} [dB]	9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-91.9	-85.9	-79.9	-73.9	-67.9
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	54	60	66	72	78

Table 5.7: Minimum median power flux density and equivalent minimum median field strength in Band IV for 70% and 95% location probability, portable outdoor reception.

Receiving condition: Portable outdoor (Class A), Band V.

Frequency	f [MHz]	800				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Antenna gain rel. to half wave dipole	G_D [dB]	0				
Effective antenna aperture	A_a [dBm^2]	-17.4				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-108.8	-102.8	-96.8	-90.8	-84.8
Min equivalent field strength at receiving place	E_{min} [dBμV/m]	37	43	49	55	61
Allowance for man made noise	P_{mmn} [dB]	0				
Height loss	L_h [dB]	12				

Location probability: 70%

Location correction factor	C_l [dB]	2.9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-93.9	-87.9	-81.9	-75.9	-69.9
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	52	58	64	70	76

Location probability: 95%

Location correction factor	C_l [dB]	9				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-87.8	-81.8	-75.8	-69.8	-63.8
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	58	64	70	76	82

Table 5.8: Minimum median power flux density and equivalent minimum median field strength in Band V for 70% and 95% location probability, portable outdoor reception.

Receiving condition: Portable indoor ground floor (Class B), Band I.

Frequency	f [MHz]	65				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Antenna gain rel. to half wave dipole	G_D [dB]	-2.2				
Effective antenna aperture	A_a [dBm^2]	2.2				
Min power flux density at receiving place	ϕ_{min} dBW/m^2]	-128.4	-122.4	-116.4	-110.4	-104.4
Min equivalent field strength at receiving place	E_{min} dBμV/m]	17	23	29	35	41
Allowance for man made noise	P_{mmn} [dB]	6				
Height loss	L_h [dB]	10				
Building penetration loss	L_b [dB]	8				

Location probability: 70%

Location correction factor	C_l [dB]	3				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-101.4	-95.4	-89.4	-83.4	-77.4
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	44	50	56	62	68

Location probability: 95%

Location correction factor	C_l [dB]	10				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-94.4	-88.4	-82.4	-76.4	-70.4
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	51	57	63	69	75

Table 5.9: Minimum median power flux density and equivalent minimum median field strength in Band I for 70% and 95% location probability, portable indoor reception at ground floor.

Note: Minimum median equivalent field strength values at 10 m a.g.l. for 50% of time and 50% of locations are expected to be:

5 dB lower than the values shown if reception is required in rooms at the first floor;
10 dB lower than the values shown if reception is required in rooms higher than the first floor.

For 7 MHz channels, 0.6 dB is to be subtracted from the input signal power, the power flux density and field strength values given in the Table above.

Receiving condition: Portable indoor ground floor (Class B), Band III.

Frequency	f [MHz]	200				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Antenna gain rel. to half wave dipole	G_D [dB]	-2.2				
Effective antenna aperture	A_a [dBm^2]	-7.5				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-118.7	-112.7	-106.7	-100.7	-94.7
Min equivalent field strength at receiving place	E_{min} [dBμV/m]	27	33	39	45	51
Allowance for man made noise	P_{mmn} [dB]	1				
Height loss	L_h [dB]	10				
Building penetration loss	L_b [dB]	8				

Location probability: 70%

Location correction factor	C_l [dB]	3				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-96.7	-90.7	-84.7	-78.7	-72.7
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	49	55	61	67	73

Location probability: 95%

Location correction factor	C_l [dB]	10				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-89.7	-83.7	-77.7	-71.7	-65.7
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	56	62	68	74	80

Table 5.10: Minimum median power flux density and equivalent minimum median field strength in Band III for 70% and 95% location probability, portable indoor reception at ground floor.

Note: Minimum median equivalent field strength values at 10 m a.g.l. for 50% of time and 50% of locations are expected to be:

> 5 dB lower than the values shown if reception is required in rooms at the first floor;
> 10 dB lower than the values shown if reception is required in rooms higher than the first floor.

For 7 MHz channels, 0.6 dB is to be subtracted from the input signal power, the power flux density and field strength values given in the Table above.

Receiving condition: Portable indoor ground floor (Class B), Band IV.

Frequency	f [MHz]	500				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBµV]	13	19	25	31	37
Antenna gain rel. to half wave dipole	G_D [dB]	0				
Effective antenna aperture	A_a [dBm^2]	-13.3				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-112.9	-106.9	-100.9	-94.9	-88.9
Min equivalent field strength at receiving place	E_{min} [dBµV/m]	33	39	45	51	57
Allowance for man made noise	P_{mmn} [dB]	0				
Height loss	L_h [dB]	12				
Building penetration loss	L_b [dB]	7				

Location probability: 70%

Location correction factor	C_l [dB]	4				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-89.9	-83.9	-77.9	-71.9	-65.9
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBµV/m]	56	62	68	74	80

Location probability: 95%

Location correction factor	C_l [dB]	14				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-79.9	-73.9	-67.9	-61.9	-55.9
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBµV/m]	66	72	78	84	90

Table 5.11: Minimum median power flux density and equivalent minimum median field strength in Band IV for 70% and 95% location probability, portable indoor reception at ground floor.

Note: Minimum median equivalent field strength values at 10 m a.g.l. for 50% of time and 50% of locations are expected to be:

6 dB lower than the values shown if reception is required in rooms at the first floor;
12 dB lower than the values shown if reception is required in rooms higher than the first floor.

Receiving condition: Portable indoor ground floor (Class B), Band V.

Frequency	f [MHz]	800				
Minimum C/N required by system	**[dB]**	**2**	**8**	**14**	**20**	**26**
Min. receiver signal input power	$P_{s\ min}$ [dBW]	-126.2	-120.2	-114.2	-108.2	-102.2
Min. equivalent receiver input voltage, 75 Ω	$U_{s\ min}$ [dBμV]	13	19	25	31	37
Antenna gain rel. to half wave dipole	G_D [dB]	0				
Effective antenna aperture	A_a [dBm^2]	-17.4				
Min power flux density at receiving place	ϕ_{min} [dBW/m^2]	-108.8	-102.8	-96.8	-90.8	-84.8
Min equivalent field strength at receiving place	E_{min} [dBμV/m]	37	43	49	55	61
Allowance for man made noise	P_{mmn} [dB]	0				
Height loss	L_h [dB]	12				
Building penetration loss	L_b [dB]	7				

Location probability: 70%

Location correction factor	C_l [dB]	4				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-85.8	-79.8	-73.8	-67.8	-61.8
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	60	66	72	78	84

Location probability: 95%

Location correction factor	C_l [dB]	14				
Minimum median power flux density at 10m a.g.l. 50% of time and 50% of locations	ϕ_{med} [dBW/m^2]	-75.8	-69.8	-63.8	-57.8	-51.8
Minimum median equivalent field strength at 10m a.g.l. 50% of time and 50% of locations	E_{med} [dBμV/m]	70	76	82	88	94

Table 5.12: Minimum median power flux density and equivalent minimum median field strength in Band V for 70% and 95% location probability, portable indoor reception at ground floor.

Note: Minimum median equivalent field strength values at 10 m a.g.l. for 50% of time and 50% of locations are expected to be:

6 dB lower than the values shown if reception is required in rooms at the first floor;
12 dB lower than the values shown if reception is required in rooms higher than the first floor.

5.4 Mobile antenna reception

The coverage criteria for fixed and portable antenna reception have been dealt with in some detail; at present it is not possible to deal with mobile antenna reception in the same detail. This is not due to any lack of interest in the subject. There is, in fact, considerable interest in mobile reception and an EC project, MOTIVATE; has been carrying out a large amount of work. However, this work is not entirely complete and further developments are taking place. These developments include receiver designs which are intended to improve mobile reception and work on diversity antennas. The latter have been in use in other areas of communications for a number of years but their application to very closely spaced antennas, as would be needed for a normal motor vehicle is new and not all of the relevant results are yet available.

For these reasons, no detailed consideration will be given here but it is expected that this topic will form the basis for a new EBU document in the BPN series.

Based on what seem to be reasonable extrapolations from the results already obtained, it is proposed that the criteria for portable outdoor reception should also be used for mobile reception until further results become available.

5.5 Examples of signal levels at various bit-rate

The signal levels for fixed and portable reception in the foregoing sections are given for five representative C/N values in the range 2 to 26 dB. For other values simple linear interpolation can be applied.

In § 2.1, the simulated performance of the DVB-T system is given in terms of the required C/N value and the associated bit-rates.

The curves below show the minimum median field strength values for the bit-rate values specified in Table 2.1 for “good” coverage in Band IV for fixed and portable reception and as a function of the ratio (guard interval)/(useful symbol period).

In calculating the minimum median field strength, an implementation margin of 3 dB has been included.

It can be seen that the required C/N ratio rises more rapidly than the bit rate for any given family, QPSK, 16 QAM or 64 QAM, of system variant. This implies that there is an excess penalty to be paid for choosing a larger value of code-rate. If the diagrams had been based on the VALIDATE results rather than on the basic DVB-T values for C/N (plus implementation margin), the effect of this excess would have been even more marked. This emphasises the comment made earlier that the code rates of 5/6 and 7/8 do not seem to be particularly attractive.

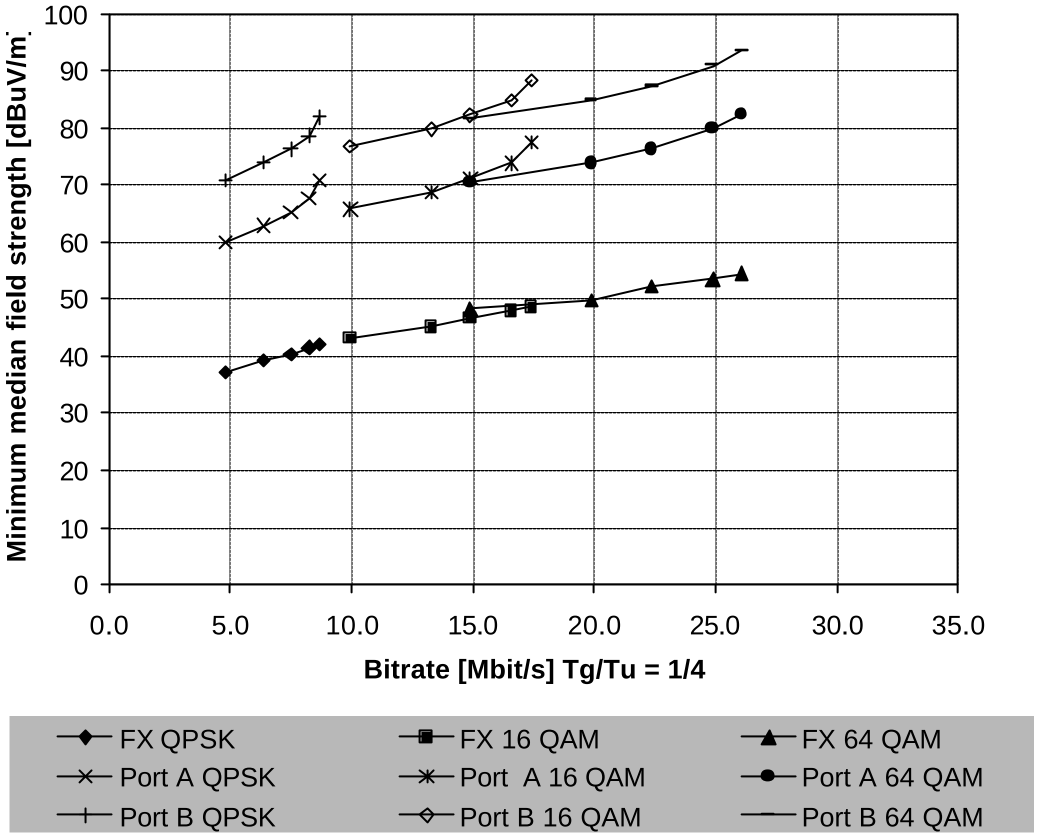


Figure 5.3: Minimum median field strength versus bitrate for “good” coverage (95%), Band IV, Tg/Tu = ¼, 8 MHz version

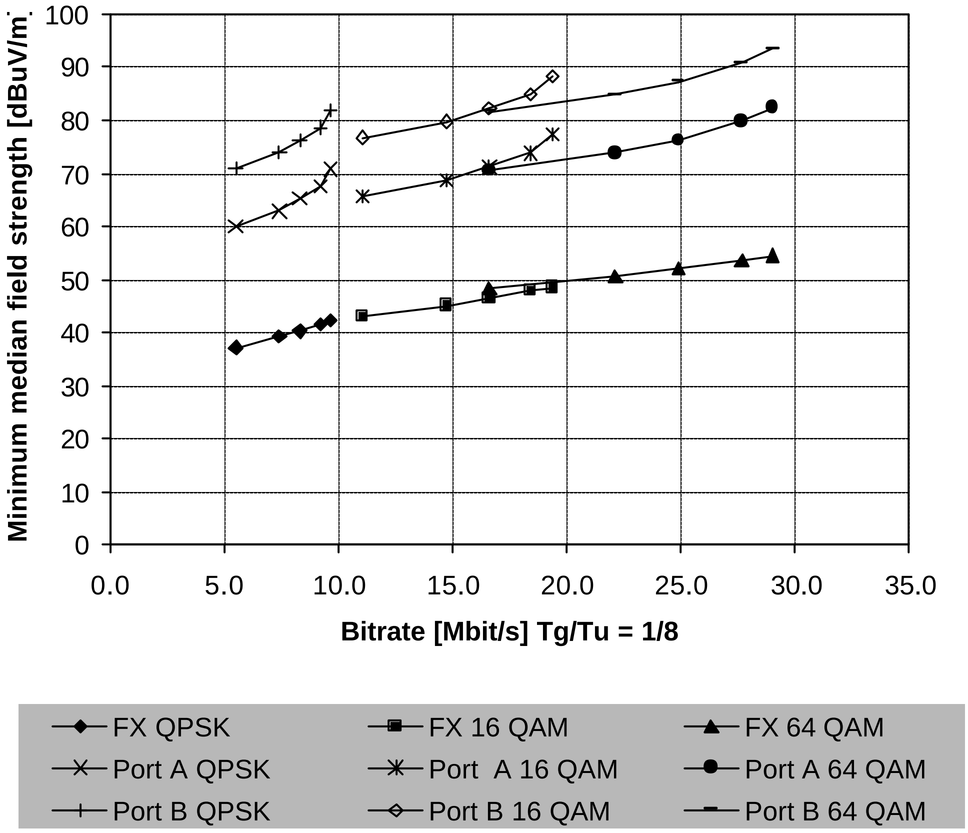


Figure 5.4: Minimum median field strength versus bitrate for "good" coverage (95%), Band IV, Tg/Tu = 1/8, 8 MHz version

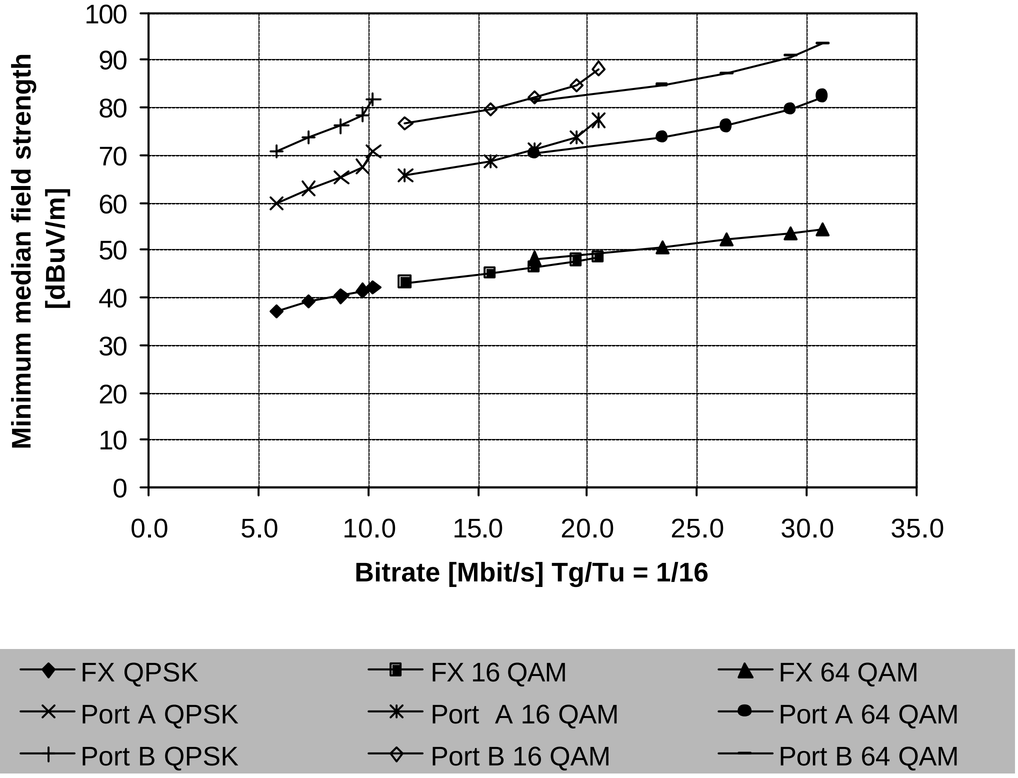


Figure 5.5: Minimum median field strength versus bitrate for “good” coverage (95%), Band IV, Tg/Tu = 1/16, 8 MHz version

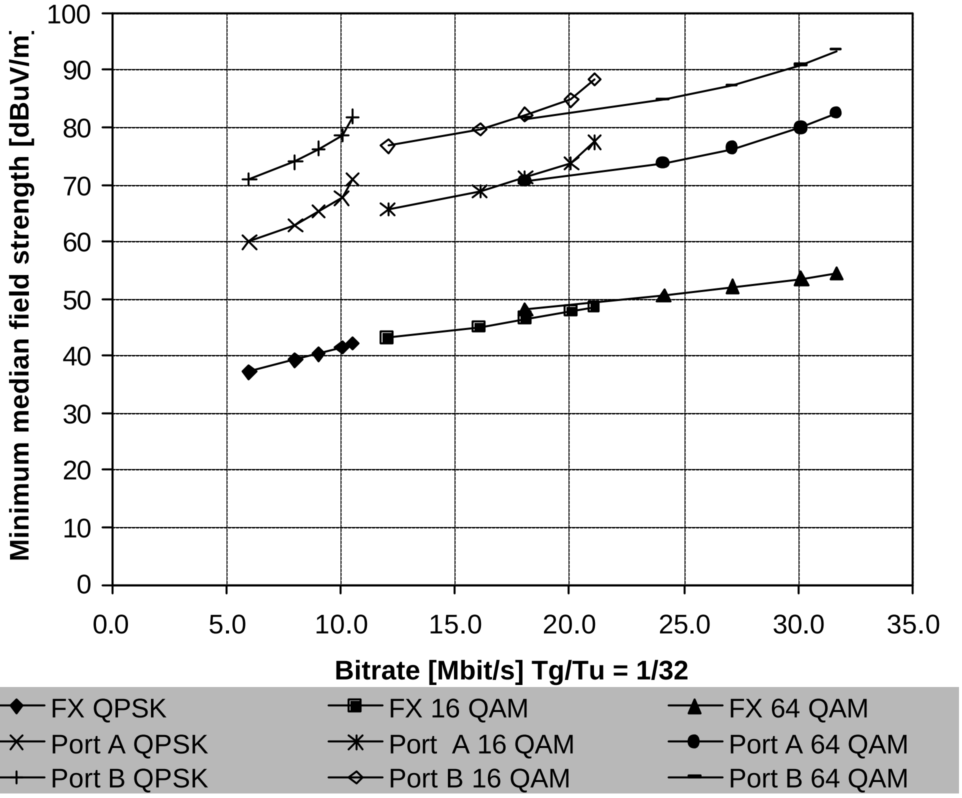


Figure 5.6: Minimum median field strength versus bitrate for “good” coverage (95%), Band IV, Tg/Tu = 1/32, 8 MHz version

6. NETWORK PLANNING

6.1 Introduction

Throughout the European Broadcasting Area (EBA) analogue television is highly developed, and most countries achieve more than 99% population coverage on at least two or three national networks. In parallel, a large number of local networks with lower coverages are operated. The need to achieve a large percentage of coverage leads to the use of very many television transmitters. The radiated power of these covers a wide range: from about 1MW effective radiated power (e.r.p.) for major stations serving large areas, to less than 1W e.r.p. for small stations intended to serve perhaps a few hundred people.

Analogue television systems (PAL, SECAM) are very sensitive to interference from other analogue television signals, and require high co-channel protection ratios (of the order of 30 dB to 45 dB, depending on the value of frequency off-set). Furthermore, adjacent channels cannot generally be used from the same transmitting location.

In addition, analogue television systems cannot operate in a single frequency network (SFN) configuration, where neighbouring transmitters cover overlapping service areas with the same programme, on the same RF channel. Therefore the existing analogue services are planned in multi-frequency network (MFN) configurations, covering adjacent service areas with different RF channels. The same RF channel is re-used only in regions separated by a large distance, to avoid harmful co-channel interference.

Television coverage in the EBA is therefore characterised by an intensive exploitation of VHF/UHF channels, with large areas where a given channel cannot be re-used because of the high protection ratios required by analogue systems. The total available RF channels (at maximum 10 channels at VHF and 48 at UHF) allow for only up to about 2 VHF programmes and 3 to 5 UHF programmes per coverage area, if high protection from interference is required. Hgher spectrum exploitation could be obtained by using precision offset techniques.

It should be noted that in some countries a more intensive use of the spectrum is achieved, but in this case it is commonly found that many programmes show a very poor technical quality, due to interference or noise, especially in the less densely populated areas.

Analogue MFNs are usually based on relatively few high power transmitters, located where possible on hills or mountains. They are fed by cable or by radio links or sometimes by satellite or optical fibres. In addition to these, to follow precisely the terrain orography in the presence of hills or mountains or other obstacles, or to improve reception in highly populated regions, a very large number of lower power transmitters has been put in operation. They are usually fed by the signals broadcast by the higher power transmitters or, sometimes, by radio links.

In conclusion, the current analogue television networks make use of a large percentage of the available VHF/UHF spectrum, and operate in MFN configurations with medium to high transmitter density. In each service area, a large number of RF channels cannot be re-used for high power analogue services, because of potential interference. Since digital systems can be significantly less sensitive to noise and interference, this spectrum could be used to introduce digital television services, capable of operating at reduced e.r.p. levels. (However, care must still be taken to ensure that these digital services do not cause interference to existing analogue services).

The digital television systems may offer improved RF performance over the analogue systems, in terms of spectrum efficiency and power requirements. First of all, digital systems allow multi-programming: for example, in a single 8 MHz channel, 2 to 4 standard definition programmes (SDTV), at about 6 Mbit/s each, can be transmitted in time division multiplex. The total capacity (from 12 to 24 Mbit/s) can also be allocated to higher quality television standards, such as enhanced definition television (EDTV, requiring about 10 to 12 Mbit/s per programme) or HDTV (requiring about 24 Mbit/s per programme). Of course, the higher capacity systems also have higher minimum C/N ratio requirements.

Digital systems can be significantly less sensitive to noise and interference, especially when the system spectrum efficiency is not too high and sophisticated modulation and error correction techniques are adopted. This can offer the possibility to operate at low e.r.p. levels (depending on the modulation) thereby reducing interference to existing analogue services.

Nevertheless, it should be taken into account that the best modulation and error correction systems show a very steep failure characteristic; a digital system can operate under severe reception condition without decoding errors, but an increase of 1 to 2 dB of the noise or interference level can suddenly interrupt the service. Therefore wide margins must be kept in the planning procedures to allow for service availability at a high percentage of locations and a high percentage of time.

Digital modulation and channel coding systems can achieve different trade-offs between spectrum efficiency and ruggedness against noise and distortion. For example, for fixed reception, a suitable spectrum efficiency can be of the order of 4 bits/s/Hz, (i.e., a useful bit-rate of about 24 Mbit/s in an 8 MHz channel), while for static portable reception a more suitable value may be 1 to 2 bits/s/Hz.

The introduction of digital terrestrial television in the immediate future has a main constraint which is the need to protect the existing analogue services. In addition, good digital service coverage is needed to provide an attractive development basis.

In many countries, due to the intensive spectrum exploitation, there is no possibility of access to unused television networks or individual station assignments (co-ordinated and included in the updated Stockholm Plan) at least at relatively high power. In these countries, the use of new channel assignments (for example, in the range 61 to 69) is almost essential in order to introduce any new digital services.

Two introductory scenarios can be foreseen for digital services:

1. Implementation of national or regional SFNs. This is possible when a group of totally unused channels can be allocated to the new digital service (e.g., some UHF frequencies between channels 35 and 38 or between 61 and 69, which are not currently allocated to television broadcasting in some European countries);

2. Implementation of MFNs or local SFNs, exploiting the frequency resources unusable by analogue MFN services.

6.2 Multi-frequency networks

The advantage of the multi-frequency planning approach is that a large part of the existing analogue network infrastructure may be re-used. This has obvious cost-saving implications for the broadcaster but should also provide benefits for the viewer. The latter will arise in any case where it is found possible to use channels for the digital transmissions from a particular site which are close to the channels used for the analogue transmissions from the same site, especially if the same polarization can be used. This should permit viewers to re-use their existing receiving antenna and feeder system. Some form of signal splitter or switch may be needed to permit separate feeds to the analogue and digital receivers although this could be avoided if the digital receiver provides loop-through facilities.

During the transition period of co-existence of analogue and digital services, and especially at the first introduction of digital services, it may be important not to place unnecessary difficulties in front of potential viewers and thus avoiding the necessity of a new receiving antenna system can be regarded as desirable.

Another aspect of conventional planning is that it makes an inherent assumption that the existing analogue services, which currently serve more than 98% of the population in most European countries, will remain in use for many years and that relatively few changes to the analogue stations will occur in that time. In particular, there are likely to be no generally-applied channel or site changes within the analogue networks.

However, it may be found desirable to introduce a limited number of channel, or even site changes at some of the lower power analogue stations where this can be shown to have a significant impact on the implementation opportunities for digital stations and services. In this context, it is important to remember that there are some 80,000 analogue television transmitters already in use in the EBA and that the resultant channel usage is very intensive.

In most countries there are few (or even no) opportunities for the introduction of new analogue stations with a significant population coverage. Opportunities exist for the introduction of new digital stations because of their greater immunity to interference and the ability of digital receivers to make use of lower input signal levels, given a suitable digital television system. Even so, these opportunities are limited by the need to protect existing analogue viewers from additional interference.

A choice has been made in Europe of the system which will be used for terrestrial digital television in Europe and it seems reasonably clear that the future will involve a transition to all digital services. It is also reasonably clear that digital television can and will be implemented in channels of about the same width as those used for analogue television - although such a channel may well contain more than one television programme. Because of this similarity of bandwidth between analogue and digital systems, it is obvious that attempts should be made to accommodate the new digital services within the same spectrum as that already used by analogue television.

This is in marked contrast with the DAB situation where the major difference in spectrum requirement for a single FM signal and a DAB block (or for a collection of 5 or 6 FM signals and a DAB block) means that sharing the same part of the spectrum is impossible.

Of course the fact that an *attempt* is made to re-use analogue television spectrum does *not* give a guarantee of success. We have some 80,000 television transmitters in use in the EBA and the philosophy of national coverage which applies in virtually all countries means that these stations are supposed to be protected against interference, whether this comes from analogue or digital stations.

6.2.1 Conventional planning of MFNs

The term "conventional planning" is used to describe the situation where the network for a digital service has a similar configuration to that for an analogue service, at least for the higher power stations. This means that digital stations would use much the same transmitter sites as analogue stations and would have comparable transmitting antenna heights, although the e.r.p.s would be lower.

The primary reasons for the lower e.r.p. values are:

- the lower minimum field strength requirement;
- the need to protect existing analogue viewers.

It is assumed that it will not be possible, in general, to change the channels used by the analogue transmissions because of the disruption to analogue reception which would be caused. However, some of the e.r.p. restrictions for digital services (examples have been found of restrictions of more than 50 dB) may be caused by the need to protect the coverage area of low power analogue stations. In such cases, analogue channel changes may be implementable and this could make a significant improvement to the digital coverage achievable. In this context, it has to be remembered that there are some of the 80,000 television stations in the EBA, some 50,000 operate at less than 100W e.r.p..

It seems likely that in many cases the digital services would use channels close to those of the analogue services, for example the adjacent channels. Generalisations with regard to choice of polarisation are not possible, but the use of the same polarisation for the digital and analogue services would at least mean that existing domestic receiving antennas could be used for the digital services without change. Because the services come from the same site and because the digital service e.r.p. would be lower than that of the analogue service (for the reasons given earlier), there would be little risk of causing adjacent channel interference to the existing analogue service viewers. If this type of interference were to exist, it would be present for 100% of the time and therefore must be avoided. It must be noted that many of the technical aspects related to the use of adjacent channel transmissions from the same site still need to be investigated.

The coverage areas for the digital services are likely to be reduced in size compared with those for the analogue services, the amount of reduction being dependent on the C/N value required. Nonetheless, it is to be expected that significant population coverages can be obtained, provided that some degradation of the analogue service due to co-channel interference can be accepted.

It seems unlikely that channels could be found which would permit the duplication of existing analogue services by digital services at all higher power analogue transmitter sites in all countries. Some very fundamental decisions will thus need to be taken. Is the aim to maximise the number of digital services in the more densely populated areas or to provide some digital services in all areas? On purely commercial grounds, the former would clearly be chosen. However, if the end of the transition period does not arrive until all viewers have digital reception capability, then it is necessary to ask why a viewer with no digital services available should purchase a digital receiver, especially as it will probably be more expensive than an analogue receiver. It certainly isn't adequate simply to stop the sale of analogue receivers while there is a significant audience relying on the analogue transmissions and some other mechanism will be needed to reduce the dependence on analogue transmissions.

6.3 Single frequency networks

6.3.1 General

Terrestrial digital services may be provided by multiple frequency networks (MFN) or single frequency networks (SFN). Current analogue television networks are operated in an MFN mode, each transmitter acting independently and having its own coverage area. To cover a larger area, national or regional, a certain number of channels is necessary which depends on the interference characteristics of the service. In an SFN all transmitters of a network use the same channel. They possess a common coverage area and cannot be operated independently. MFN and SFN concepts are based, in principle, on the same network topology, i.e. main transmitters with auxiliary gap fillers, if necessary.

OFDM, the modulation technique which enables the reception (and constructive summation) of more than one useful RF signal, is described in chapter 2.

Digital transmitter networks operated in SFN mode need a high degree of synchronicity which necessitates a larger effort in network operation as compared to the MFN approach. Further information on this topic may be found in DVB documentation.

6.3.2 Spectrum efficiency

Spectrum efficiency is regarded as a major advantage of the SFN concept as compared to the MFN approach. Spectrum efficiency is an important feature in a situation where spectrum is scare, for example, in the introductory phase of digital television, when most of the television spectrum is still occupied by analogue services, as well as in the long term, when a large number of programmes has to be provided to make terrestrial digital television attractive for the consumer.

Current analogue services are operated as MFNs. Within the UHF band, with 40 channels, 2 to 4 well-protected full-coverage analogue programmes can be achieved (depending upon the geographic situation of an individual country). Digital systems will be more efficient than this. Using MFNs, it can be expected that 3 to 6 full coverage networks could be implemented; with 4 programmes per channel, this would amount to 12 to 24 programmes. Using SFNs, it can be expected that the number of full-coverage networks (and the number of programmes delivered) is two to three times higher. If the target for coverage were changed to be the more densely populated areas only, the number of channels available could theoretically be around 40. All of these figures are based on theoretical considerations and the effect of practical considerations has to be checked case by case, for example, taking account of services in neighbouring countries.

6.3.3 Echo delay spread in SFNs

Terrestrial television broadcasting in VHF/UHF bands is characterised by multipath propagation, due to the presence of obstacles and reflections in the propagation environment. Therefore the signal at the receiver is characterised by the presence of a main signal component, and of many echoes, with variable amplitude and delay

(Ricean channel). In the case of portable reception, the principal signal can be absent (Rayleigh channel). The delay of these "natural echoes" is usually limited to 20-30 µs, corresponding to difference of propagation path of about 6 to 9 km.

The presence of SFN transmitters and gap-fillers produces a significantly more critical multipath propagation environment, introducing "artificial echoes" of high amplitude and long delay. These artificial echoes are superposed on the natural echoes. The delay spread of the artificial echoes is proportional to the transmitter distance, and it is determined by the transmitter network geometry. For example, assuming that in a large SFN with transmitter distance D=100 km the relevant delay spread is 330 µs, for a dense SFN with D=10 km it would be only 33 µs.

In the case of large area SFNs the delay of the artificial echoes is the dominant factor, while for dense networks the natural and artificial echo delays can be similar. In general, since the two phenomena are independent, they are studied separately: in this analysis only the artificial echoes produced by the SFN network are considered. **Annex 6.1** gives a methodology to analyse the performance of regular SFNs, including dense networks.

The delay spread of the echoes is one of the most important parameters in the design of a digital television system. In fact the receiving system complexity increases with the echo delay on the channel.

For OFDM systems the guard interval will be determined by the maximum delay and the coverage required, to achieve a long guard interval a large number of carriers and a large FFT size is required (see Chapter 2).

A system suitable for operation with a large delay is more complex and sensitive to phase noise, therefore more expensive tuners are required. Since in dense networks the delays are significantly lower, they would allow the use of lower-cost receivers.

The modulation and channel coding scheme also has an important impact on the performance in a SFN. Very robust systems (with relatively low spectrum efficiency, e.g. with 2 bit/s/Hz) can operate with low C/N and C/I values. Therefore they are not degraded by the attenuated echoes coming from distant transmitters, characterised by long delay, and require shorter guard intervals.

6.3.4 Network gain

In an SNF many receiving locations can be covered by more than one transmitter, thus introducing a certain level of redundancy in the signal sources and improving the service availability, especially when portable reception is required. Particularly in portable reception, the field strength from a single transmitter shows statistical variations due to the presence of obstacles on the propagation path. This field strength variation can be reduced by the presence of several transmitters, located in different directions, since when one source is shadowed, others may be easily receivable. This fact is known as "network gain" (see also **Annex 6.1**). Numerical examples are given in § 6.4.2.

As a result of network gain, SFNs can be operated at lower power for the main transmitters and the field strength distribution is more homogeneous as compared to MFNs. The impact of these features for fixed reception may not be very prominent but portable reception with its non-favourable receiving sites and non-elaborate receiving antennas will benefit from these features to a large amount. The SFN approach seems to be the most reasonable way to provide satisfactory coverage for larger areas when portable reception is envisaged.

6.3.5 Planning of SFNs

Since the MFN and SFN approaches are based on the same network transmitter topology, SFNs can use, in principle, the network structure of the existing MFN analogue networks. In general, it can be expected that fewer gap fillers are needed with SFNs because of their more uniform field strength distribution. The specific case of dense networks is dealt with in § 6.3.6.3.

The introduction of SFN-based DVB services is faced with the major problem that most (or all, in some countries) of the television spectrum is occupied by analogue services which use a MFN structure. Even if some free channel assignments exist for digital services, this is only of limited use for the introduction of an SFN-based large area service since a network can only operate in the SFN mode under the condition that its channel is cleared for the entire service area. If there are still analogue services using this channel - and this is probable as long as there is any national or regional analogue service in operation - the affected analogue transmitters would have to be shifted in frequency. Among these transmitters there will be main stations with a considerable amount of population coverage. It is questionable whether it makes sense, from the accompanying large cost efforts for broadcasters and consumers, to re-arrange an analogue service which will later be phased out. However, there may be suitable channel configurations that make this transformation practicable. In particular, for smaller area networks comprising only two or three high power transmitters the SFN approach may be applicable and attractive.

In some countries the possibility exists that in the UHF band one or more channels will be released for the implementation of digital services on a nation-wide scale. These channels are either not yet allocated to television broadcasting, or they are already allocated but not used by television services. These countries are offered a good chance to implement an SFN-based digital service on a national or regional scale, which potentially represents the introduction of an attractive long term scenario from the very beginning.

In general, the use of these channels will not be possible on an entire nation-wide basis because of neighbouring countries which probably use these channels for analogue television or other services. Co-ordination will be difficult in these cases, as long as the neighbours operate these channels on an MFN basis.

6.3.6 Types of SFNs

SFNs can be implemented in different ways. **Annex 6.2** gives definitions of the various types of SFN being considered.

6.3.6.1 Large area SFNs

Large area SFNs are built from at least two up to several dozens of high power transmitters together with associated medium and low power transmitters. They form the best way of exploiting the high spectrum efficiency inherent in the SFN approach.

In the case that a group of new frequencies is allocated to the new digital services, a straightforward approach is the introduction of some national SFNs, and smaller SFNs to cover the regional programming requirements. This scenario could equally apply to the long term situation for digital television, when the analogue services will have been phased-out. Agreements between neighbouring countries would need to be reached to ensure equitable usage of such channels.

On the other hand, in a country with fully developed analogue networks and few unused but accessible assignments it is unlikely that large-scale SFNs could be implemented. One possibility which might be explored would be to implement general channel changes at existing analogue stations. However, it seems unlikely that this could be undertaken in practice because of the widespread disruption of existing reception for the country concerned and for its neighbours.

6.3.6.2 Mini SFNs

In a mini SFN an existing main station and many (perhaps all) of its auxiliary low power stations would share the same channel. This is an attractive concept in terms of channel economy and homogeneity of the field strength provision but there are still a number of technical matters to be examined.

For example, there are likely to be viewers of the existing analogue transmissions from the main station who are situated close to the relay station sites. Such viewers are likely to experience interference from the digital transmissions from the relay station if these use channels adjacent to those of the analogue services. Finally, in the case of fixed reception, the receiving antennas used by the viewers of the analogue services from the relay stations are unlikely to be suitable for reception of the new digital services because of channel differences. On the other hand, for portable reception where this fact is irrelevant, the concept of mini SFNs provides an attractive means of increasing digital coverage because of the more homogeneous field strength distribution.

6.3.6.3 Dense networks

A variant of the SFN approach is the concept of dense networks which employs a different network topology. A large number of low power stations is distributed over the service area (potentially with a main transmitter at the centre), providing an homogeneous field strength distribution. Dense networks may serve to supplement conventional MFNs and SFNs in areas where the coverage otherwise would be inadequate due to terrain orography or overspill into neighbouring service areas. Dense networks can be operated at very low powers which considerably lowers their interference potential. Thus, a large scale MFN may be implemented in such a way that the MFN high power transmitters are substituted by local dense networks, partly ore entirely, offering more possibilities for co-ordination with other services. Because of the high field strength homogeneity, in particular, portable reception benefits from a dense network implementation.

Such networks are likely to be more expensive to install than conventional networks because of the need for additional transmitter sites, but they can have the advantage of reducing the impact of co-channel interference from the digital network and thus the coverage areas may be increased in size. However, there is a significantly increased risk of causing interference to existing analogue viewers in the case that a channel adjacent to that of an analogue transmission is used for the digital service. This is simply because most of the transmitters in the digital dense network will not be co-sited with the analogue transmitters and this will lead to high level digital signals in areas where the analogue signal is relatively weaker. Therefore dense network configurations need careful study on a case-by-case basis to ensure that major interference to existing viewers is not caused.

A more detailed description of the application of the dense network concept is given in **Annex 6.4**.

6.4 Multiple signal effects

In general, the reception of digital services is faced with a multi-signal environment, multiple interference as well as multiple wanted signals in the case of SFNs. To assess the wanted and unwanted resultant field strengths the individual signals have to be combined. Since signal strengths are described by statistical quantities they have to be combined statistically (see § 3.4).

Basically, this is true for both location and time statistics. However, it is usual to treat them in different ways. Time statistics are taken account of by using tabulated field strength propagation curves for the appropriate time percentages. Location statistics are dealt with by using field strength distributions.

General aspects of time and location statistics and mathematical methods to perform statistical summation are described in § 3. The impact of signal summation effects on planning methods and parameters is discussed in the present section.

6.4.1 Single signals and propagation margins

Location statistics of an individual (logarithmic) field strength originating from one transmitter is described by means of a normal distribution which is characterised by two parameters, mean value and standard deviation. Accordingly, the power of the signal is then distributed log-normally.

In § 3.3, the key role of coverage probability targets as planning parameters for a digital system is discussed. These target figures are related to the field strength distribution parameters. 50% coverage probability is determined by the mean value of the distribution, for the calculation of higher (and also lower) coverage probabilities both mean value and standard deviation of the signal distribution are needed.

In the case of a single signal, where the distribution parameters are known a priori, propagation margins to cater for higher coverage probabilities, as described in §5, are easily calculated, e.g., the propagation margin for a 95% coverage probability is given by $1.23\times\sigma$, where σ denotes the standard deviation. This is how the minimum median field strengths for planning are determined in § 5. The same applies to propagation margins for protection ratios when one wanted and one unwanted field are involved.

6.4.2 Multiple signals and network gain

When a multi-signal situation is encountered, the parameters of the resulting signal distribution are no longer known a priori. Mean value and, especially, standard deviation strongly depend on the particular signal configuration having to be determined by means of statistical procedures. As a consequence, minimum field strengths and propagation margins no longer have fixed values, they rather become variables depending on the number, strength and spread of the individual single fields. However, two general trends can be identified. Firstly, the mean value of the composite signal is larger than the arithmetic sum of the individual means and, secondly, the standard deviation of the composite signal is smaller than that of the individual signals, both facts creating the effect of network gain (in the case of wanted signals). Its physical background, location diversity, is discussed in more detail in § 6.3.4.

Some examples are given to assess the significance of field strength summation effects. (Though being taken from DAB investigations, i.e., in particular relating to a 99% coverage probability target, they are qualitatively also valid for DVB).

Maximum statistical network gain is achieved if the contributing fields are of equal strength. In the case of, e.g., 3 single signals it amounts to 6.6 dB. This means, it would allow for an overall power reduction in an SFN by a factor of 4 as compared to a single transmitter coverage.

Not all locations covered by an SFN benefit to such an amount from network gain. As a second example, an edge location of a particular 7-transmitter hexagon SFN is chosen. Though situated on the fringe of the coverage area it still experiences a network gain of 5.5 dB, reducing the minimum field strength for planning by that amount.

Similarly, propagation margins for protection ratios are reduced by signal summation effects. Again, as an example, an edge location in a 7-transmitter hexagon SFN is chosen, now interfered with by a second, identical SFN. Here field summation effects for both wanted and unwanted signals lead to a reduction of the necessary propagation margin of about 6 dB, indicating the ability of the wanted SFN to cope with a 4 times higher interference without losing the coverage probability target.

The examples show that signal summation effects in SFNs may impact the coverage of a digital service to a significant amount.

It has already been stated that signal summation effects increase the mean value and lower the standard deviation of the resulting sum signal distribution as compared to the outcome of a non-statistical treatment. This is an important finding, since it gives the possibility to fix the results of the non-statistical treatment as an upper bound for initial planning estimates. Allowing for some additional implementation margin, they form an appropriate basis for planning when detailed information about the transmitter characteristics of a network is not available, e.g., when setting up an allotment plan. These figures are given in chapter 5.

On the other hand, detailed planning, e.g., installing an assignment plan or implementing a real transmitter network, has to take account of signal summation effects. Propagation margins for minimum field strengths and protection ratios then no longer form suitable planning parameters. They have to be replaced by the more basic coverage probability targets. Their relation to the sum distribution parameters of the wanted and unwanted sum fields is briefly described in **Annex 6.3**.

6.4.3 Multiple interference and self interference

Time statistics for interfering fields are taken account of by basing calculations on 1% time propagation curves, whereas wanted field calculations are based on 50% (or 99%) time propagation curves. Statistical signal summation effects for interfering fields with respect to location statistics are effective, in principle, in the same manner as described for wanted fields in the previous section. However, their impact on coverage calculations is not that important because of the asymmetrical characteristics of the sum field distribution. Therefore, it is often justified to treat multiple interference with simpler statistical procedures.

In considering SFNs it should be recognised that not all the transmitters in a network will contribute to the wanted signal. Depending on the system and network parameters, such as guard interval and distances between transmitters, some signals may become interferers. This effect is called the self interference of the SFN. It is of larger importance for the DVB system with its higher protection demand than for DAB, and has to be met by careful network design.

With respect to signal summation, self interference fields are treated as 'normal' unwanted signals. 1% time propagation curves are used, and they are added to the other source of possible interference from outside the SFN.

A special situation may arise if a self interfering signal is shifted (in time) only slightly outside the guard interval. Then the field is not totally interfering but also contributes partly to the wanted signal, as described in chapter 2. The effect is well known for DAB where it plays an important part when the coverage of an SFN is to be assessed. Its significance for the DVB system with its different demodulation scheme is not yet finally established and needs further theoretical and experimental investigation.

However, if the effect has to be taken into account, a problem arises with the treatment of the interfering and the contributing signal parts. Usually, unwanted field strengths are calculated on the basis of 1% time propagation curves and wanted fields on the basis of 50% time propagation curves. If both parts emerge from the same field the question is whether to adopt the 1% time or the 50% time propagation curves as the basis of the calculation. A possible treatment could be to base it on 50% time propagation curves as long as the major part of the signal shows a contributing behaviour, otherwise to base it on 1% time propagation curves. But it should be kept in mind that this is a rather rough approach. A satisfactory treatment seems to be possible only if time statistics are performed more thoroughly, no longer relying on two or three propagation curves only.

In addition, a similar problem is encountered with location statistics. Usually, wanted and unwanted signals are treated as statistically independent. In the case of an interfering and a contributing signal part emerging from the same field this is obviously not true. The impact of this 'self correlation' effect on coverage calculations has not yet been evaluated and needs further investigation.

6.4.4 Receiver synchronisation

In an SFN multi signal environment with relatively long time delays between the single signals, the question whether an individual delayed signal lies inside or outside the guard interval depends on the way the FFT window of the receiver, where the signals are evaluated, is triggered. In principle, the best trigger strategy is to optimise the ratio of wanted and unwanted (self interference) signal parts. However, even in computer simulations this is an time consuming task. Therefore, more simple synchronisation strategies are usually employed, as for example triggering on the first signal (above an appropriate threshold), or on the strongest signal.

Computer simulations show that for critical reception situations the choice of the synchronisation strategy has a significant impact on the coverage probability that is achieved. It should therefore be carefully chosen when assessing the coverage of a digital service. Eventually, when DVB consumer receivers are available, it has to be lined up with their average behaviour.

6.4.5 Correlations

Correlations between RF signals have been reported to be of non-vanishing significance for the evaluation of the coverage of broadcasting services. Nevertheless, no generally agreed assessment of correlations has yet been established.

Basically, correlation is not a signal summation effect, it may also occur in the presence of only one wanted and one unwanted field. In this case, correlation increases coverage for a given configuration of wanted and unwanted field strengths.

In a multi-signal situation, the opposite effect can be observed. Correlations between wanted signals reduce the network gain of a transmitter network and correlations between unwanted signals increase their interference potential, both effects lowering coverage for a given configuration of wanted and unwanted signal strengths.

In view of the uncertain general assessment of correlations and the different effects they produce with respect to coverage, it seems to be justified to neglect them in planning calculations, at least at the present time.

ANNEX 6.1

CHARACTERISATION OF THEORETICAL SFNs

Studies have been undertaken to characterise the impact of the digital television system performance (guard interval, protection ratios) on the service availability in the service area, versus the dimension of a SFN (large area or dense). The analysis methodology has been defined and a number of results have been obtained for DVB networks.

In a single frequency network, all transmitters broadcast exactly on the same RF channel and the transmitted signals are fully synchronised. The service areas of these transmitters usually overlap.

Compared with a conventional multiple frequency network (MFN), an SFN allows significant improvements in spectrum utilisation, but it imposes heavy constraints in the design of the transmission system. In fact the useful signal is interfered with by the artificial echoes produced by the other transmitters, characterised by large amplitudes and long delays. The echo delays depend on the difference of the propagation path lengths, and can be of the order of some tens to some hundreds of microseconds, depending on the transmitter distance (e.g., a path difference of 10 km corresponds to a delay of about 33 µs).

These SFN echoes are superposed on the echoes generated by the obstacles (mountains, hills, buildings) often present in the propagation environment (multipath echoes). In general the delays associated with the multipath echoes are shorter than 20-30 µs. This Annex refers only to the artificial SFN echoes, while the natural multipath echoes are neglected.

The performance of a digital television system in an SFN heavily depends on the echo delay and amplitude characteristics. Only OFDM systems are considered here, with powerful channel coding schemes suitable to operate under very severe multipath propagation conditions, such as those produced in SFNs. These systems (see chapter 2) can process the echoes (natural or artificial) in such a way that, up to a certain amount of delay spread, all the fields contribute constructively to the wanted signal. This offers the possibility of establishing SFNs.

A uniform infinite lattice network is used to study the theoretical performance of a SFN, usually based on hexagonal service areas.

The ITU-R propagation model described in ITU-R Rec. P.370 is usually used to evaluate the field strength produced by each transmitter in the network in a given receiving point. Mean values for the field-strength location distributions are taken for the land 50% location / 50% time-curves for the useful components of the SFN signal. For interfering signals, it is more usual to use the 50% location / 1% time-curves, which correspond to greater impairment. Calculations are carried out with a location variation standard deviation of 5.5 dB for individual signals.

For DVB services, both fixed reception (with roof-top directive antennas) and portable reception are of interest. ITU-R propagation curves give field strengths which are valid for reception with an antenna situated 10 metres above ground level (a.g.l.). This model is suitable for DVB fixed reception with roof-top antennas. For portable DVB reception, a 10-30 dB receiving antenna conversion factor can be subtracted from the predicted field strength (see chapter 5). For large area SFNs, high (e.g. 150 to 300

m) transmitting antenna masts can be considered, while for dense networks smaller (e.g. 37.5 m) antenna heights seem more realistic.

A location coverage of 95% is generally demanded for DVB services, at least for fixed reception and roof-top antennas. It is well known that in this high-probability domain, the statistical network gain of a SFN provides a significant part of the overall coverage. Particularly for portable reception in shadowed areas, the space diversity of the signal sources provides a reduction in the field-strength variations and improvement in the coverage. It is therefore necessary to treat the statistical aspects as thoroughly as possible. Non-statistical approaches lead to severe under-estimation of the coverage and give an incorrect impression of the validity of SFN concept.

The statistical summation of the field-strengths should be performed by means of a "Monte Carlo" technique. For every location, the signal components from the various transmitters are randomly generated with the suitable statistical distributions, and according to the delay and the system guard interval, an equivalent aggregate carrier to noise C/N and interference ratio C/I is obtained. For a first investigation of the SFN performance, a simplifying assumption of "interference limited network" (i.e. no noise) can be done. In the case of roof-top directive antenna, it is assumed that it is pointed in the direction of the strongest transmitter.

The combination of C/N and C/I is compared with the system threshold (relevant to a severe multipath environment, such as a Rayleigh channel), to determine whether this particular receiving point is served or not served. To achieve statistically significant results, this procedure is repeated thousands of times for each "small area" or “pixel”, and then repeated on a regular grid over the complete service area.

This method can provide the coverage probability for the service area and overall aggregate values of percentage of served locations. An important indicator of the network performance is the percentage of locations served in the worst pixel. Alternatively, the performance can be quantified by means of the percentage of pixels for which a given coverage target is achieved.

This analysis can allow the optimisation of the system parameters (guard interval, threshold C/N and C/I) given a theoretical network configuration (transmitter distance, antenna height), or alternatively, permits a choice of network parameters given a digital modulation/coding system.

ANNEX 6.2

TERMINOLOGY RELATED TO TRANSMITTING STATIONS AND SINGLE FREQUENCY NETWORKS FOR DIGITAL TELEVISION SERVICES

Transmitting stations for digital services

High power station:

A station with an e.r.p. greater than 10 kW and an effective antenna height usually greater than 150 metres.

Medium power station:

A station with an e.r.p. in the range 100 W to 10 kW (inclusive) and an effective antenna height usually in the range 75 to 150 metres.

Low power station:

A station with an e.r.p. less than 100 W and an effective antenna height usually less than 75 metres.

Single Frequency Networks

Large area SFN:

An SFN which contains more than one high power station together with any associated medium and low power stations, usually with a composite coverage greater than about 10,000 sq. km.

Mini SFN:

One high power station together with at least one (and probably several) associated medium or low power stations.

Dense SFN:

A network of low to medium power stations.

National SFN:

An SFN covering a whole country.

Regional or Local SFN:

An SFN covering part of a country.

ANNEX 6.3

EVALUATION OF COVERAGE PROBABILITY

In a receiving situation where signal combination effects become important minimum median field strengths and propagation margins for protection ratios are no longer suitable planning parameters. They have to be replaced by the more fundamental system values for minimum field strengths and protection ratios and the appropriate coverage probability targets, and a statistical evaluation of the signal configuration has to be performed.

In assessing coverage and compatibility, basically the same procedure as in the non-statistical case is applied. At the location under consideration, wanted and unwanted signal levels are evaluated and the wanted signal level is compared to the unwanted signal level and the noise level. If the wanted signal level exceeds the combined noise and interference level the location is regarded as covered. However, the way to end up at this result is slightly different for the two approaches.

The statistical approach performs the evaluation (prediction and statistical summation) of the wanted and unwanted signals at the location of the receiving antenna taking account of individual signal variation effects separately, whereas the non-statistical approach shifts all statistical effects into propagation margins for minimum field strengths and protection ratios.

The statistical procedure is as follows:

- Evaluate with an appropriate prediction method the parameters (mean value and standard deviation) of the wanted and unwanted individual fields at the receiving location. For an ITU-R Rec. P.370 prediction this means that height loss and building penetration loss, including statistical spread, have to be incorporated at this stage. In practice, the correlations between wanted and unwanted signals with regard to height loss and building penetration loss is neglected because of a lack of knowledge of their magnitudes. This is different from the non-statistical approach where these quantities are incorporated into the minimum field strength;

- Add the appropriate protection ratios to the individual unwanted fields to get the respective nuisance fields. The protection ratios are the system values C/N given in the tables 2.1 to 2.3 increased by the appropriate implementation margin;

- Treat noise as an additional interfering field. This is done by taking the system value of the minimum field strength as mean value of the interfering field and attributing to it a standard deviation of 0 dB. The system value of the minimum field strength is given by the "minimum equivalent field strength at a receiving location" of the tables 5.1 to 5.12 increased by the "allowance for man made noise";

- Evaluate the distribution parameters of wanted and unwanted sum fields by means of one of the statistical summation methods described in § 3.3. (At present, this means that the Monte Carlo method should be used as other methods are still in a development stage, at least for the general case.) Mean value and standard deviation of the respective sum fields F_{Σ}^{w} and F_{Σ}^{u} are denoted by $\overline{F}_{\Sigma}^{w}, \sigma_{\Sigma}^{w}$ and $\overline{F}_{\Sigma}^{u}, \sigma_{\Sigma}^{u}$ ('w' for wanted, 'u' for unwanted, i.e. nuisance field);

- The coverage probability CP at the considered location is given by

$$CP = P(F_{\Sigma}^{w} - F_{\Sigma}^{u} \geq 0) \ ,$$

where the right hand side expression describes the probability P that the wanted field exceeds the unwanted field. P can be evaluated in the following way:

$$P(F_{\Sigma}^{w} - F_{\Sigma}^{u} \geq 0) = I\left(\overline{F}_{\Sigma}^{w} - \overline{F}_{\Sigma}^{u}, \sqrt{(s_{\Sigma}^{w})^{2} + (s_{\Sigma}^{u})^{2}}\right),$$

and the function I is given by

$$I(F, \sigma) = \frac{1}{2}\left[1 + \operatorname{erf}\left(\frac{-F}{\sqrt{2}\sigma}\right)\right] \ .$$

The error function erf is evaluated with the help of tables or parametrisations. These can be found in ITU-R Rep. 945 or mathematical handbooks.

ANNEX 6.4

DENSE NETWORKS

In the case of SFNs, the use of dense networks can offer some advantages over networks based on high power transmitters separated by large distances (60 to some hundreds of kilometres).

1. National and regional Dense Networks

Particularly in the case of regional SFNs, but also for national SFNs, it is possible to consider various forms of dense networks, with all of the transmitters using the same channel, but having significantly lower e.r.p. than that required by a single transmitter serving the same area. For digital terrestrial broadcasting, the concept of "distributed emission" can provide the needed field strength over the entire service area by a number of low power, synchronised SFN transmitters, located on a more-or-less regular lattice, or to use on-channel repeaters receiving their signal off-air from the main transmitter, to improve the coverage of the main transmitter. In the latter case, the re-transmitters need not be synchronised in time, and no parallel transmission infrastructure is needed to bring the signal to these on-channel repeaters.

Although the low power transmitter themselves should be relatively low-cost, dense networks are likely to be more expensive to install than conventional networks, because of the need for a large number of additional transmitter sites. Nonetheless, they have many advantages over a conventional high power networks. First of all, they provide a more reliable field strength over the entire service area, thus avoiding the need for a power overscaling of the central transmitter, while achieving high service availability and continuity (even with steep failure characteristic systems). The second advantage is the possibility to increment progressively the coverage area in a flexible way. Furthermore, local high density SFNs could be used to supplement large SFNs in areas where the coverage would otherwise be inadequate, due to the terrain orography. Finally, they offer a reduction of the impact of co-channel interference at the border of the service area, by introducing a sharper field strength roll-off. This can be further improved by a suitable exploitation of the transmitting antenna directivity.

For example, it is possible to envisage transmitter topologies in which the central part of the service area is covered by a large SFN (with high power transmitters separated by large distances), but near the border a dense transmitter network is installed (with low e.r.p., and with low-height and directive antennas). This allows the e.r.p. to be “tailored” according to the service area contour, reducing the interference to adjacent areas and keeping high the service availability inside the wanted area. This technique can be useful also on the borders of national SFNs.

2. Local area dense networks

The introduction of new digital services can be carried out exploiting the frequency resources left unused by analogue MFNs, introducing digital MFNs on a national or regional or local basis, depending on the spectrum availability and the service requirements. The implementation of digital services can be achieved by a progressive introduction of low e.r.p. digital signals from the already available transmitting installations, possibly on RF channels adjacent to the existing analogue signals. This minimises the installation cost for the broadcasters and the impact on the viewers, not requiring the installation of new transmitting or, possibly, receiving antennas. This approach, exploiting the frequency resources left partly unused by analogue MFNs, requires a case-by-case optimisation of the digital service planning, to minimise the interference on analogue services and maximise the service area coverage.

Exercises based on this procedure led to very different results in terms of percentage coverage, depending on the spectrum availability of each country. In the case of intensive exploitation of the spectrum resources by analogue television services, this introductory approach cannot aim at providing full coverage for digital services, but rather a coverage oriented to highly populated areas (towns), and cannot achieve a good coverage for portable receivers, because of the e.r.p. limitation needed to protect existing services.

A step forward, when this approach offers insufficient coverage, is to set up new low power transmitting stations, (relay stations or "gap fillers") around a main transmitter, sharing the same RF channels. This dense network configuration can also be regarded as mini SFN and offers the possibility of achieving good coverage in metropolitan areas, of following the service area orography, improving the coverage in hilly and mountainous regions, and of better controlling the service area contours, reducing the co-channel interference on adjacent areas. In the case of coverage of highly populated areas, the transmitter network could be very dense (e.g. an inter-transmitter distance of 5 km) and of low-power.

However, there is a significantly increased risk of causing interference to existing analogue transmissions on adjacent channels, since the transmitters of the local SFN will not be co-sited with the analogue transmitters, and this will lead to the presence of high level digital signals in areas where the analogue signals are weaker. This could produce holes in the coverage area of the analogue services.

In addition, in the case of fixed reception, the receiving antennas used by the viewers of the analogue services are unlikely to be usable for the digital services, because of the different station locations and frequency differences (fixed receiving antennas for VHF/UHF television are directional and frequency selective).

Studies on DAB-like systems (256 µs guard interval, C/N=10 dB) operating as regular SFNs indicate that a "protection zone" of "r" km is required to reduce mutual interference at the border of two SFNs. The r/D ratio (D=transmitter distance within a regular SFN) decreases from 3 to 4 to about 2 by reducing D from 90 km to 40 km.

This confirms the advantages offered by dense networks at the border of an SFN service area, reducing the interference levels to other networks. The use of directional transmitting antennas at the border of the service area is suggested to further improve the interference situation on these "micro cellular structures".

The studies also analyse the performance of local SFNs including only a limited group of N transmitters. The results indicate that for a transmitter distance D=60 km, with N<7 transmitters, large separation distances are required before frequency reuse is possible (a minimum of 7 RF channels are required to cover large areas). For a larger number of transmitters (N=19), the required number of RF channels is reduced to 3 (of course, this result neglects the necessity for different coverages in different countries or regions). These benefits in spectrum efficiency can be obtained also in small local networks, provided that a dense network structure with a large number of transmitters is adopted.

7. PLANNING METHODS

7.1 Introduction

Terrestrial digital television services can be planned using allotments and/or assignments. The methods for both these approaches are given in this section and they can be used in preparation for and during, an international planning conference. The planning of an individual station (or group of stations), intended to provide coverage to a specified area, is also covered.

7.1.1 Assignment Planning

In the past, terrestrial television planning in Europe has been by way of assignment conferences. In assignment planning, a significant amount of individual station planning is needed to prepare for a planning conference. Stockholm'52 and Stockholm'61 were two such conferences related to terrestrial television and European broadcasters have gained much experience in assignment planning, particularly since the planning methods and criteria of the '61 conference are still applied to analogue television planning.

Assignment planning is appropriate where:

- a broadcaster wishes to use an existing transmission infrastructure for environmental and economic reasons;
- there is a need to share spectrum with existing analogue television transmissions in the same country.

At the completion of the assignment plan, the locations and characteristics of the transmitters in the planning area are known, and the transmitters can be brought into service without further co-ordination.

7.1.2 Allotment Planning

The alternative possibility of obtaining *allotments* at a conference has received considerable attention in recent years, particularly because of the opportunities offered by SFNs. Allotment planning for SFNs is probably best carried out where "free" spectrum is available or can be made available. Allotments may also be applicable for MFN planning where a country has no plans to use specific transmitter sites and wishes to retain some flexibility for late future.

In allotment planning, a channel is "given" to an administration to provide coverage over all or part of its territory, but as there are no agreed definitions of words such as "national" or "regional", care is needed in their application. At the allotment planning stage, in general nothing is known of the actual location of the transmitter sites nor of the transmission characteristics to be used. The only parameters available are a definition of the area to be covered and the channel to be used. Thus in order to carry out the planning exercises it is necessary to define some reasonably realistic reference transmission conditions so that any necessary compatibility calculations can be made.

7.1.3 Planning constraints

The constraints on planning are the same for allotment and assignment planning and are:

- compatibility with existing analogue television services;
- protection of other services (chapter 14);
- Mutual protection of digital television allotments or assignments;

7.1.4 Digital television planning in Europe

It is possible that terrestrial digital television planning in Europe in the reasonably near future will have to be based on a mixture of assignment and allotment planning. To reduce the complexity of planning it would seem to be more convenient if only one of these approaches was used in any given country, or at least in any given segment of the spectrum in that country. However, assignment planning offers many advantages; not least, the results are implementable without any intermediate conversion process.

7.2 Elements of planning

7.2.1 Planning criteria

The planning criteria consist of the following elements

- Protection ratios (chapter 2)
- Percentage of time for which protection is required (chapter 4)
- Percentage of locations for which protection is required (chapter 4)
- Signal levels and C/N values (chapter 2 and 5)

For planning the initial introduction of digital television in Europe it will be necessary to restrict the planning studies to a representative sub-set of C/N values. This is because the differences between the C/N values for the many options within the DVB specification is less than the inherent accuracy of the propagation prediction methods available (including the assumptions necessary in the case of portable reception).

7.2.2 Propagation prediction methods

As discussed in chapter 3, either ITU-R Rec. P 370 or terrain databank based methods may be used for propagation predictions. Even though the Rec. P.370 method cannot take into account any fine (or even medium) scale information related to the propagation path, at the time of writing there is general international agreement only for this method. For national planning or bilateral co-ordination, prediction methods based on terrain databank models may be used, subject to the agreement of all parties concerned.

7.2.3 Combination of multiple signals

In SFNs in particular, an appropriate method must be used to combine multiple wanted and unwanted signals at a received location. Examples of such methods are given in chapter 3.

7.2.4 Databases for planning

Terrestrial digital television broadcasting will be primarily accommodated in the same bands as analogue television. Extensive compatibility calculations will be needed in planning studies and subsequent co-ordination to facilitate this accommodation. These calculations require databases containing:

- existing and planned analogue transmitter stations;
- proposed digital transmitter station assignments;
- allotment plans containing, for example, areas to be covered;
- details of other services.

In order to facilitate the establishment and maintenance of suitable television transmitter databases, the EBU has designed and is using a format for the electronic exchange of the data for the analogue television transmitters. The EBU has also, in co-operation with the CEPT, designed a digital transmitter database format. Details of these transmitter database formats are given in chapter 10. Further consideration is needed with regard to suitable contents and formats for databases for allotments and for other services. The latter, in particular, will require additional study to determine suitable compatibility criteria and calculation methods (see chapter 14).

7.3 Procedures for the protection of analogue television services

This section is applicable to both assignment and allotment planning for digital television. In either case, before a channel is chosen for a digital television service, it is necessary to establish the size of the analogue coverage area for each station and channel in use (or planned and fully co-ordinated).

To calculate the coverage area of an analogue television station, two elements are necessary:

- the parameters particular to an individual transmitting station (co-ordinates, height of the antenna, radiated power, etc.) which are used to calculate the wanted signal,

- the system parameters such as the minimum wanted field strength and the protection ratios which are used to calculate the individual nuisance fields. With the appropriate method of combination of these individual nuisance fields, the usable field strength can be calculated

It is the usable field strengths calculated for different test points at the edge of the coverage area which are used to decide if a new transmitter can be accepted without any further calculation. In practice, the maximum increase of the usable field strength caused by the new transmitter is calculated and the new transmission is accepted if this increase is below an agreed value.

7.3.1 Establishment of the size of analogue television coverage areas

Because a certain amount of iteration is involved, the analogue coverage areas are determined in three stages and reference should be made to Figs 7.1 and 7.2 for clarification of the following texts.

Stage 1. Calculation of noise limited coverage area (minimum wanted field strength)

In the first stage, using ITU-R Rec. P.370, the noise-limited service area is found, which is the area that could be served if there were no interference. It may be approximated on the basis of 36 radii, at 10 degree intervals, starting at true north. Where known, the HRP of the transmitting antenna and individual values of height above mean terrain should be taken into account.

Stage 2. Identification of interferers

In the second stage, the impact of co-channel and adjacent-channel interference from other analogue transmitters is calculated for each wanted station. First, the sub-set of possible interferers is established. This consists of the stations which can produce a nuisance field which is no more than 12 dB below the minimum (usable) field-strength at worst-case locations. This corresponds to an interference increase of 0.5 dB (power sum method) but adds a small safety margin because the identification of the, so-called, worst-case locations is subject to a certain degree of approximation. (It is to be noted that the value of 0.3 dB is a compromise choice).

Stage 3. Calculation of interference limited coverage area

The nuisance field-strength from each of the interfering stations in this sub-set is calculated at each of the 36 points around the periphery of the service area of the wanted station. (That is, at the service radius on each of the 36 bearings described above). These calculations include the relevant protection ratio values and the value of any receiving antenna discrimination. The power sum of these nuisance field-strengths is found for each of the 36 points. These power sums represent the total interference at each of the 36 points.

If the power sum at a point is less than the minimum wanted field strength, no further calculation is required, and the coverage radius is that of Stage 1 above.

If the power sum at a point is greater than the minimum wanted field strength, it is then necessary to find the new radius at which the field-strength from the wanted station equals the sum of the nuisance fields.

Because, in general, the coverage radius thus calculated will not equal the service radius on the same bearing and thus the nuisance field-strengths will change, the process of the previous paragraph is repeated to obtain a close approximation to the required coverage radius on each of 36 bearings.

The process described above is repeated for each transmitter on a given channel and is also repeated for all UHF channels.

It must be noted that a given analogue station will normally have different coverage areas on different channels and this can be important when considering the relative coverage of digital and analogue services.

An example of the type of result which the above approach can give is shown in Fig. 7.3 The solid line in this Figure shows the results of the coverage calculations in 36 radial directions. The shaded area shows the results of the coverage as established by survey measurements. In view of the approximations involved, it is considered that the match achieved is quite good.

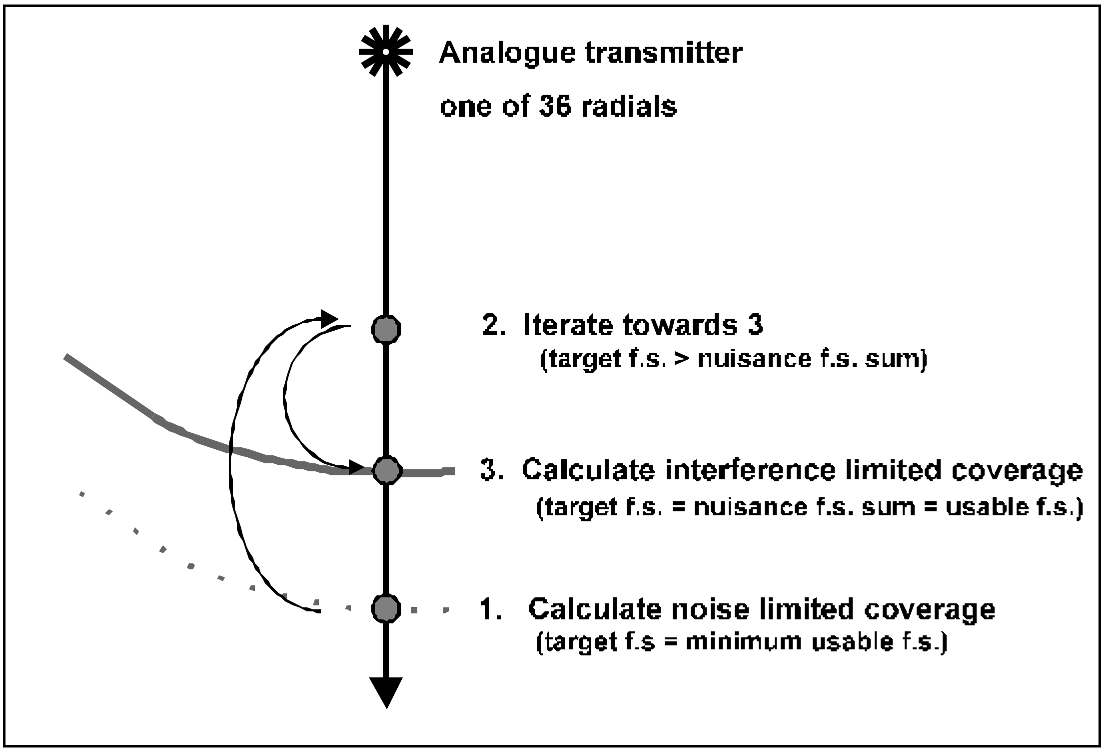


Fig. 7.1: Calculation of test points for the analogue interference limited coverage

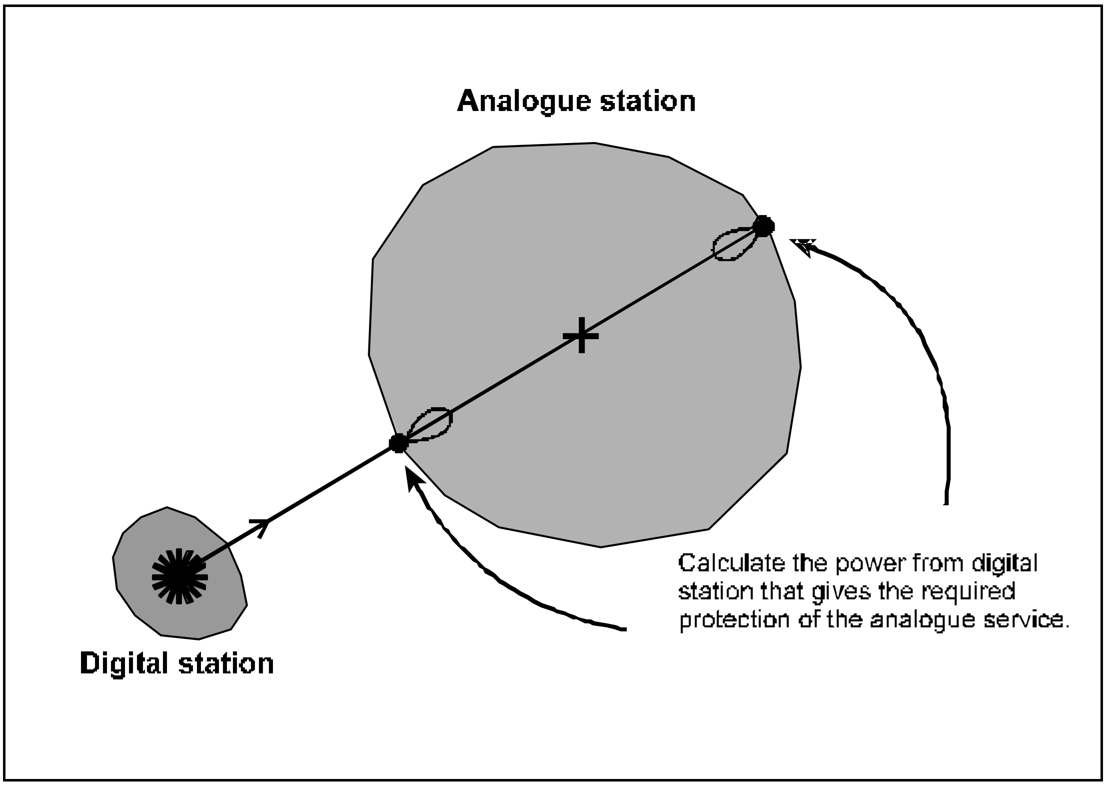


Fig. 7.2: Calculation of digital television coverage

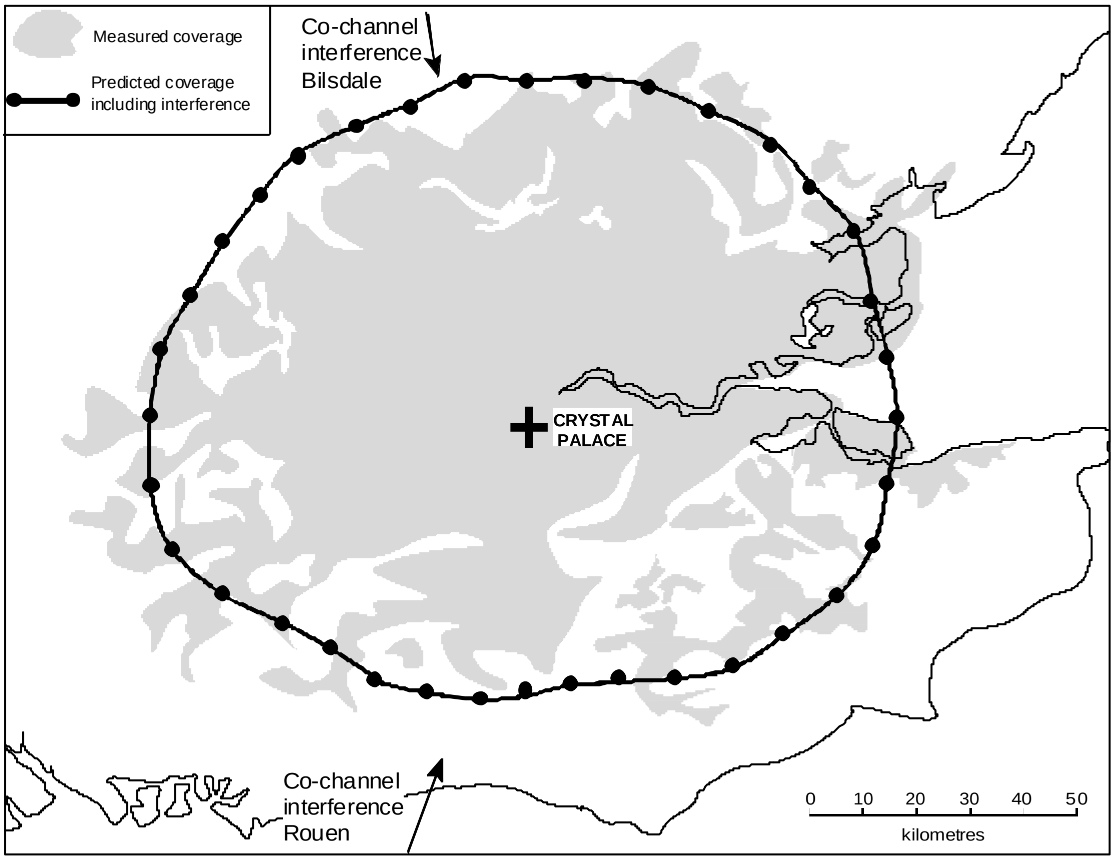


Fig. 7.3: Comparison of BBC measured coverage and EBU computer generated test points for Crystal Palace analogue television on channel 33

7.3.2 Protection on national boundaries

In some cases, for example where there are no existing or planned analogue services to be protected, it may be desirable to establish a set of test points, for the purpose of calculation of potential interference, along the boundary of a country. Agreements will need to be reached on the criteria needed for the establishment of such test points and the ways in which they may be used.

7.4 Protection of other services

A number of sharing situations exist and these vary from one country to another, both in terms of the “other service” involved and its status in Radio Regulatory terms. The calculation process will need to consider both assignments and allotments as the basis for digital television planning. Further details are given in Chapter 14.

7.4.1 Calculation of the protection of other services

A calculation should be made at each of the calculation test points used in the definition of the other service. This calculation should take into account:

- the signal level to be protected at each of the test points;
- receiving antenna discrimination (polarisation and directivity), where relevant;
- the protection ratio for the frequency difference between the other service and the interfering signals;
- the signal level from the interfering transmitter.

From the above information, the protection margin (at each test-point) may be calculated for the other service. These margins may be used to provide guidance during any necessary co-ordination discussions.

The calculation of the interfering signal level is dependent upon the other service being considered. ITU-R Rec. P.370 may be used for terrestrial other services, taking into account the relevant % of time for which protection is needed. However, the relevant ITU-R Rec. P.370 should be used to calculate the interfering field strength for aeronautical (or satellite) services.

7.5 Planning methods for individual digital television assignments

This section describes a method for finding channels for individual digital television transmitters in the case of MFN planning.

7.5.1 Establishment of the characteristics of a digital television station

For a given transmitting site, the following characteristics have to be established for a digital television station:

- channel(s);
- polarisation;
- transmitting antenna height;
- maximum e.r.p.;
- horizontal radiation pattern.

Many iterations may be required in the choice of the characteristics which will give maximum coverage of the digital service, while at the same time not causing unacceptable levels of interference to existing analogue stations. The requirement to transmit using the same polarisation as the analogue service (to enable viewers to receive the digital service with existing antennas) may be considered more important than maximising radiated power levels.

For a particular choice (or trial choice) of channel and polarisation, the maximum permissible radiated power of the digital service must be determined.

For each analogue station which may suffer interference from the DVB-T station with the proposed characteristics, the following steps should be carried out:

> at each point representing the coverage area of the analogue station, calculate the power sum of the nuisance field strengths of other existing analogue stations. These values have already been established in the course of the procedures described in § 7.3;
>
> at the same points, calculate the combined nuisance field of the proposed DVB-T station together with the existing analogue stations;
>
> compare the combined nuisance field strengths calculated as above. If there is an increase of no more than an agreed value (say, 0.3 dB), then the e.r.p. of the digital station is acceptable. Otherwise, the e.r.p. is adjusted so that an acceptable value of interference is achieved.

In this way the maximum permissible radiated power of the digital station in all directions can be determined.

In the interests of spectrum efficiency the following factors may be taken into account:

- the effects of receiving antenna discrimination should be allowed for where applicable;
- the use of terrain based propagation methods, to take account of terrain shielding;
- the predicted interfering signal levels from other existing analogue broadcasts.

7.5.2 Establishment of the size of digital television coverage areas

When the characteristics of the digital station have been established, its coverage can be calculated for a specified system variant requiring a certain C/N. This calculation should take into account:

- interference from analogue stations to the potential digital station coverage area;
- interference from other digital stations;
- interference from other services.

In order to do this, the signal summation methods described in Chapter 3 should be used. As a result of this process, for each small area, the percentage of locations served is obtained. The predicted digital service area can also be calculated using the method outlined in § 7.3.

7.5.3 Protection of previously co-ordinated digital television services

In the context of a planning conference, the coverage area to be protected should be taken to be the area within the set of boundary test-points used in the definition of the assignment. The target for protection should be 99% time and 95% of locations either for fixed antenna or portable reception (although the protection and coverage criteria for portable reception may need to be reviewed).

A comparison between the size of a digital station coverage area (calculated as in § 7.5.2) and the area defined by the requirement may be used to provide guidance during any co-ordination process at planning conference or during bi-lateral or multi-lateral co-ordination meetings.

It is recommended that this is carried out in a similar way to the protection of analogue services, that is by the calculation of a "reference coverage area" as defined by a set of test points. In an international co-ordination process the impact of a new transmission on this coverage area can be evaluated and a decision can be made on the possibility to accept this new transmission.

Whilst it may be possible to plan for a number of digital system variants , which could change from day to day or even during the day, it is recommended that only one system variant should be used for co-ordination in order to avoid unnecessary complications. It may be necessary for a planning conference to decide on the digital system variant for which planning is undertaken in order to provide for equality of opportunity for all countries participating in the conference.

7.6 Allotment Planning Methods

7.6.1 General

The primary purpose of allotment planning is to provide a group of administrations the right to use specified frequencies or channels without the need for detailed knowledge of the assignments which would be used in practice. In order for this to be done, certain constraints must be accepted; these are related to the maximum amount of interference which the assignments will be permitted to create when they are implemented.

An allotment is related to the use of a given channel within a defined area and it is normally the case that any interference generated by an allotment <u>within</u> its own area will not be taken into account. Thus it is normally only necessary to specify the signal levels radiated towards the outside of the allotment.

A convenient method for doing this would be to define a reference transmitter (for MFN planning) or a reference network (for SFN planning). Such a reference source may be considered to be situated at any point, or at specified points on the boundary of the allotment. The potential interference created by such a reference source may readily be calculated by means of agreed propagation prediction methods.

After the allotment has been agreed, it must be converted into one or more assignments in order that a service may be provided. There is a somewhat difficult compromise to be achieved here. If a reference source is chosen which has a relatively low interference potential (for example, by specifying that its power is low) then the process of agreeing the allotment will be simplified. However, the conversion of such an allotment into a set of useful assignments may be relatively difficult. On the other hand, the specification of a reference source with a relatively high interference potential may make the agreement more difficult to achieve, but the implementation will be easier. In any case, it is extremely unlikely that the signal level versus distance curves for the reference source and a real set of assignments will be identical and thus the relative interference potential can be expected to be a function of distance from the edge of the allotment. This may be particularly important in any case where the propagation path consists of both land and sea sections.

7.6.2 Reference transmitter

For planning purposes it would be necessary to define a reference source to represent the interference potential of an allotment in an MFN planning environment.

7.6.3 Reference network

For planning purposes it would be necessary to define a reference network to represent the interference potential of an SFN.

7.6.4 Use of reference source

For co-ordination purposes, one of the most important characteristics of an assignment or an allotment is its interference potential. For an assignment or a centrally situated reference source for an allotment, this interference potential is easily calculated using, for example, ITU-R Rec. P.370. Even in the case of a reference source situated on a boundary, the calculations are not difficult, the only complexity is that the reference source is imagined to be situated at the nearest point on its nominal coverage boundary to any service being protected.

In the case of a reference network the calculations required are less simple because it is the combination of signals from all of the transmitters in the network which constitute the source of potential interference. In order to have these combined signal levels for terrestrial paths available in a readily usable form, it is desirable o calculate tables of signal level versus distance from a reference point in the reference network. Such tables would need to be calculated by a statistical method, for example using a Monte Carlo approach and would need to provide results for:

- several percentages of time, say 1, 10 and 50;
- all-land paths;
- all-cold-sea paths;
- all-warm-sea paths.

Results for mixed land sea paths can be obtained by the use of a suitable interpolation function.

Tables, as calculated above, relate to the combined signal levels achieved for a specified percentage of locations. Many other services require protection for the case of 50% locations. However, there may be some other services which require protection for other location percentages and this needs to be verified before results for any such tables are calculated. In any case, the 5% location tables would be needed to permit the calculation of the compatibility between different digital television SFNs.

If it becomes necessary to protect any airborne or satellite-borne receivers, it is more appropriate to make a free-space propagation calculation taking the sum of the (arithmetic) powers of the transmitters (reduced as appropriate by transmitting antenna directivity) in the reference network.

8. TRANSMISSION ASPECTS

8.1 Transmitting Antennas

8.1.1 Introduction

The implementation of a network for terrestrial television is of course dependent on the provision of suitable transmitting antennas radiating from suitable locations. In general, the most appropriate aperture on existing structures is already used by the service for which the mast was built. On the supposition that new structures for most stations will be prohibitively expensive, the re-use of existing antennas is of primary interest. If this is not possible, other alternatives will need to be considered.

The purpose of this section is to consider the re-use of existing antennas and the options available for mounting digital television antennas on structures already used for analogue television.

8.1.2 Description of existing television transmitting antennas

In Europe, a typical television network consists of high-power main stations using horizontal polarisation and low to medium power relay stations using horizontal or possibly vertical polarisation.

The transmitting antennas are often mounted on a cantilever spine on top of the mast or tower. Mounting on a spine, rather than directly on the structure ensures that the arrays of radiating elements are as close as possible to one another in the horizontal plane. The closer the radiating phase centres, the more uniform (and controllable) the horizontal radiation pattern.

In most main stations and, in some countries, also many relay stations, the entire antenna system is enclosed in a fibreglass cylinder. This cylinder provides weather protection for the antenna and in many cases also forms part of the mechanical support structure for the antenna.

UHF antennas are generally designed for a specific set of channels spread over the entire UHF band or grouped in sub-bands, for example, Band IV, Lower Band V or Upper Band V. Typically, the antennas only show a satisfactory impedance match for analogue television at the channels they are designed for and in the close vicinity thereof. This is normally also the case even where antenna systems are equipped with wide band panels.

8.1.3 Options for digital television antennas

8.1.3.1 Share antenna with analogue television

This is possible if:

- the digital television and analogue television transmissions are co-polarised;
- the existing antenna will operate satisfactorily at the frequencies being proposed for digital television;

- the radiation pattern of the existing antenna satisfies any restrictions in the radiated power of the digital television which are needed to avoid interference into other services;
- the antenna system is capable of handling the total power of all services to be transmitted.

If these conditions are satisfied, then only additional combining equipment is required.

The performance of the existing antenna is worth some consideration. If the digital television channel is close to one of the analogue channels, the radiation pattern will almost certainly be similar to that for analogue television. The impedance match should also be similar. For other channels the radiation pattern may not be very different but the impedance match will in many cases be unacceptable for analogue television. However, digital television may not be so sensitive in this respect. Even if the reflected power is problematic, it may be the case that it can be diverted into a load. Alternatively, the internal feed system of the antenna could be re-engineered.

If digital television and analogue television are cross-polarised it may be possible to engineer new antennas shared by both analogue and digital television, which would have individual input ports to produce either vertical polarisation or horizontal polarisation for either of the services. The isolation between the ports may be such that special measures to improve isolation are not necessary. Of course, separate main feeders would be required for each service.

8.1.3.2 Share analogue television aperture

This option is for a separate digital television antenna to be constructed in the same aperture as that used for the analogue television and will mainly be of interest when the digital television will be radiated with a different linear polarisation than that of the analogue television service. Whether this is a feasible option will depend on the design of the existing antenna. For certain types of antennas (such as a batwing) it will probably not be feasible. Where it is possible, the coupling between antennas (and supporting metalwork) must be low enough to avoid mutual interference to the radiation patterns of each service.

A significant factor concerning this option is the available space in which to engineer any new antenna. As already stated, many main and relay stations use fibreglass cylinders for weather shielding. It is unlikely that the relay stations in this category will have sufficient space for any new metalwork inside the fibreglass cylinder. The main stations may be slightly less difficult, but this could still impose a severe logistical constraint on an already difficult design.

Another way out could, in some cases, be to remove half of the existing antenna, used for analogue television, and replace it with a new antenna for digital television. This will imply a loss in antenna gain of about 3 dB for the analogue television service.

Construction of a new antenna for digital television on the outside of the glassfibre cylinder is considered unrealistic for structural reasons. Furthermore such a spacing between the radiating elements and the structure axis is not conducive to providing satisfactory radiation patterns.

8.1.3.3 Completely separate digital television antenna occupying its own aperture

For sites where acceptable aperture on an existing antenna is available, this may be the preferred option. In MFNs, the radiation pattern of the new antenna(s) can be designed to match any restrictions in radiated power which are necessary to prevent interference into existing analogue television services. If the available aperture is relatively low on the structure, the required coverage may not be realised. If the structure tapers, the lower the aperture the greater the face width. The phase centres of the radiating elements become further apart and as a consequence dips in the horizontal radiation pattern become deeper or the antenna becomes very complex and thereby very expensive. Nevertheless, less-than-ideal coverage must be balanced against complex and expensive engineering solutions.

Other practical considerations must also be taken into account. There must be room for new feeders to be connected to the antennas and the structure must be strong enough to carry the windload of the new antenna as well as the new feeder cables.

8.1.3.4 Further considerations

If digital television is to match analogue television coverage, similar antenna heights will be necessary. This being the case, it is a reasonable assumption that at the majority of transmitting sites, no space will be readily available. It may be that some reconfiguration of existing antennas will provide the required aperture, although it is unlikely that this will be usual.

If digital television and analogue television are to be co-polarised, it may be most effective to look into the possibility of sharing existing antennas. In some cases, the existing antennas may need to be re-engineered to accommodate the new channel(s). This may not necessarily be prohibitively expensive.

If digital television and analogue television are not co-polarised, serious thought may be given to the following options:

- *Sharing aperture.*

  Computer modelling can give an indication of possible configurations and interactions, but as the situation is so complex, practical models and measurements will also be necessary. Such development work is costly, time consuming and requires a wide range of expertise. Bearing in mind the earlier comments regarding available space inside fibreglass cylinders, it must be accepted that the outcome of such a study may not be promising;

- *Dual polarised antenna.*

  Antenna panels suitable for dual polarisation (separate input connectors) are available on the market, normally used for elliptic (circular) polarisation. The use of a dual polarised antenna for the radiation of both analogue digital television will in fact imply a complete renewal of all parts of the existing antenna. The gain in each of the planes in a dual polarised antenna will generally not differ from that of a single polarised antenna by more than 1 dB. The radiation pattern for analogue television can be maintained while the pattern for digital television can be designed to have either the same or a different shape;

- *Reduction of the existing aperture.*

  If a reduction of the existing antenna to half of its original size, causing a 3 dB reduction of the antenna gain is acceptable, a new antenna for digital television having approximately the same gain as the remaining part of the existing antenna can be accommodated within the aperture available. The horizontal radiation pattern may be the same as that of the analogue service(s) or it may be different in order to allow for any required restrictions.

It must be noted that all three options also imply the installation of an extra set of feeders.

8.1.3.5 Conclusions

If digital television and analogue television services are co-polarised, it is possible that they may be able to share transmitting antennas. As far as cost and complication is concerned, this is the preferred outcome.

If digital television and analogue television services are not co-polarised and no space is available for a new separate digital television antenna, significant re-engineering on the existing antenna will be necessary.

For sites with suitable free aperture the preferred option may be to construct an exclusive digital television antenna.

8.2 Suppression of unwanted emissions

In the starting phase of terrestrial digital television, channels will have to be found mainly between those already in use for analogue television. In some cases it will be necessary to use channels adjacent to existing analogue television channels. To avoid interference into the analogue television services it is considered important to limit the out-of-channel emissions from digital television transmitters as much as possible. This leads to a need for defined spectrum masks for digital television transmitters.

The modulation scheme to be used for digital television will be quite complex, for example OFDM 64QAM. Such a modulation scheme will demand a very high degree of linearity in the transmitter power amplifier in order to avoid intermodulation products.

The “natural” sidebands of the OFDM spectrum can (and must) be cut off in a suitable filter at IF in the modulator. The sidebands will, however, re-appear at RF due to intermodulation products, between the individual carriers, occurring in the amplifier chain of the transmitter. In order to achieve a reasonable (although still rather low) efficiency of the transmitter, extensive linearity precorrection must be applied. Very non-linear amplifying components like klystrons are not expected to be readily usable for digital television.

The prevailing types of intermodulation products falling in or near the digital television channel are the third and the fifth order products. The third order products will fall in the range:

Channel centre frequency +/- 1.5 (OFDM signal bandwidth)

and the fifth order intermodulation products will fall in the range:

Channel centre frequency +/- 2.5 (OFDM signal bandwidth)

Intermodulation products falling inside the channel will act as interference from a co-channel (non SFN) digital television transmitter and cause an increased bit error rate. The maximum acceptable level of intermodulation inside the channel can thus be estimated to be approximately equal to the minimum required C/N for the digital system in question. If this maximum level is reached no margin for noise or interference is left.

Intermodulation products falling outside of the channel could cause a noise-like co-channel interference to existing analogue television services operating on one or more channels adjacent or near to the digital television channel. The protection ratio needed for the analogue television service will be near to 40 dB, depending on the analogue system used. If the analogue television signal is radiated from the same station (or antenna) sufficient attenuation of the intermodulation products from the digital television transmitter is fairly easily specified. If the analogue television signal is not radiated from the same site as the digital television signal but still covering the same area or a part of it, the necessary attenuation of digital television intermodulation products can be quite difficult to achieve. In both cases a suitable spectrum mask filter is needed.

Where analogue and digital television transmitters using adjacent channels are co-sited and serving a common area also the out-of-band emissions from the analogue transmitter must be considered.

Due to non-linearity, mainly in the power amplifier(s), the suppressed part of the lower (vestigial) sideband tends to re-appear. This can affect a DVB-T signal transmitted in the lower adjacent channel. In analogue television transmitters using a common power amplifier for vision and sound also an image to the sound carrier(s) is found below the vision carrier.

Above the sound carrier(s) in the analogue channel harmonic distortion products from the video signal components appear causing an extension ranging into the upper adjacent channel.

In order to deal with adjacent channel compatibility defined spectrum masks for analogue television are needed.

8.2.1 Asymmetrical spectrum masks for DVB-T

It is generally expected that digital television transmitters to a large extend will be co-sited with existing analogue television transmitters and, as far as possible, will use the same polarisation. On this basis spectrum masks for digital television transmitters, covering interference into various analogue television systems, can be derived on the basis of known protection ratios for the individual parts of the analogue signal.

Digital television transmitters are expected only to operate in the frequency bands envisaged for television. In most cases only protection of analogue television in adjacent channels has to be considered, exceptions being channels such as 5, 21, 60 or 69, where other services demanding high protection operate at frequencies just outside of the television channel. However, even in such cases only one side of the spectrum mask needs to show the shape of the mask for critical cases while the other side can have an out-of-band attenuation satisfactory for analogue television.

The protection ratios used for the adjacent channels have been taken from the EBU publication BPN 003 "Technical Bases for T-DAB Services Network Planning and Compatibility with existing Broadcasting Services" assuming that there is no influence on the value of the protection ratio whether the digital signal (OFDM) is a T-DAB signal or a DVB-T signal.

The examples presented have all been based on the following assumptions:

- the digital and the analogue transmitters are co-sited;
- no polarisation discrimination;
- no offset is used on either of the transmitters except System L sound transmitters, where a positive offset of 50 kHz has been taken into account.
- the e.r.p. of the analogue transmitter (peak-sync) and the digital transmitter (total power) are the same.

Proportional corrections must be applied if:

- the radiated powers of the analogue and the digital television transmitters are not equal;
- the analogue and the digital television signals are not radiated with the same polarisation and if polarisation can be assumed.

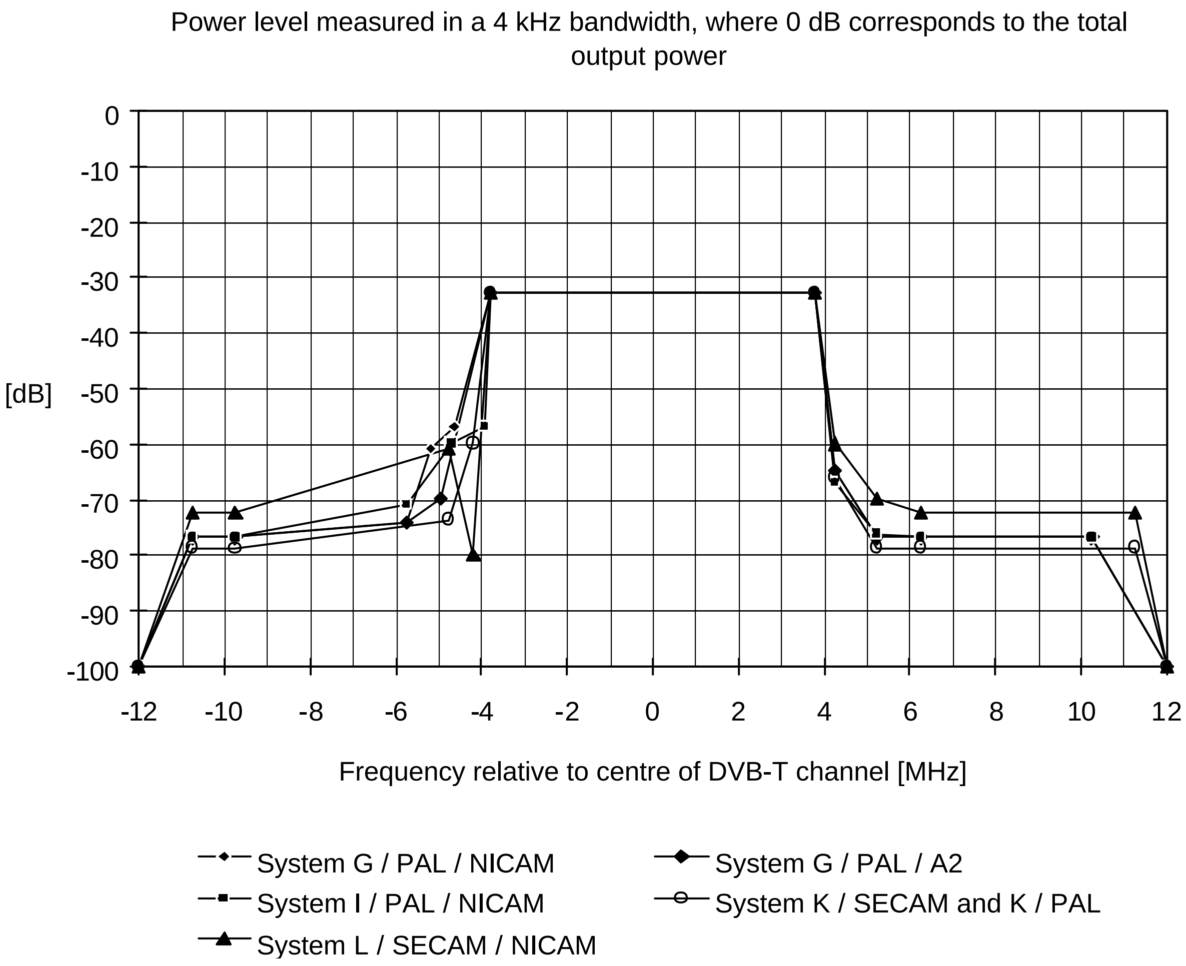
The protection ratios used for analogue television are based on protection ratios taken from EBU BPN 003 and recalculated to impairment grade 4.5. From these protection ratios the maximum permissible relative power in a 4 kHz bandwidth is calculated for a set of representative frequencies in the analogue channel.

The relative level in a 4 kHz bandwidth at the lower end of the lower adjacent channel and at the upper end of the upper adjacent channel has been chosen to -100 dB.

For details about the derivation of the values see Annex 8.1.

Two sets of spectrum masks for 8 MHz channels are given in Figure 8.1 and 8.2 respectively and for 7 MHz channels in Figure 8.3 and 8.4. The sets shown in Figure 8.1 and Figure 8.3 are based directly on the protection ratios derived in Annex 8.1 for the lower adjacent channel. In the upper adjacent channel the sound carrier demands less protection than the vision carriers. This would lead to spectrum masks having less attenuation further away from the DVB-T channel than just outside of it. For this reason the protection ratios for the vision carrier are repeated at frequencies corresponding to the upper end of the video sideband in the upper adjacent channel. This will, however, lead to an over-protection of about 5 dB at these frequencies.

These masks are considered to cover the minimum protection needed for co-sited analogue and digital television transmitters having equal radiated powers.



Breakpoints										
	G / PAL / NICAM		G / PAL / A2		I / PAL / NICAM		K / SECAM K / PAL		L / SECAM / NICAM	
See Note below	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB
1	-12	-100	-12	-100	-12	-100	-12	-100	-12	-100
2	-10.75	-76.9	-10.75	-76.9	-10.75	-76.9	-10.75	-78.7	-10.75	-72.4
3	-9.75	-76.9	-9.75	-76.9	-9.75	-76.9	-9.75	-78.7	-9.75	-72.4
4	-5.75	-74.2	-5.75	-74.2	-5.75	-70.9	-4.75	-73.6	-4.75	-60.9
5	-5.185	-60.9	-5.185	n.a.	-4.685	-59.9	-4.185	-59.9	-4.185	-79.9
6	n.a.	n.a.	-4.94	-69.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
7	-4.65	-56.9	n.a.	n.a.	-3.925	-56.9	n.a.	n.a.	n.a.	n.a.
8	-3.8	-32.8	-3.8	-32.8	-3.8	-32.8	-3.8	-32.8	-3.8	-32.8
9	+3.8	-32.8	+3.8	-32.8	+3.8	-32.8	+3.8	-32.8	+3.8	-32.8
10	+4.25	-64.9	+4.25	-64.9	+4.25	-66.9	+4.25	-66.1	+4.25	-59.9
11	+5.25	-76.9	+5.25	-76.9	+5.25	-76.2	+5.25	-78.7	+5.25	-69.9
12	+6.25	-76.9	+6.25	-76.9	+6.25	-76.9	+6.25	-78.7	+6.25	-72.4
13	+10.25	-76.9	+10.25	-76.9	+10.25	-76.9	+11.25	-78.7	+11.25	-72.4
14	+12	-100	+12	-100	+12	-100	+12	-100	+12	-100

Figure 8.1: Spectrum masks for a digital terrestrial television transmitter operating on a channel adjacent to a co-sited analogue television transmitter, 8 MHz

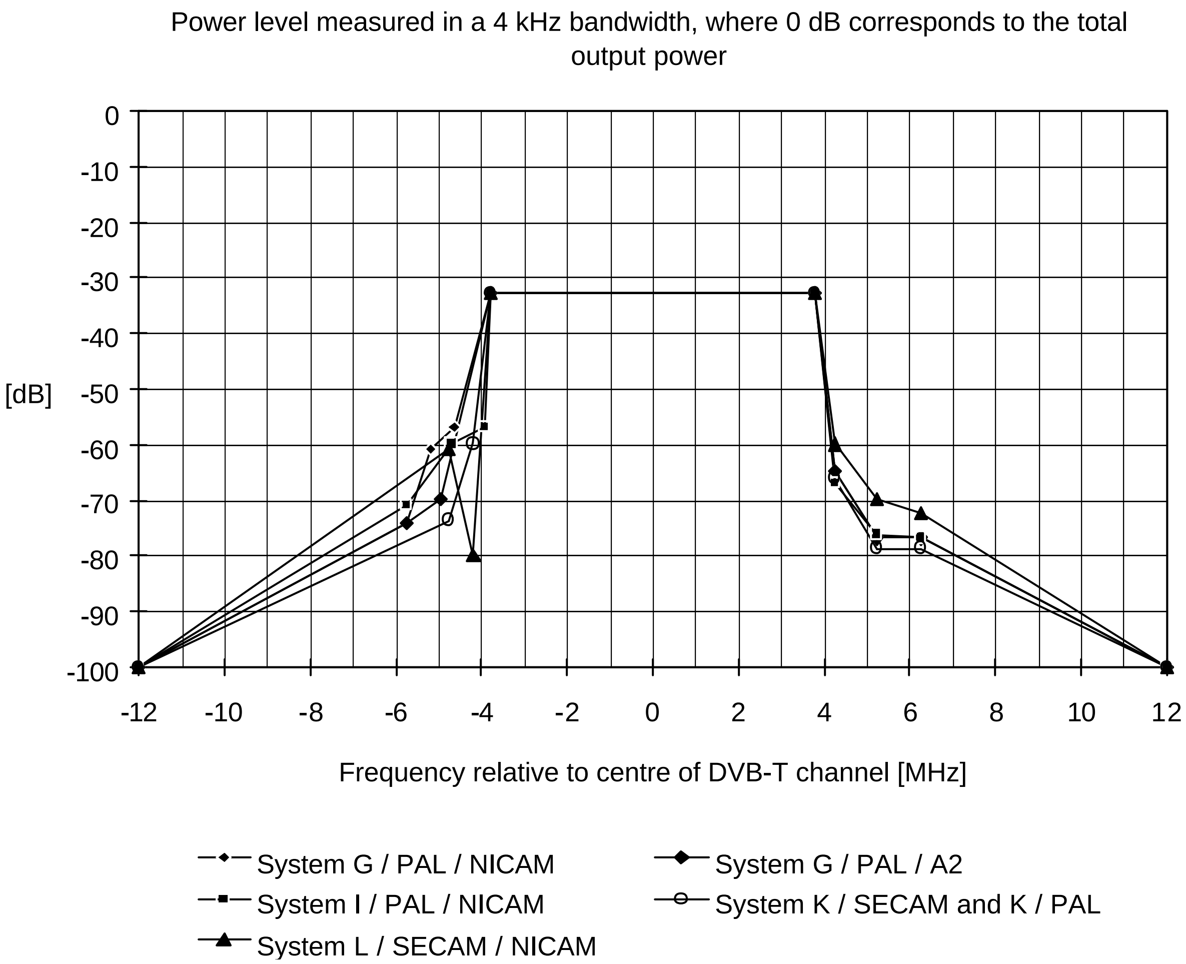
Notes to the tables of breakpoints in Figures 8.1, 8.2, 8.3 and 8.4:

For details about the determination of breakpoints and attenuations, see Annex 8.1.

1. Lower end of lower adjacent channel
2. Vision carrier in lower adjacent channel
3. Vision carrier + 1 MHz in lower adjacent channel
4. Upper end of video sideband in lower adjacent channel
5. Upper end of the RF bandwidth of the first soundcarrier in lower adjacent channel
6. Upper end of the RF bandwidth of the A2 second soundcarrier in lower adjacent channel
7. Upper end of the RF bandwidth of the NICAM signal in the lower adjacent channel
8. Lower end of the RF bandwidth of the DVB-T signal
9. Upper end of the RF bandwidth of the DVB-T signal
10. Lower video sideband (vision carrier - 1 MHz) in upper adjacent channel
11. Vision carrier in upper adjacent channel
12. Vision carrier + 1 MHz in upper adjacent channel
13. Upper end of video sideband in upper adjacent channel
14. Upper end of upper adjacent channel

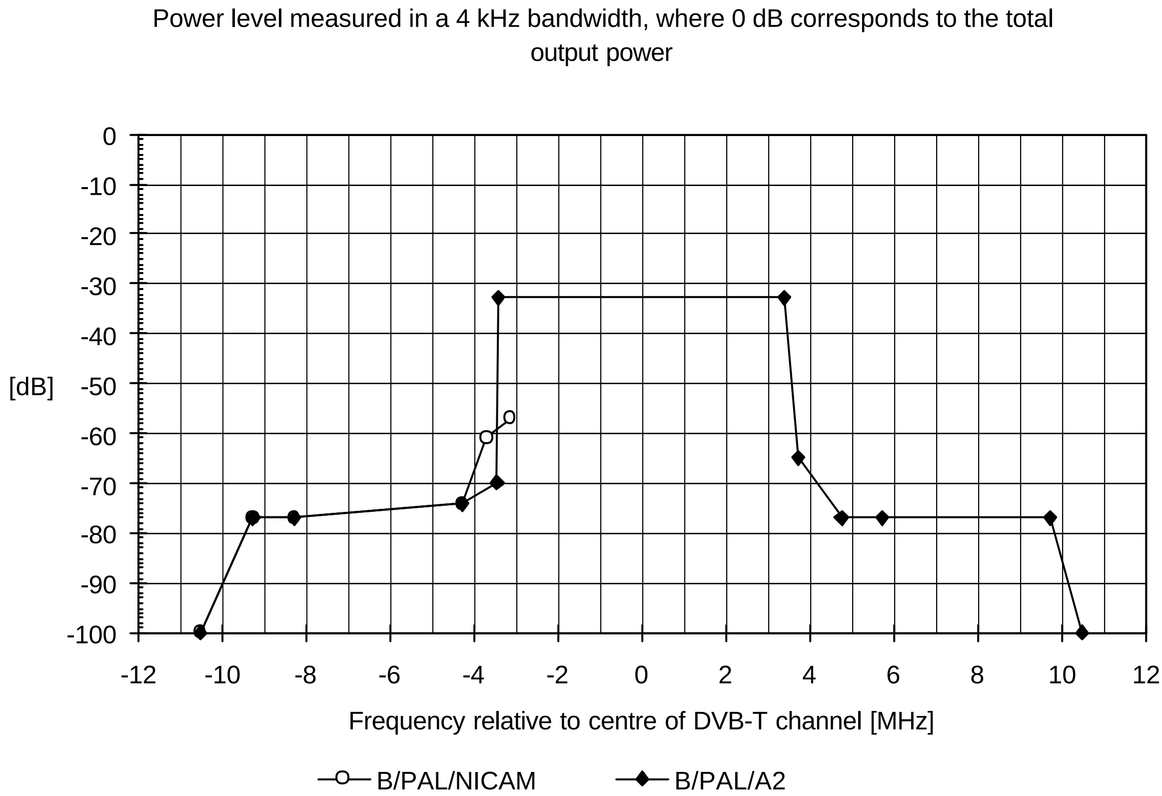
In the tables in Figures 8.1, 8.2, 8.3 and 8.4 some cells are marked with “n.a.”. This means that this part of the analogue television signal does not exist or has no influence on the shape of the spectrum mask.

As it can be assumed that some degree of general selectivity will be introduced with a spectrum mask filter it is believed that in general, straight lines can be drawn from the breakpoints representing the upper end of the video sideband in the lower adjacent channel to the end point at the lower end of the lower adjacent channel. In the same way straight lines are drawn from the breakpoints representing the vision carriers in the upper adjacent channel to the end point at the upper end of the upper adjacent channel. Spectrum masks corresponding to those shown in Figure 8.1 but based on the assumption above are shown in Figure 8.2 for 8 MHz channels and in Figure 8.4 for 7 MHz channels.



Breakpoints										
	G / PAL / NICAM		G / PAL / A2		I / PAL / NICAM		K / SECAM K / PAL		L / SECAM / NICAM	
See Notes to Fig. 8.1	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB
1	-12	-100	-12	-100	-12	-100	-12	-100	-12	-100
4	-5.75	-74.2	-5.75	-74.2	-5.75	-70.9	-4.75	-73.6	-4.75	-60.9
5	-5.185	-60.9	-5.185	n.a.	-4.685	-59.9	-4.185	-59.9	-4.185	-79.9
6	n.a.	n.a.	-4.94	-69.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
7	-4.65	-56.9	n.a.	n.a.	-3.925	-56.9	n.a.	n.a.	n.a.	n.a.
8	-3.8	-32.8	-3.8	-32.8	-3.8	-32.8	-3.8	-32.8	-3.8	-32.8
9	+3.8	-32.8	+3.8	-32.8	+3.8	-32.8	+3.8	-32.8	+3.8	-32.8
10	+4.25	-64.9	+4.25	-64.9	+4.25	-66.9	+4.25	-66.1	+4.25	-59.9
11	+5.25	-76.9	+5.25	-76.9	+5.25	-76.2	+5.25	-78.7	+5.25	-69.9
12	+6.25	-76.9	+6.25	-76.9	+6.25	-76.9	+6.25	-78.7	+6.25	-72.4
14	+12	-100	+12	-100	+12	-100	+12	-100	+12	-100

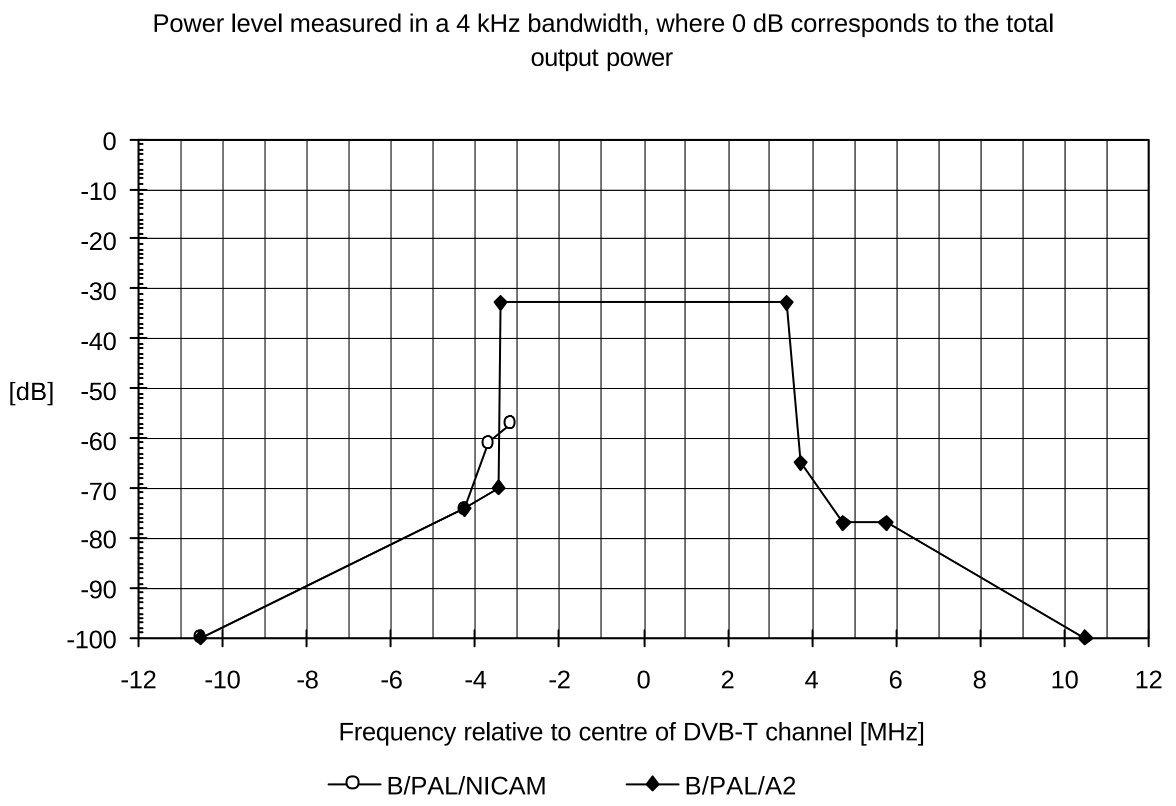
Figure 8.2: Spectrum masks for a digital terrestrial television transmitter operating on a channel adjacent to a co-sited analogue television transmitter, 8 MHz



Breakpoints				
See notes	B / PAL / NICAM		B / PAL / A2	
to Fig. 8.1	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB
1	-10.5	-100	-10.5	-100
2	-9.25	-76.9	-9.25	-76.9
3	-8.25	-76.9	-8.25	-76.9
4	-4.25	-74.2	-4.25	-74.2
5	-3.685	-60.9	-3.685	n.a.
6	n.a.	n.a.	-3.44	-69.9
7	-3.15 *)	-56.9	n.a.	n.a.
8	-3.35	-32.8	-3.4	-32.8
9	+3.35	-32.8	+3.4	-32.8
10	+3.75	-64.9	+3.75	-64.9
11	+4.75	-76.9	+4.75	-76.9
12	+5.75	-76.9	+5.75	-76.9
13	+9.75	-76.9	+9.75	-76.9
14	+10.5	-100	+10.5	-100

*) The NICAM signal overlaps the DVB-T signal if relative offset is less than 200 kHz

Figure 8.3: Spectrum masks for a digital terrestrial television transmitter operating on a channel adjacent to a co-sited analog System B television transmitter, 7 MHz



Breakpoints				
See notes	B / PAL / NICAM		B / PAL / A2	
to Fig. 8.1	rel. freq. MHz	rel. level dB	rel. freq. MHz	rel. level dB
1	-10.5	-100	-10.5	-100
4	-4.25	-74.2	-4.25	-74.2
5	-3.685	-60.9	-3.685	n.a.
6	n.a.	n.a.	-3.44	-69.9
7	-3.15 *)	-56.9	n.a.	n.a.
8	-3.35	-32.8	-3.35	-32.8
9	+3.35	-32.8	+3.35	-32.8
10	+3.75	-64.9	+3.75	-64.9
11	+4.75	-76.9	+4.75	-76.9
12	+5.75	-76.9	+5.75	-76.9
14	+10.5	-100	+10.5	-100

*) The NICAM signal overlaps the DVB-T signal if relative offset is less than 200 kHz

Figure 8.4: Spectrum masks for a digital terrestrial television transmitter operating on a channel adjacent to a co-sited analog System B television transmitter, 7 MHz

8.2.2 Symmetrical spectrum mask for DVB-T in 7 MHz and 8 MHz channels

For digital television transmitters using the channels adjacent to other services (low power or receive only) this spectrum mask may not give enough attenuation on the side of the digital television channel falling in the frequency band where the other service operates.

In such cases, special spectrum masks have to be defined, based on the characteristics of the other service and the distance between the digital television transmitter and the service area (or receiving installation) of the other service. It must, however, be borne in mind that spectrum mask filters showing a higher attenuation close to the digital television channel will be very expensive and imply a higher insertion loss.

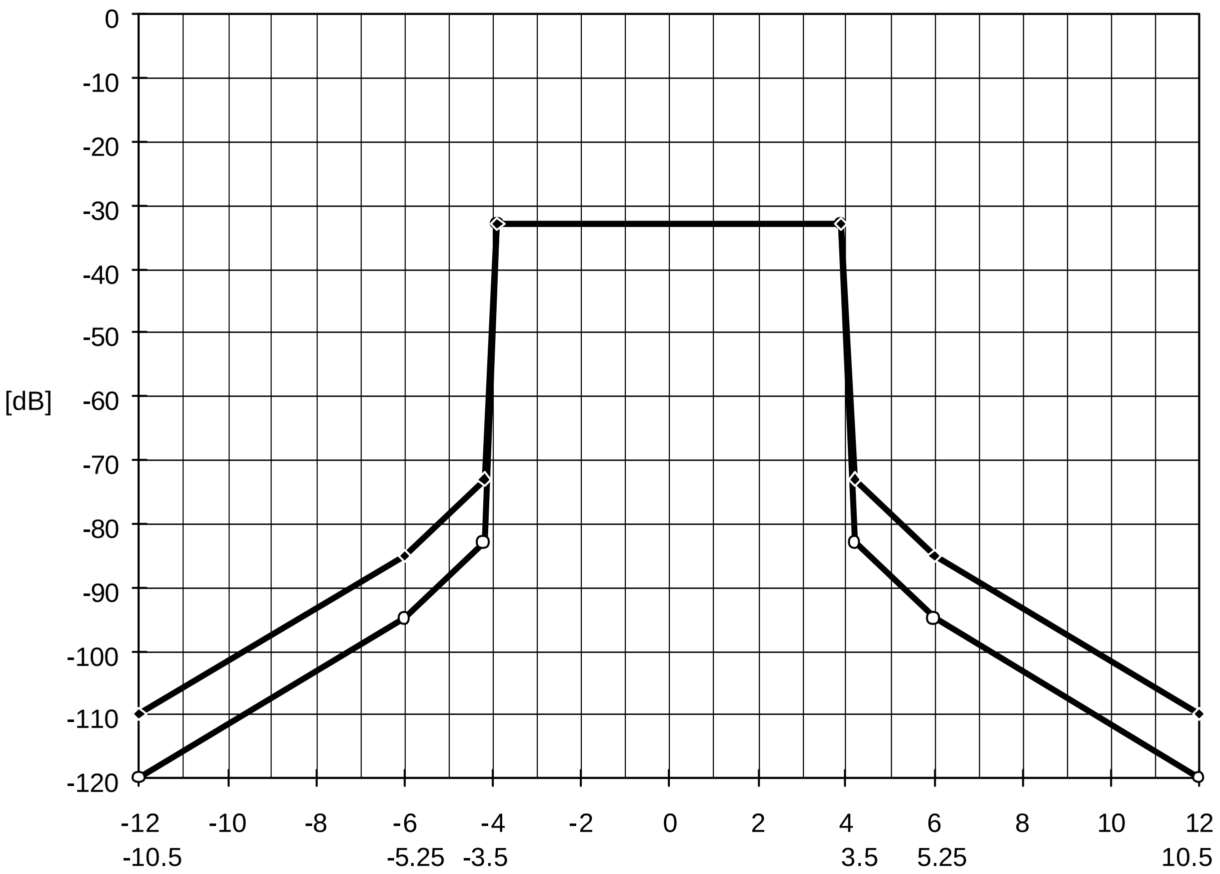
Two symmetrical spectrum masks are shown in Figure 8.5. The mask having a shoulder attenuation of 40 dB is intended for non-critical cases and the mask with a shoulder attenuation of 50 dB is intended for sensitive cases.

The mask for non-critical cases should also be used for measurements of protection ratios for analogue television interfered with by DVB-T.

The shape of the masks have been based on:

- the natural spectrum of a 7.6 MHz OFDM signal (for 8 MHz channels) and a 6.7 MHz OFDM signal (for 7 MHz channels);
- the amplitude response of an IF SAW-filter;
- the power amplifier of the transmitter produces intermodulation outside of the channel at a level limited by the amount of intermodulation acceptable inside the channel;
- the mask for sensitive cases also include the amplitude response of a six-cavity bandpass filter at the output of the transmitter.

Power level measured in a 4 kHz bandwidth, where 0 dB corresponds to the total output power



Frequency relative to centre of DVB-T channel [MHz],
upper scale: 8 MHz channel; lower scale: 7 MHz channel
upper curve: non-critical cases; lower curve: sensitive cases

Breakpoints					
8 MHz channels			7 MHz channels		
	Non-critical cases	Sensitive cases		Non-critical cases	Sensitive cases
Relative Frequency [MHz]	Relative Level [dB]	Relative Level [dB]	Relative Frequency [MHz]	Relative Level [dB]	Relative Level [dB]
-12	-110	-120	-10.5	-110	-120
-6	-85	-95	-5.25	-85	-95
-4.2	-73	-83	-3.7	-73	-83
-3.9	-32.8	-32.8	-3.35	-32.8	-32.8
+3.9	-32.8	-32.8	+3.35	-32.8	-32.8
+4.2	-73	-83	+3.7	-73	-83
+6	-85	-95	+5.25	-85	-95
+12	-110	-120	+10.5	-110	-120

Figure 8.5: Symmetrical spectrum masks for non-critical and for sensitive cases

8.3 Analogue television

Based on information from the Radio Regulations (Article 3 and Appendix S3) and ITU-R Rep. 624-4 spectrum masks have been established for a number of analogue television systems in use.

For transmitters operating in the frequency range 30 MHz to 235 MHz the unwanted power measured at the output terminal of the transmitter shall be attenuated at least 60 dB relative to the mean output power and shall not exceed 1 milliwatt. The maximum limit is thus proportional for transmitters with output powers up to 1 kW and fixed for higher output powers.

For transmitters operating in the frequency range 235 MHz to 960 MHz the unwanted power measured at the output terminal of the transmitter shall be attenuated at least 60 dB relative to the mean output power and shall not exceed 20 milliwatt. The maximum limit is thus proportional for transmitters with output powers up to 20 kW and fixed for higher output powers.

The mean power of a television transmitter depends considerably on the picture content. For transmitters using negative modulation the highest mean power is achieved at “Black with sync” and no pedestal where the mean power of the vision signal is 2.5 dB lower than the peak sync power. This leads to an out-of-band attenuation of 62.5 dB relative to peak sync power for transmitters within the “proportional” power range.

For transmitters using positive modulation the highest mean power occurs with an all-white picture where the mean power of the vision signal is 1.2 dB lower than the nominal transmitter output power.

If intermodulation products between the vision carrier and the sound carrier(s) are considered it is assumed that the sum of the vision power and the sound power(s) shall be used as reference.

When typical antenna gains and feeder losses for VHF transmitters are taken into consideration then transmitter output powers up to 1 kW corresponds to radiated powers of up to 10 kW and the fixed limit of 1 milliwatt corresponds to an e.r.p. of 10 milliwatt. For UHF the values become 400 kW and 400 milliwatt respectively. It is assumed that most antenna systems will show the same or nearly the same gain in the adjacent channels as in the channel used. It is also assumed that diplexers inserted into the feeder line do not contribute to the attenuation of unwanted emissions in the adjacent channels.

At this state only analogue UHF transmitters are considered. In the original ST61 Plan totally 4479 UHF stations are listed. These stations can be subdivided into the following categories:

2041 stations	e.r.p. ≤ 400 kW
818 stations	400 kW < e.r.p. ≤ 500 kW
1589 stations	500 kW < e.r.p. ≤ 1 MW
31 stations	e.r.p. > 1 MW (maximum = 2 MW)

The 400 kW limit thus only applies to less than the half of the stations. For stations with an e.r.p. > 400 kW the out-of-band attenuation shall be increased accordingly (for 2 MW by additional 7 dB).

8.3.1 Reference bandwidth for analogue television spectrum masks

Generally it is considered desirable to use a low reference bandwidth in order to show the real spectrum of the signal in question, on the other hand it is necessary to use a bandwidth wide enough to make it possible to measure the RF spectrum realisticly.

For DVB (and DAB) spectrum masks are based on the power measured in a 4 kHz bandwidth.

In analogue television three different types of modulation are used (ignoring the colour subcarrier): AM, FM and QPSK. The signal components have different bandwidths and use different “quiescent” modulation, e.g. the vision carrier is always modulated with at least a sync-signal and the NICAM subcarrier is always occupying a constant bandwidth whereas FM- or AM- sound carriers are not modulated when no sound signal is present.

Tests have shown that power spectrum of the vision carrier and its sideband(s) can be measured correctly with a spectrum analyser using “max. hold” and resolution bandwidths down to 50 kHz. At 10 kHz resolution bandwidth the level is shown about .2 dB too low and at 3 kHz resolution bandwidth the level error is about 1 dB. In all cases the video bandwidth of the spectrum analyser was 100 kHz. A resolution bandwidth of 300 kHz and a video bandwidth also of 300 kHz were used as reference. When measuring the contour of the video sideband(s) with narrow resolution bandwidths a very slow sweep rate is mandatory, 10 seconds is recommended for video frequencies swept from 100 kHz to 6 MHz.

The power spectrum of FM sound carriers can only be measured correctly (at full deviation) if the resolution bandwidth of the spectrum analyser is at least equal to the highest modulation frequency, i.e. 15 kHz, otherwise the result will depend on the modulation frequency and the deviation. The video bandwidth of the spectrum analyser should be somewhat higher, e.g. 30 kHz.

AM sound carriers can be measured correctly with even very low resolution bandwidths as long as the modulation frequency is kept constant or swept very slowly.

For QPSK carriers like NICAM the measured level depends only on the resolution bandwidth of the spectrum analyser and scaling can be done from or to any relevant bandwidth.

As a result of the above described differences between the individual components of an analogue television signal a reference bandwidth of 50 kHz is used for spectrum masks for analogue television.

Description of breakpoint	Frequency relative to vision carrier in analogue channel [MHz]	Frequency relative to centre of channel [MHz]	Analogue tv-system G / PAL (mono), V / S ratio = 10 dB	Analogue tv-system G / PAL / NICAM V / S / N ratio = 13 / 20 dB	Analogue tv-system G / PAL / A2 V / S / s ratio = 13 / 20 dB	Analogue tv-system I / PAL / NICAM V / S / N ratio = 10 / 20 dB	Analogue tv-system K / SECAM V / S ratio = 10 dB	Analogue tv-system L / SECAM V / S ratio = 10 dB
Lower end of lower adjacent 8 MHz channel	-9.25	-12	-62.5	-62.5	-62.5	-62.5	-62.5	-61.2
Image of colour subcarrier system G and I. Lower limit of colour subc. image system K	-4.43	-7.18	-46	-46	-46	-46.7	-46	n.a.
Image of colour subcarrier system L	-4.3	-7.05	n.a.	n.a.	n.a.	n.a.	n.a.	[-13] -30= -43
Upper limit of colour subcarrier image. system K	-4.23	-6.98	n.a.	n.a.	n.a.	n.a.	-46	n.a.
Attenuation of lower video sideband. System G and I	-3	-5.75	-36	-36	-36	-36.7	n.a.	n.a.
Attenuation of lower sideband system L	-2.7	-5.45	n.a.	n.a.	n.a.	n.a.	n.a.	[-13] -15= -28
Lower end of channel	-1.25	-4	-36	-36	-36	-16.7	-36	[-13]
Lower corner of vestigial sideband. system G and K	-0.75	-3.5	-16	-16	-16	n.a.	-16	n.a.
Lower end of sync. signal spectrum	-0.13	-2.88	-16	-16	-16	-16.7	-16	[-13]
Vision carrier (for system L at an all 100% white picture)	0	-2.75	0	0	0	0	0	0
Upper end of sync. signal spectrum	0.13	-2.62	-16	-16	-16	-16.7	-16	[-13]
Upper end of video sideband. system G	5	2.25	-16	-16	-16	n.a.	n.a.	n.a.
Gap between video sideband and 1st sound carrier. system G	5.25	2.5	-20	-20	-20	n.a.	n.a.	n.a.
Lower corner of 1st sound carrier. system G	5.435	2.685	-10	-13	-13	n.a.	n.a.	n.a.
Upper end of video sideband. system I	5.5	2.75	n.a.	n.a.	n.a.	-16.7	n.a.	n.a.
Upper corner of 1st sound carrier. system G	5.565	2.815	-10	-13	-13	n.a.	n.a.	n.a.
Lower corner of NICAM signal. system G / NICAM	5.6	2.85	n.a.	-20	n.a.	n.a.	n.a.	n.a.
Lower corner of 2nd sound carrier. system G / A2	5.675	2.925	n.a.	n.a.	-20	n.a.	n.a.	n.a.
Gap between video sideband and 1st sound carrier. system I	5.75	3	n.a.	n.a.	n.a.	-20	n.a.	n.a.
Upper end of spectrum used by system G / mono	5.8	3.05	-62.5	n.a.	n.a.	n.a.	n.a.	n.a.
Upper corner of 2nd sound carrier. system G / A2	5.805	3.055	n.a.	n.a.	-20	n.a.	n.a.	n.a.
Lower corner of 1st sound carrier. system I	5.9346	3.1846	n.a.	n.a.	n.a.	-10	n.a.	n.a.
Upper end of spectrum used by system G / A2	5.97	3.22	n.a.	n.a.	-62.5	n.a.	n.a.	n.a.
Upper end of video sideband. system K and L	6	3.25	n.a.	n.a.	n.a.	n.a.	-16	[-13]

Upper corner of 1st sound carrier. system I	6.0646	3.3146	n.a.	n.a.	n.a.	-10	n.a.	n.a.
Upper corner of NICAM signal. system G / NICAM	6.1	3.35	n.a.	-20	n.a.	n.a.	n.a.	n.a.
Gap between video sideband and 1st sound carrier. system K and L	6.25	3.5	n.a.	n.a.	n.a.	n.a.	-20	-20
Upper end of spectrum used by system G / NICAM	6.28	3.53	n.a.	-62.5	n.a.	n.a.	n.a.	n.a.
Lower corner of NICAM signal. system I / NICAM	6.302	3.552	n.a.	n.a.	n.a.	-25	n.a.	n.a.
Lower corner of 1st sound carrier system K and L	6.435	3.685	n.a.	n.a.	n.a.	n.a.	-10	-10
Centre of NICAM signal. system I / NICAM	6.552	3.802	n.a.	n.a.	n.a.	-20	n.a.	n.a.
Upper corner of 1st sound carrier system K and L	6.565	3.815	n.a.	n.a.	n.a.	n.a.	-10	-10
Upper end of 8 MHz channel	6.75	4	n.a.	n.a.	n.a.	n.a.	-54	-54
Upper end of spectrum used by system K and L *)	6.8	4.05	n.a.	n.a.	n.a.	n.a.	-62.5	-61.2
Upper corner of NICAM signal. system I / NICAM	6.802	4.052	n.a.	n.a.	n.a.	-25	n.a.	n.a.
Upper end of spectrum used by system I / NICAM	6.94	4.19	n.a.	n.a.	n.a.	-62.5	n.a.	n.a.
Upper end of upper adjacent 8 MHz channel	14.75	12	-62.5	-62.5	-62.5	-62.5	-62.5	-61.2

Table 8.1: Breakpoints for spectrum masks for analogue television systems. based on 50 kHz bandwidth

Note: *) Because of 50 kHz reference bandwidth used

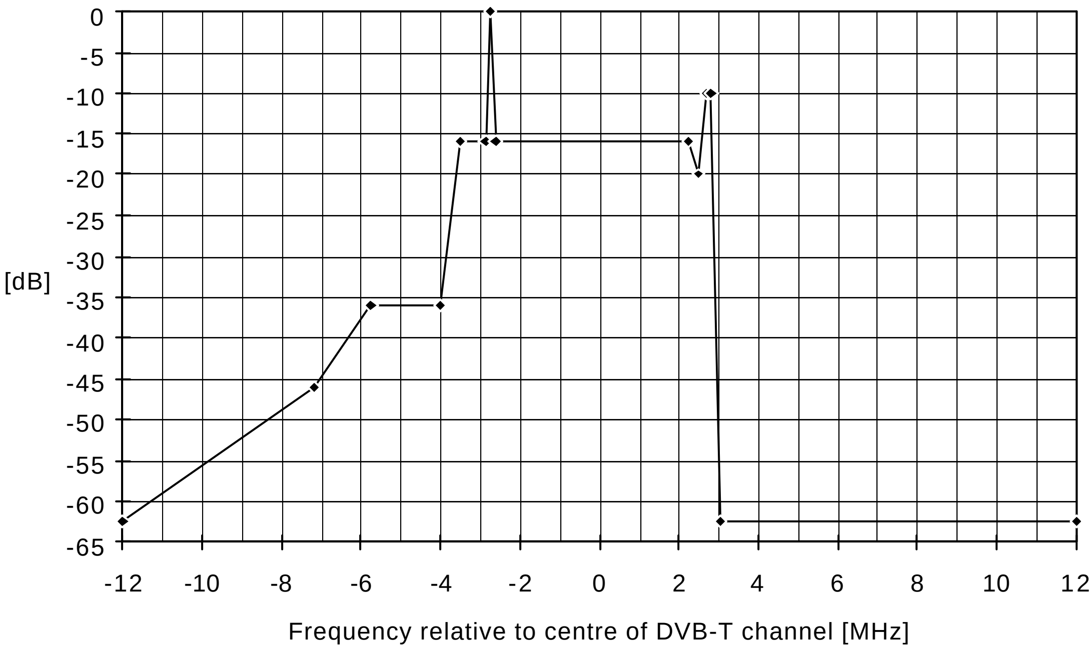


Figure 8.6 Analogue system G / PAL / mono. V / S ratio = 10 dB

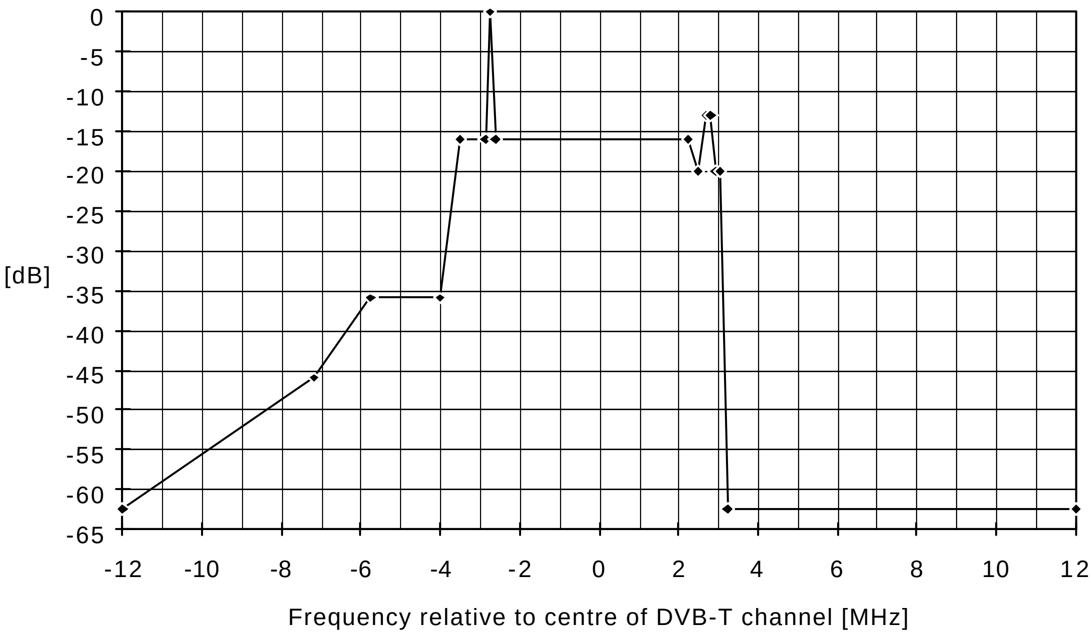


Figure 8.7 Analogue system G / PAL / A2. V / S / s ratio = 13 dB / 20 dB

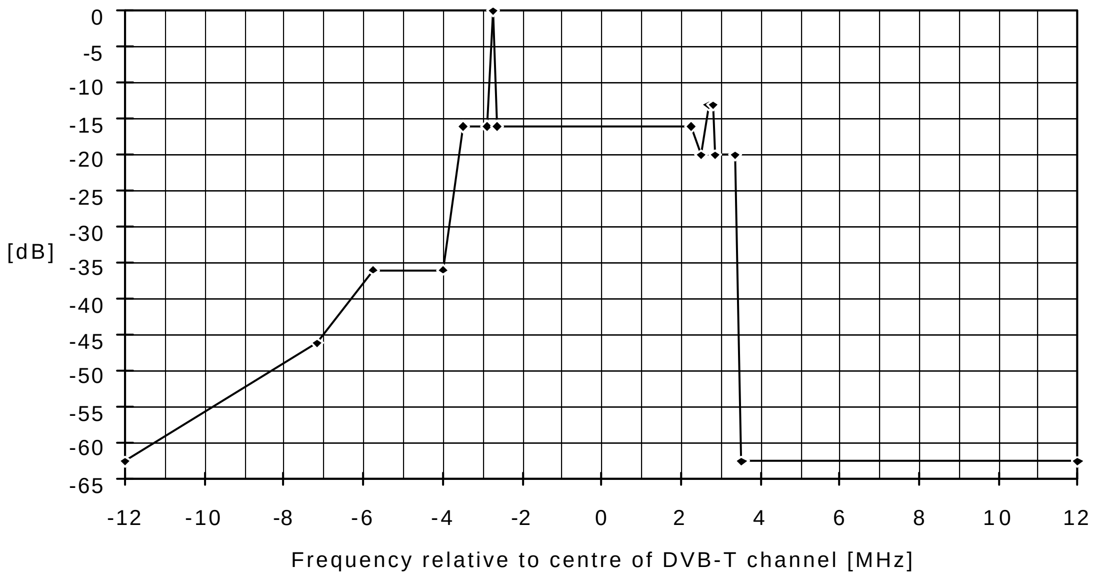


Figure 8.8 Analogue system G / PAL / NICAM. V / S / N ratio = 13 dB / 20 dB

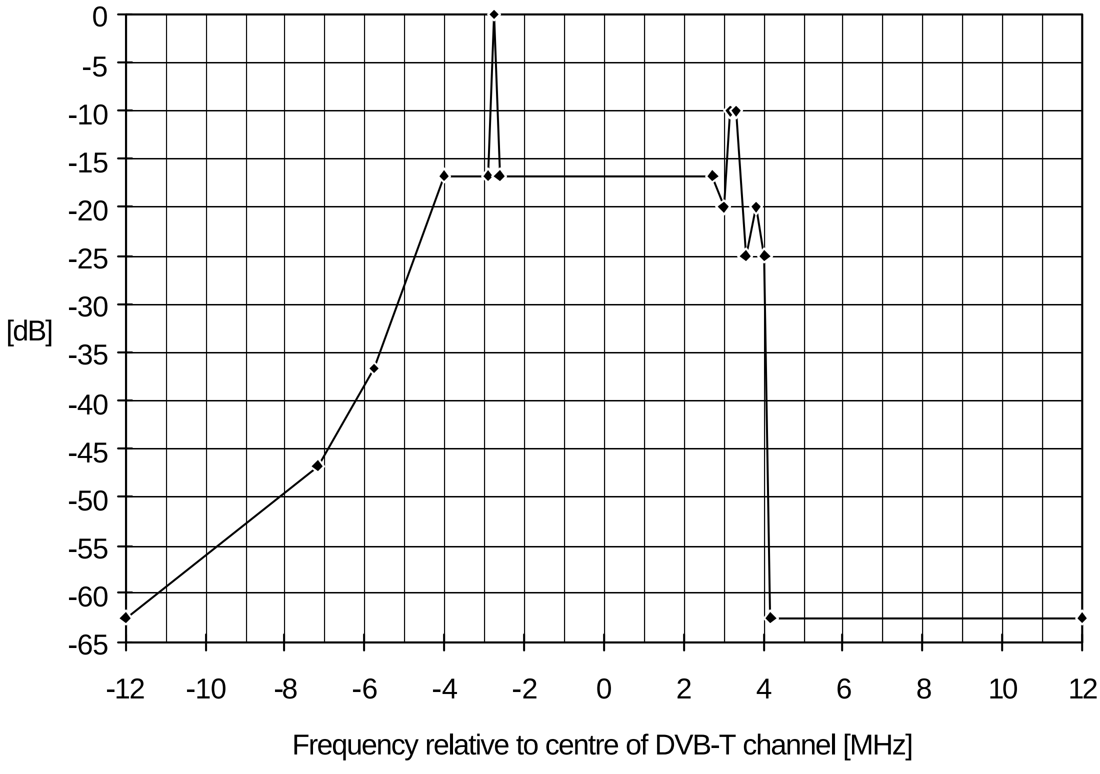


Figure 8.9 Analogue system I / NICAM. V / S / N = 10 dB / 20 dB

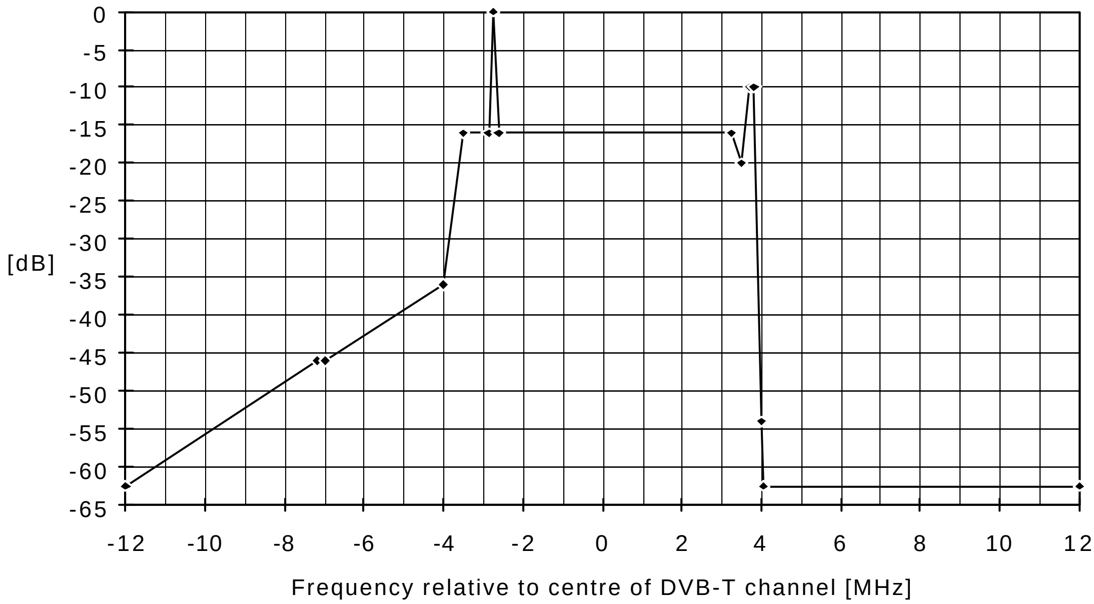


Figure 8.10 Analogue system K / SECAM. V / S ratio = 10 dB

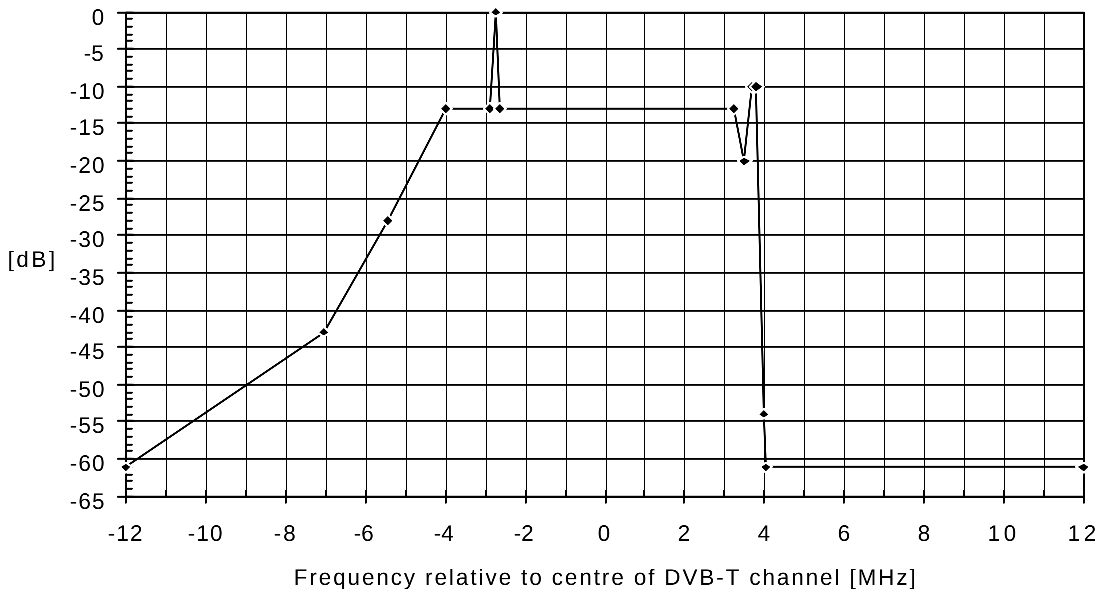


Figure 8.11 Analogue system L / SECAM. V / S ratio = 10 dB

8.4 Measured transmitter power spectra

To illustrate the performance of typical high power transmitters the power spectrum was measured on three UHF transmitters. Two of these being identical 40 kW pulsed klystron transmitters but operating on different channels (31 and 53) while the third transmitter is a 10 kW tetrode transmitter operating on channel 53. All three transmitters are less than 10 years old.

The residual carrier level was set to 11%.

The spectra with FM-sound and NICAM are shown in Figure 8.12. 8.13 and 8.14 respectively.

The "extra sideband" appearing above the NICAM subcarrier has been identified as the second harmonic of the sine-wave contained in the video signal. It is seen that the suppression of this unwanted signal is significantly different for the two types of transmitters tested. It is also seen that the suppression of the (re-inserted) lower sideband differs between the two (identical) klystron transmitters.

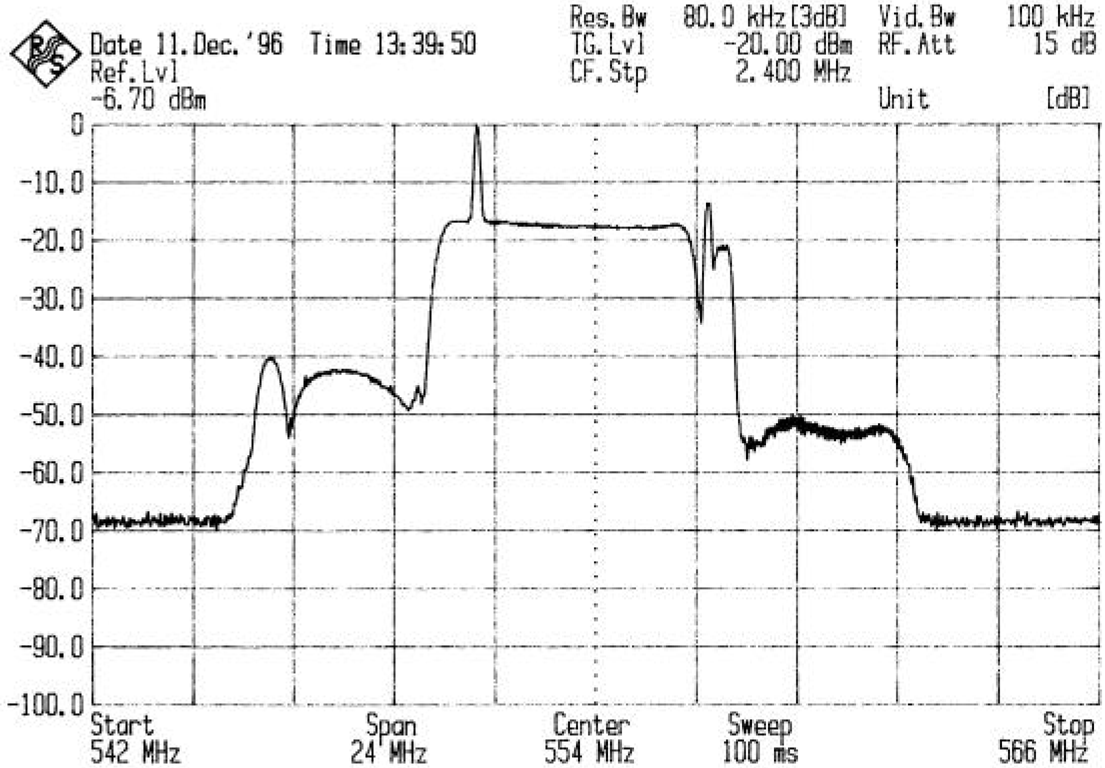


Figure 8.12: Spectrum for a System G 40 kW pulsed klystron transmitter with FM-sound and NICAM carriers

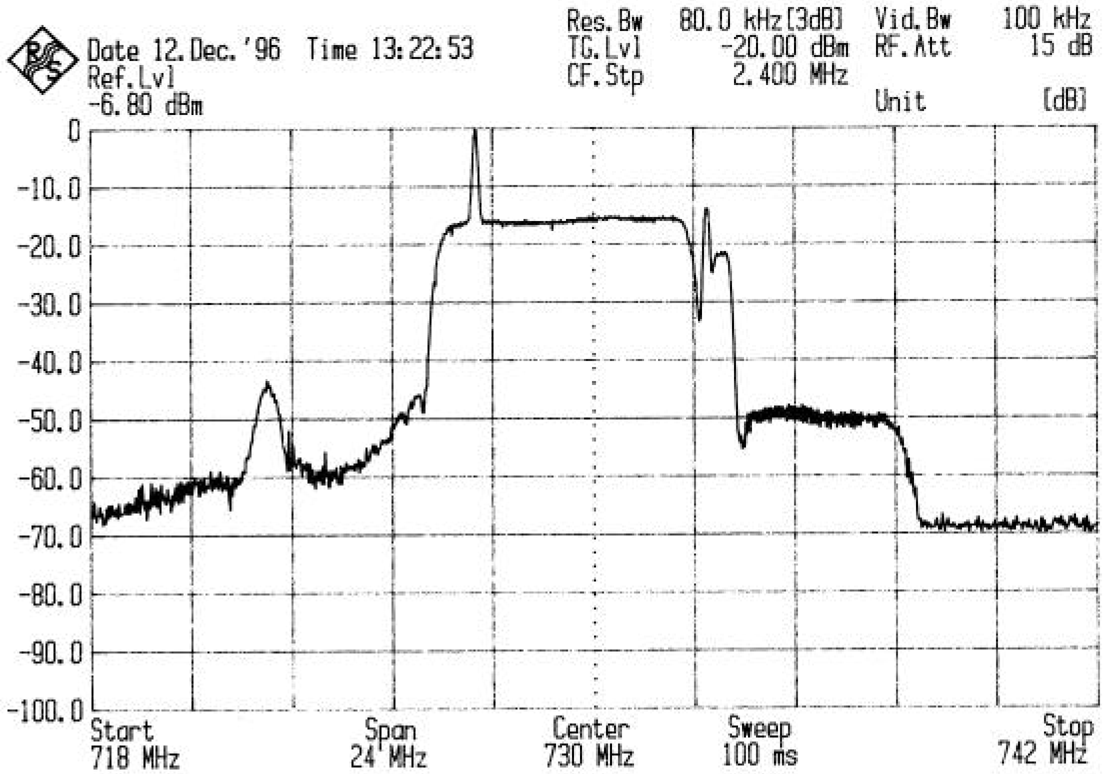


Figure 8.13: Spectrum for a System G 40 kW pulsed klystron transmitter with FM-sound and NICAM carriers

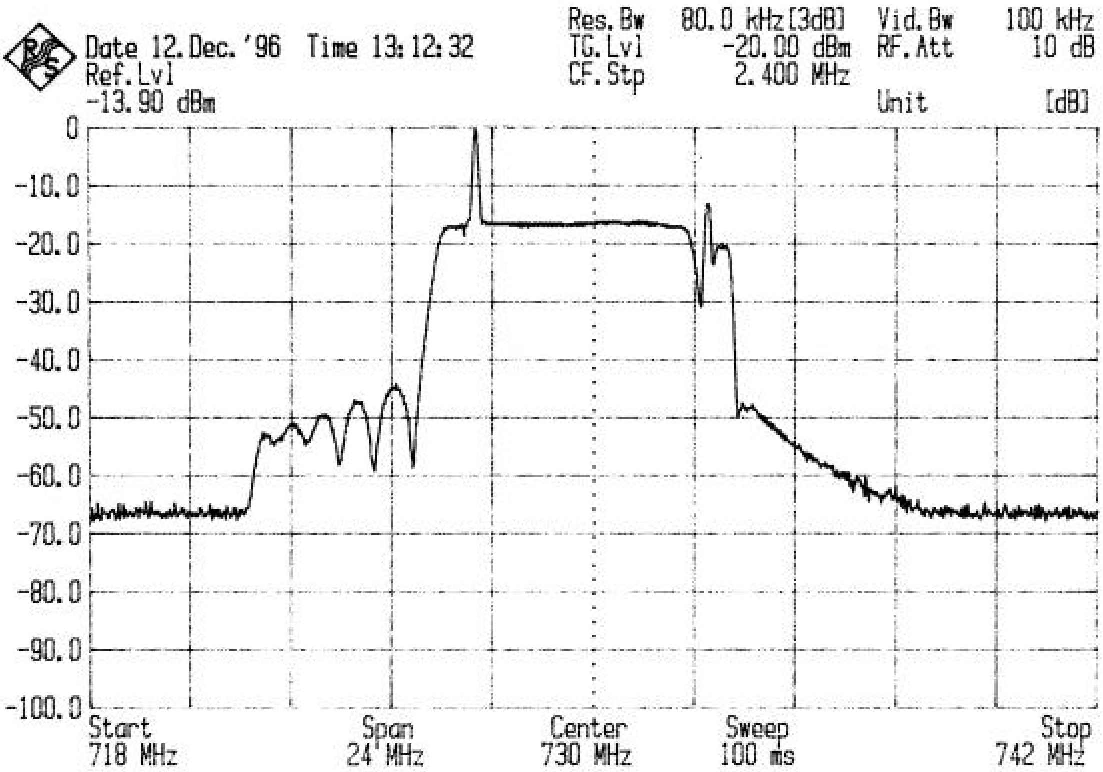


Figure 8.14: Spectrum for a System G 10 kW tetrode transmitter with FM-sound and NICAM carriers

Annex 8.1

Derivation of protection ratio values used for the asymmetrical DVB-T spectrum masks.

8 MHz channels

G / PAL / NICAM interfered with by DVB-T

Vision carrier in lower adjacent channel

Frequency: 1.25 MHz.
corresponding to -10.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in lower adjacent channel:

Frequency: 2.25 MHz
corresponding to -9.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in lower adjacent channel:

Bandwidth: 5 MHz
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to -5.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 48.3 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(48.3 +25.9) dB = -74.2 dB

Analogue mono FM-soundcarrier in lower adjacent channel:

Bandwidth: (2 * (Δf + $f_{mod.\ max}$)) = 130 kHz
Centre frequency of subcarrier: 5.5 MHz above the vision carrier
Upper end of band: (1.25 + 5.5 + (0.130 / 2))MHz = 6.815 MHz.
corresponding to -5.185 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 35 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(35 +25.9) dB = -60.9 dB

NICAM subcarrier in lower adjacent channel:

Bandwidth: 500 kHz
Centre frequency of subcarrier: 5.85 MHz above the vision carrier
Upper end of NICAM signal: (1.25 + 5.85 + (0.5 / 2))MHz = 7.35 MHz.
corresponding to -4.65 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 31 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(31 +25.9) dB = -56.9 dB

Lower video sideband in upper adjacent channel:

Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +4.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 39 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(39 +25.9) dB = -64.9 dB

Vision carrier in upper adjacent channel:
Frequency: 1.25 MHz.
corresponding to +5.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in upper adjacent channel:
Frequency: 2.25 MHz
corresponding to +6.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in upper adjacent channel:
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to +10.25 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier: -76.9 dB

G / PAL / A2 interfered with by DVB-T

Vision carrier in lower adjacent channel
Frequency: 1.25 MHz.
corresponding to -10.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in lower adjacent channel:
Frequency: 2.25 MHz
corresponding to -9.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in lower adjacent channel:
Bandwidth: 5 MHz
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to -5.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 48.3 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB

Maximum relative level in 4 kHz: -(48.3 +25.9) dB = -74.2 dB

Analogue mono FM-soundcarrier in lower adjacent channel:

Bandwidth: (2 * (Δf + $f_{mod.\ max}$)) = 130 kHz
Centre frequency of subcarrier: 5.5 MHz above the vision carrier
Upper end of band: (1.25 + 5.5 + (0.130 / 2))MHz = 6.815 MHz.
corresponding to -5.185 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 35 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(35 +25.9) dB = -60.9 dB

As the necessary protection ratio is lower than that for the second soundcarrier and the centre frequency is further away from the DVB-T channel. this value is ignored.

Second analogue FM-soundcarrier in lower adjacent channel:

Bandwidth: (2 * (Δf + $f_{mod.\ max}$)) = 130 kHz
Centre frequency of subcarrier: 5.742 MHz above the vision carrier
Upper end of band: (1.25 + 5.742 + (0.13 / 2))MHz = 7.06 MHz.
corresponding to -4.94 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 44 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(44 +25.9) dB = -69.9 dB

Lower video sideband in upper adjacent channel:

Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +4.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 39 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(39 +25.9) dB = -64.9 dB

Vision carrier in upper adjacent channel:

Frequency: 1.25 MHz.
corresponding to +5.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in upper adjacent channel:

Frequency: 2.25 MHz
corresponding to +6.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in upper adjacent channel:

Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to +10.25 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier: -76.9 dB

G / PAL (Vision/sound ratio = 10 dB) interfered with by DVB-T for information only. not included in the curves in Figures 8.1 and 8.2

Vision carrier in lower adjacent channel
Frequency: 1.25 MHz.
corresponding to -10.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in lower adjacent channel:
Frequency: 2.25 MHz
corresponding to -9.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in lower adjacent channel:
Bandwidth: 5 MHz
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to -5.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 48.3 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(48.3 +25.9) dB = -74.2 dB

Lower adjacent mono FM-soundcarrier:
Bandwidth: (2 * (Δf + $f_{mod.\ max}$)) = 130 kHz
Centre frequency of subcarrier: 5.5 MHz above the vision carrier
Upper end of band: (1.25 + 5.5 + (0.130 / 2))MHz = 6.815 MHz.
corresponding to -5.185 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 34 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(34 +25.9) dB = -59.9 dB

Lower video sideband in upper adjacent channel:
Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +4.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 39 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(39 +25.9) dB = -64.9 dB

Vision carrier in upper adjacent channel:
Frequency: 1.25 MHz.
corresponding to +5.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB

Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in upper adjacent channel:

Frequency: 2.25 MHz
corresponding to +6.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in upper adjacent channel:

Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to +10.25 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier: -76.9 dB

I / PAL / NICAM interfered with by DVB-T

Vision carrier in lower adjacent channel:

Frequency: 1.25 MHz.
corresponding to +5.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 50.3 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(50.3 +25.9) dB = -76.2 dB

As the necessary protection ratio is lower than that for the vision carrier and the centre frequency is further away from the DVB-T channel. the value for the maximum relative level is replaced by that for tision carrier + 1 MHz: -76.9 dB

Vision carrier + 1 MHz in lower adjacent channel:

Frequency: 2.25 MHz
corresponding to -9.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in lower adjacent channel:

Bandwidth: 5 MHz
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to -5.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 45 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(45 +25.9) dB = -70.9 dB

Analogue mono FM-soundcarrier in lower adjacent channel: (-10 dB)

Bandwidth: $(2 * (\Delta f + f_{mod.\ max})) = 130$ kHz
Centre frequency of subcarrier: 6.0 MHz above the vision carrier
Upper end of band: (1.25 + 6.0 + (0.130 / 2))MHz = 7.315 MHz.
corresponding to -4.685 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 34 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(34 +25.9) dB = -59.9 dB

NICAM subcarrier in lower adjacent channel: (-20 dB)

Bandwidth: 550 kHz (-10 dB). used to determine the upper limit and 364 kHz (-3 dB). used determine the 4 kHz correction factor
Centre frequency of subcarrier: 6.55 MHz above the vision carrier
Upper end of NICAM signal: (1.25 + 6.55 + (0.55 / 2))MHz = 8.075 MHz. corresponding to -3.925 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 31 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(31 +25.9) dB = -56.9 dB

Lower video sideband in upper adjacent channel:

Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +4.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 41 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(41 +25.9) dB = -66.9 dB

Vision carrier in upper adjacent channel:

Frequency: 1.25 MHz.
corresponding to +5.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 50.3 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(50.3 +25.9) dB = -76.2 dB

Vision carrier + 1 MHz in upper adjacent channel:

Frequency: 2.25 MHz
corresponding to +6.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in upper adjacent channel:

Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to +10.25 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier + 1 MHz: -76.9 dB

K / SECAM. K / PAL. D / SECAM and D / PAL (Vision/sound ratio = 10 dB) interfered with by DVB-T

Vision carrier in lower adjacent channel

Frequency: 1.25 MHz.
corresponding to -10.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 52.8 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(52.8 +25.9) dB = -78.7 dB

Vision carrier + 1 MHz in lower adjacent channel:
Frequency: 2.25 MHz
corresponding to -9.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 52.8 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(52.8 +25.9) dB = -78.7 dB

Upper end of video sideband in lower adjacent channel:
Bandwidth: 6 MHz. used to determine the 4 kHz correction factor
5 MHz is the significant point on the protection ratio curve
Upper sideband frequency: (1.25 + 6) MHz = 7.25 MHz.
corresponding to -4.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 47.7 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(47.7 +25.9) dB = -73.6 dB

Analogue mono FM-soundcarrier in lower adjacent channel:
Bandwidth: $(2 * (\Delta f + f_{mod.\ max})) = 130$ kHz
Centre frequency of subcarrier: 6.5 MHz above the vision carrier
Upper end of band: (1.25 + 6.5 + (0.130 / 2))MHz = 7.815 MHz.
corresponding to -4.185 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 34 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(34 +25.9) dB = -59.9 dB

Lower video sideband in upper adjacent channel:
Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +4.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 40.2 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(40.2 +25.9) dB = -66.1 dB

Vision carrier in upper adjacent channel:
Bandwidth: 6 MHz
Frequency: 1.25 MHz.
corresponding to +5.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 52.8 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(52.8 +25.9) dB = -78.7 dB

Vision carrier + 1 MHz in upper adjacent channel:
Frequency: 2.25 MHz
corresponding to +6.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 52.8 dB

Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(52.8 +25.9) dB = -78.7 dB

Upper end of video sideband in upper adjacent channel:
Upper sideband frequency: (1.25 + 6) MHz = 7.25 MHz.
corresponding to +11.25 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier: -78.7 dB

L / SECAM / NICAM interfered with by DVB-T

Vision carrier in lower adjacent channel
Frequency: 1.25 MHz.
corresponding to -10.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 44 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(44 +25.9) dB = -69.9 dB

As the necessary protection ratio is lower than that for the vision carrier and the centre frequency is further away from the DVB-T channel. the value for the maximum relative level is replaced by that for the vision carrier + 1 MHz: -72.4 dB

Vision carrier + 1 MHz in lower adjacent channel:
Frequency: 2.25 MHz.
corresponding to -9.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 46.5 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(46.5 +25.9) dB = -72.4 dB

Upper end of video sideband in lower adjacent channel:
Bandwidth: 6 MHz
Upper sideband frequency: (1.25 + 6) MHz = 7.25 MHz.
corresponding to -4.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 35 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(35 +25.9) dB = -60.9 dB

Analogue mono AM-soundcarrier in lower adjacent channel:
Bandwidth: 30 kHz
Centre frequency of subcarrier: 6.5 MHz above the vision carrier
Allowance for positive soundcarrier offset: 50 kHz
Upper end of band: (1.25 + 6.5 + 0.05 + (0.030 / 2))MHz = 7.815 MHz.
corresponding to -4.185 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 54 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(54 +25.9) dB = -79.9 dB

Lower video sideband in upper adjacent channel:

Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +4.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 34 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(34 +25.9) dB = -59.9 dB

Vision carrier in upper adjacent channel:

Frequency: 1.25 MHz.
corresponding to +5.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 44 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(44 +25.9) dB = -69.9 dB

Vision carrier + 1 MHz in upper adjacent channel:

Frequency: 2.25 MHz.
corresponding to +6.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 46.5 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(46.5 +25.9) dB = -72.4 dB

Upper end of video sideband in upper adjacent channel:

Upper sideband frequency: (1.25 + 6) MHz = 7.25 MHz.
corresponding to +11.25 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier + 1 MHz: -72.4 dB

7 MHz channels

B / PAL / NICAM interfered with by DVB-T

Vision carrier in lower adjacent channel

Frequency: 1.25 MHz.
corresponding to -9.25 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in lower adjacent channel:

Frequency: 2.25 MHz
corresponding to -8.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in lower adjacent channel:

Bandwidth: 5 MHz
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to -4.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 48.3 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(48.3 +25.9) dB = -74.2 dB

Analogue mono FM-soundcarrier in lower adjacent channel:

Bandwidth: $(2 * (\Delta f + f_{mod.\ max})) = 130$ kHz
Centre frequency of subcarrier: 5.5 MHz above the vision carrier
Upper end of band: (1.25 + 5.5 + (0.130 / 2))MHz = 6.815 MHz.
corresponding to -3.685 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 35 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(35 +25.9) dB = -60.9 dB

NICAM subcarrier in lower adjacent channel:

Bandwidth: 500 kHz
Centre frequency of subcarrier: 5.85 MHz above the vision carrier
Upper end of NICAM signal: (1.25 + 5.85 + (0.5 / 2))MHz = 7.35 MHz.
corresponding to -3.15 MHz relative to centre of the DVB-T channel.

<u>Note:</u> This frequency is inside the DVB-T bandwidth (+/-3.33 MHz).
The values given below are thus only relevant if the analogue System B and the DVB-T transmitters are offset from each other by more than 200 kHz.

Protection ratio for Grade 4.5: 31 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB

Maximum relative level in 4 kHz: -(31 +25.9) dB = -56.9 dB

Lower video sideband in upper adjacent channel:
Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +3.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 39 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(39 +25.9) dB = -64.9 dB

Vision carrier in upper adjacent channel:
Frequency: 1.25 MHz.
corresponding to +4.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in upper adjacent channel:
Frequency: 2.25 MHz
corresponding to +5.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in upper adjacent channel:
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to +9.75 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier: -76.9 dB

B / PAL / A2 interfered with by DVB-T

Vision carrier in lower adjacent channel
Frequency: 1.25 MHz.
corresponding to -9.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in lower adjacent channel:
Frequency: 2.25 MHz
corresponding to -8.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in lower adjacent channel:
Bandwidth: 5 MHz
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to -4.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 48.3 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(48.3 +25.9) dB = -74.2 dB

Analogue mono FM-soundcarrier in lower adjacent channel:

Bandwidth: (2 * (Δf + $f_{mod.\ max}$)) = 130 kHz
Centre frequency of subcarrier: 5.5 MHz above the vision carrier
Upper end of band: (1.25 + 5.5 + (0.130 / 2))MHz = 6.815 MHz.
corresponding to -3.685 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 35 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(35 +25.9) dB = -60.9 dB

As the necessary protection ratio is lower than that for the second soundcarrier and the centre frequency is further away from the DVB-T channel. this value is ignored.

Second analogue FM-soundcarrier in lower adjacent channel:

Bandwidth: (2 * (Δf + $f_{mod.\ max}$)) = 130 kHz
Centre frequency of subcarrier: 5.742 MHz above the vision carrier
Upper end of band: (1.25 + 5.742 + (0.13 / 2))MHz = 7.06 MHz.
corresponding to -3.44 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 44 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(44 +25.9) dB = -69.9 dB

Lower video sideband in upper adjacent channel:

Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +3.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 39 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(39 +25.9) dB = -64.9 dB

Vision carrier in upper adjacent channel:

Frequency: 1.25 MHz.
corresponding to +4.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in upper adjacent channel:

Frequency: 2.25 MHz
corresponding to +5.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in upper adjacent channel:

Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to +9.75 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier: -76.9 dB

B / PAL (Vision/sound ratio = 10 dB) interfered with by DVB-T
for information only. not included in the curves in Figures 8.3 and 8.4

Vision carrier in lower adjacent channel
Frequency: 1.25 MHz.
corresponding to -9.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in lower adjacent channel:
Frequency: 2.25 MHz
corresponding to -8.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in lower adjacent channel:
Bandwidth: 5 MHz
Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to -4.25 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 48.3 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(48.3 +25.9) dB = -74.2 dB

Lower adjacent mono FM-soundcarrier:
Bandwidth: (2 * (Δf + $f_{mod.\ max}$)) = 130 kHz
Centre frequency of subcarrier: 5.5 MHz above the vision carrier
Upper end of band: (1.25 + 5.5 + (0.130 / 2))MHz = 6.815 MHz.
corresponding to -3.685 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 34 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(34 +25.9) dB = -59.9 dB

Lower video sideband in upper adjacent channel:
Frequency: (1.25 - 1) MHz = 0.25 MHz
corresponding to +3.75 MHz relative to centre of the DVB-T channel

Protection ratio for Grade 4.5: 39 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(39 +25.9) dB = -64.9 dB

Vision carrier in upper adjacent channel:
Frequency: 1.25 MHz.

corresponding to +4.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Vision carrier + 1 MHz in upper adjacent channel:

Frequency: 2.25 MHz
corresponding to +5.75 MHz relative to centre of the DVB-T channel.

Protection ratio for Grade 4.5: 51 dB
Correction for 4 kHz bandwidth: 10 * log(1540 / 4) = 25.9 dB
Maximum relative level in 4 kHz: -(51 +25.9) dB = -76.9 dB

Upper end of video sideband in upper adjacent channel:

Upper sideband frequency: (1.25 + 5) MHz = 6.25 MHz.
corresponding to +9.75 MHz relative to centre of the DVB-T channel.

Taken equal to the value for the vision carrier: -76.9 dB

9 SPECTRUM AVAILABILITY

9.1 Present situation

Within the European Broadcasting Area (EBA), the spectrum which is currently allocated to broadcasting and which may be used for terrestrial television is :

VHF Band I	47 to 68 MHz
VHF Band II	84 to 100 MHz
VHF Band III	174 to 230 MHz (the lower band edge is 162 MHz in Morocco)
UHF Band IV	470 to 582 MHz
UHF Band V	582 to 862 MHz

These bands are not exclusive to television and there is sharing with fixed, mobile and some other services in a number of countries.

Band II is only relevant to the Eastern parts of Europe and is used elsewhere for VHF/FM sound broadcasting. Indeed, even in many countries in Eastern Europe this band is now being used only for VHF/FM. Its possible use for television thus need not be considered further.

Within Bands I and III there are several channel/frequency assignment arrangements. In Eastern Europe, in France and in Ireland, channels are 8 MHz wide, in other countries the channel width is 7 MHz. In addition, there are several possible vision frequencies for a given channel within the countries using 7 MHz channels and there is, of course, no alignment of channel edges between countries using 7 MHz channels and those using 8 MHz channels. Furthermore, the upper part of Band III, above 216 MHz, is now agreed to be for the future use of terrestrial DAB (T-DAB) in many European countries.

Within Bands IV and V, there is a standard channel/frequency assignment arrangement with the channels in all countries being 8MHz wide with the upper and lower edges of each channel being the same for all countries in the EBA.

The channel positions and situation are shown in Annex 9.1 and details of channel frequencies in Annex 9.2.

Clearly the overlapping channel systems in both Bands I and III results in a very complex situation. It is partly because of this complexity that most of the studies concerning the possible introduction of digital television in Europe have concentrated on the possibilities offered within Bands IV and V. There is little loss of generality as a result, Bands IV and V having some four times the capacity of Bands I and III. However, Band III is an essential part of the analogue television infrastructure in many countries in the EBA. It will be necessary to evaluate the use of Band III in future digital television studies, especially as there may be economic benefits and opportunities to develop mobile reception.

9.2 Limitations

Not all of the spectrum identified above is actually available for television broadcasting in all countries in the EBA. While there are specific restrictions in many countries, there are also some restrictions which are relatively common.

Channels 35 to 37 in Band IV, from 582 to 606 MHz have been used for airport radar installations in some countries and this has caused restrictions both to them and to neighbouring countries. Most of these restrictions have now been lifted, except in channel 36).

Channels 38, 606 to 614 MHz, is used in some countries by Radio Astronomers. This usage demands a very high degree of protection and this causes severe restrictions over quite a wide area.

Finally, channels above 60 in Band V, that is from 790 MHz upwards (channels 61 to 69), are used in some countries for military (tactical radio) services. These services require a high degree of protection and the result is that the usage of these channels is subject to severe restrictions in most European countries. In the report from the second CEPT Detailed Spectrum Investigation, it is recommended that the channels 61 to 69 are made available for television and that all new channels becoming available for television shall be used for digital television only.

A pictorial representation of the usage of each channel is given in Figures 1 and 2 in Annex 9.3. The impact of the restrictions discussed above can be clearly seen in Figure 2.

9.3 Current spectrum usage

Most countries in the EBA operate several programme chains and the general adoption of a policy of attempting to obtain near-national coverage for each of these chains leads to a need for very many television transmitters. The radiated power of these covers a wide range: from about 1 MWatt (effective radiated power or e.r.p.) for major stations serving large areas or major population centres to less than 1 Watt e.r.p. for small stations intended to serve perhaps a few hundred people.

The number of programme chains varies from country to country depending upon :

- national resources;
- national policies regarding coverage requirements and interference standards;
- the geographic situation of an individual country and, in particular, how many neighbours it has.

As a generalisation, it can be stated that all European countries have 2 to 4 nationally available programme chains which each cover in excess of 98% of the population and such a generalisation applies to most countries in the EBA. Some countries have additional chains and/or individual stations covering densely populated areas.

9.4 Additional spectrum

In countries, where little or none of the currently available spectrum for terrestrial television is left unused and where extra spectrum (e.g. channels 61 to 69) can be made available, this would permit the introduction of digital television services, which, inherently, are more frequency efficient than the analogue services now in operation in the channels which are available.

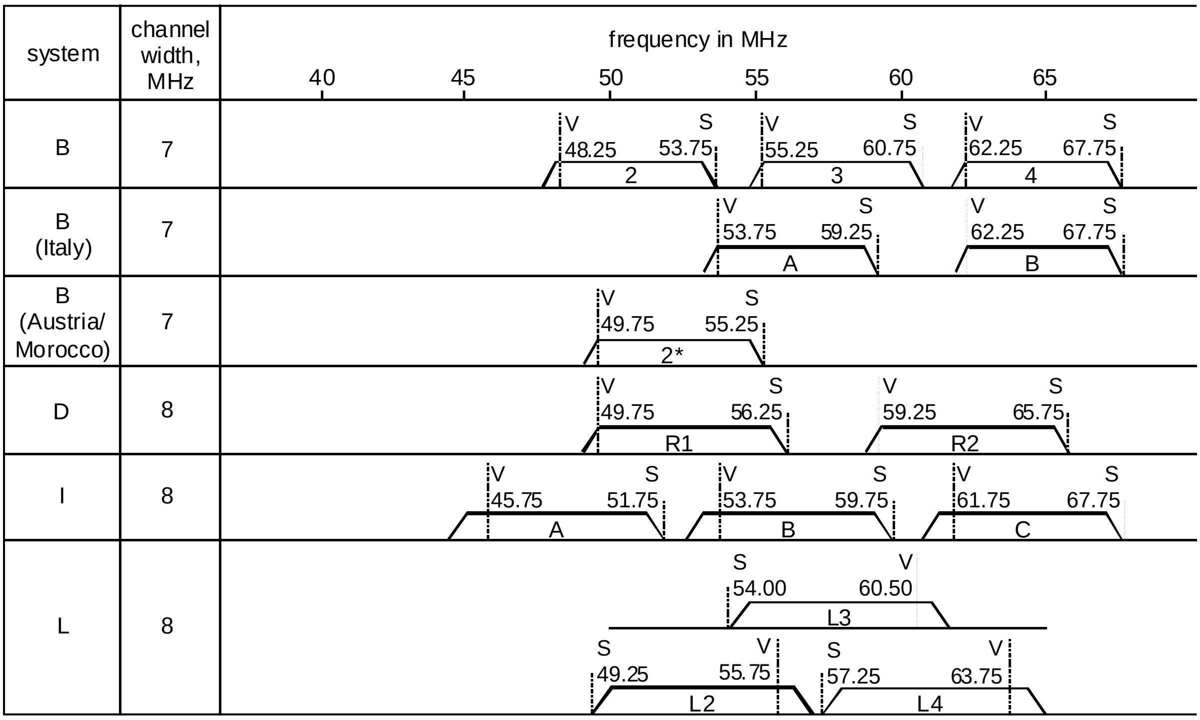


Figure 1: Channel positions in television Band I

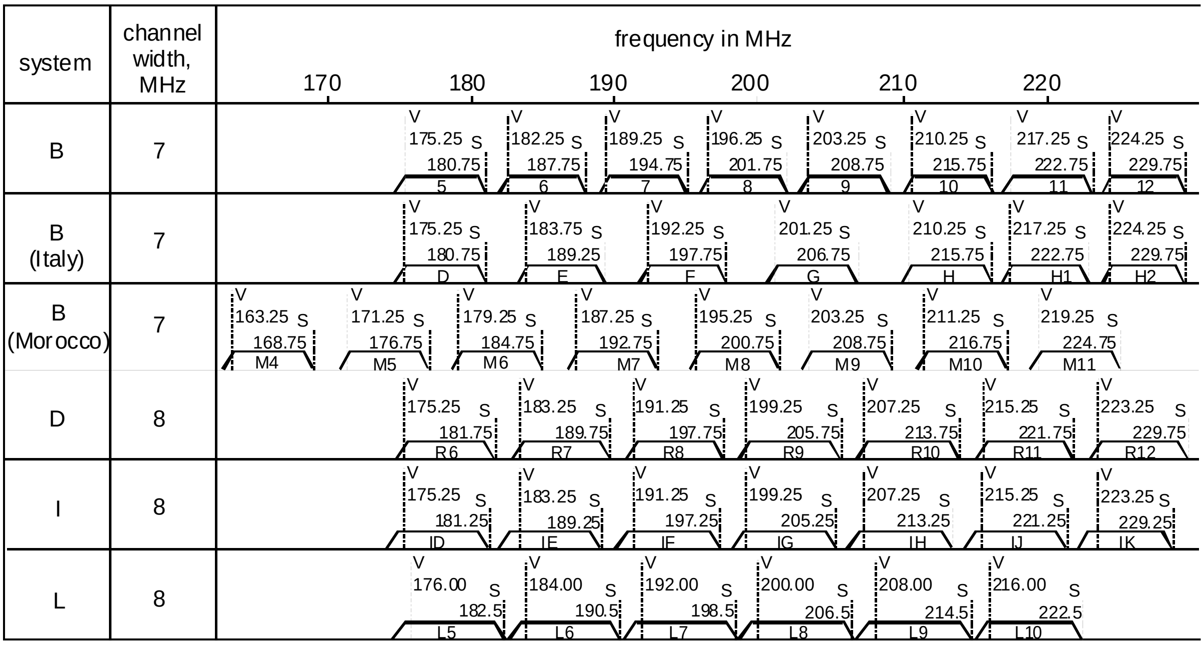


Figure 2: Channel positions in television Band III

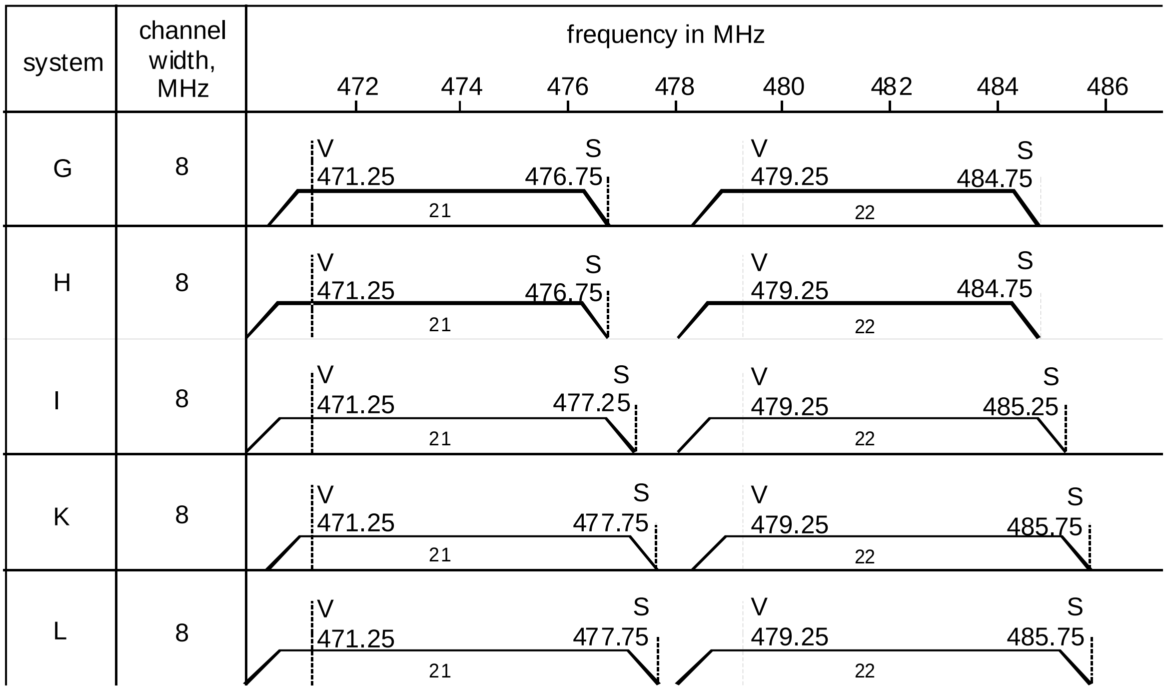


Figure 3: Channel positions in television Bands IV & V

TABLE 1
Television systems in use in the EBA

System	Number of lines	Channel width MHz	Vision bandwidth MHz	Vision/Sound separation MHz	Vestigial side-band MHz	Vision modulation	1st Sound modulation	2nd Sound system	Vision/2nd Sound sep. MHz
B	625	7	5	+5.5	0.75	C3F Negative	F3E (FM)	A2/NICAM	5.74/5.85
D	625	8	6	+6.5	0.75	C3F Negative	F3E (FM)	[NICAM]	[5.85]
G	625	8	5	+5.5	0.75	C3F Negative	F3E (FM)	A2/NICAM	5.74/5.85
H	625	8	5	+5.5	1.25	C3F Negative	F3E (FM)	NICAM	5.85
I	525	8	5.5	+5.996	1.25	C3F Negative	F3E (FM)	NICAM	6.55
K	625	8	6	6.5	0.75	C3F Negative	F3E (FM)	[NICAM]	[5.85]
L	625	8	6	6.5	1.25	C3F Positive	A3E (AM)	NICAM	5.85

ANNEX 9.2

Frequencies for Television Channels in the EBA

TABLE 1
VHF System B

Channel	Channel boundaries MHz		Vision carrier MHz	Sound carrier MHz	A2 Sound carrier MHz	NICAM carrier MHz
2	47	54	48.25	53.75	53.99	54.1
2*	48.25	55.5	49.75	55.25	-	-
3	54	61	55.25	60.75	60.99	61.1
4	61	68	62.25	67.75	67.99	68.1
5	174	181	175.25	180.75	180.99	181.1
6	181	188	182.25	187.75	187.99	188.1
7	188	195	189.25	194.75	194.99	195.1
8	195	202	196.25	201.75	201.99	202.1
9	202	209	203.25	208.75	208.99	209.1
10	209	216	210.25	215.75	215.99	216.1
11	216	223	217.25	222.75	222.99	223.1
12	223	230	224.25	229.75	229.99	230.1

TABLE 2
VHF System B (Italy)

Channel	Channel boundaries MHz		Vision carrier MHz	Sound carrier MHz	A2 Sound carrier MHz
A	52.50	59.50	53.75	59.25	59.49
B	61.00	68.00	62.25	67.75	67.99
C	81.00	88.00	82.25	87.75	87.99
D	174.00	181.00	175.25	180.75	180.99
E	182.50	189.50	183.75	189.25	188.49
F	191.00	198.00	192.25	197.75	197.99
G	200.00	207.00	201.25	206.75	206.99
H	209.00	216.00	210.25	215.75	215.99
H1	216.00	223.00	217.25	222.75	222.99
H2	223.00	230.00	224.25	229.75	229.99

TABLE 3
VHF System B (Morocco)

Channel	Channel boundaries MHz		Vision carrier MHz	Sound carrier MHz
M4	162	169	163.25	168.75
M5	170	177	171.25	176.75
M6	178	185	179.25	184.75
M7	186	193	187.25	192.75
M8	194	201	195.25	200.75
M9	202	209	203.25	208.75
M10	210	217	211.25	216.75
M11	218	225	219.25	224.75

TABLE 4
VHF System D

Channel	Channel boundaries MHz		Vision carrier MHz	Sound carrier MHz	NICAM carrier MHz
R1	48.5	56.5	49.75	56.25	55.60
R2	58	66	59.25	65.75	65.10
R3	76	84	77.25	83.75	83.10
R4	84	92	85.25	91.75	91.10
R5	92	100	93.25	99.75	99.10
R6	174	182	175.25	181.75	181.10
R7	182	190	183.25	189.75	189.10
R8	190	198	191.25	197.75	197.10
R9	198	206	199.25	205.75	205.10
R10	206	214	207.25	213.75	213.10
R11	214	222	215.25	221.75	221.10
R12	222	230	223.25	229.75	229.10

TABLE 5
VHF System I

Channel	Channel boundaries MHz		Vision carrier MHz	Sound carrier MHz	NICAM carrier MHz
IA	44.50	52.50	45.75	51.75	52.30
IB	52.50	60.50	53.75	59.75	60.30
IC	60.50	68.50	61.75	67.75	68.30
ID	174	182	175.25	181.25	181.80
IF	182	190	191.25	197.25	197.80
IG	190	198	199.25	205.25	205.80
IH	206	214	207.25	213.25	213.80
IJ	214	222	215.25	221.25	221.80
IK	222	230	223.25	229.25	229.80

TABLE 6
VHF System L

Channel	Channel boundaries MHz		Vision carrier MHz	Sound carrier MHz
L2	49.00	57.00	55.75	49.25
L3	53.75	61.75	60.50	54.00
L4	57.00	63.75	63.75	57.25
L5	174.25	182.75	176.00	182.50
L6	182.75	190.75	184.00	190.50
L7	190.75	198.75	192.00	198.50
L8	198.75	206.75	200.00	206.50
L9	206.75	214.75	208.00	214.50
L10	214.75	222.75	216.00	222.50

TABLE 7
UHF System G, H, I, K, L

Channel	Channel boundaries MHz		Vision carrier MHz	System G System H sound carrier MHz	System G A2 sound carrier MHz	System G System H System L NICAM carrier MHz	System I Sound carrier MHz	System K System L Sound carrier MHz	System I NICAM carrier MHz
21	470	478	471.25	476.75	476.99	477.1	477.25	477.75	477.8
22	478	486	479.25	484.75	484.99	485.1	485.25	485.75	485.8
23	486	494	487.25	492.75	492.99	493.1	493.25	493.75	493.8
24	494	502	495.25	500.75	500.99	501.1	501.25	501.75	501.8
25	502	510	503.25	508.75	508.99	509.1	509.25	509.75	509.8
26	510	518	511.25	516.75	516.99	517.1	517.25	517.75	517.8
27	518	526	519.25	524.75	524.99	525.1	525.25	525.75	525.8
28	526	534	527.25	532.75	532.99	533.1	533.25	533.75	533.8
29	534	542	535.25	540.75	540.99	541.1	541.25	541.75	541.8
30	542	550	543.25	548.75	548.99	549.1	549.25	549.75	549.8
31	550	558	551.25	556.75	556.99	557.1	557.25	557.75	557.8
32	558	566	559.25	564.75	564.99	565.1	565.25	565.75	565.8
33	566	574	567.25	572.75	572.99	573.1	573.25	573.75	573.8
34	574	582	575.25	580.75	580.99	581.1	581.25	581.75	581.8
35	582	590	583.25	588.75	588.99	589.1	589.25	589.75	589.8
36	590	598	591.25	596.75	596.99	597.1	597.25	597.75	597.8
37	598	606	599.25	604.75	604.99	605.1	605.25	605.75	605.8
38	606	614	607.25	612.75	612.99	613.1	613.25	613.75	613.8
39	614	622	615.25	620.75	620.99	621.1	621.25	621.75	621.8
40	622	630	623.25	628.75	628.99	629.1	629.25	629.75	629.8
41	630	638	631.25	636.75	636.99	637.1	637.25	637.75	637.8
42	638	646	639.25	644.75	644.99	645.1	645.25	645.75	645.8
43	646	654	647.25	652.75	652.99	653.1	653.25	653.75	653.8
44	654	662	655.25	660.75	660.99	661.1	661.25	661.75	661.8
45	662	670	663.25	668.75	668.99	669.1	669.25	669.75	669.8
46	670	678	671.25	676.75	676.99	677.1	677.25	677.75	677.8
47	678	686	679.25	684.75	684.99	685.1	685.25	685.75	685.8
48	686	694	687.25	692.75	692.99	693.1	693.25	693.75	693.8
49	694	702	695.25	700.75	700.99	701.1	701.25	701.75	701.8
50	702	710	703.25	708.75	708.99	709.1	709.25	709.75	709.8
51	710	718	711.25	716.75	716.99	717.1	717.25	717.75	717.8
52	718	726	719.25	724.75	724.99	725.1	725.25	725.75	725.8
53	726	734	727.25	732.75	732.99	733.1	733.25	733.75	733.8
54	734	742	735.25	740.75	740.99	741.1	741.25	741.75	741.8
55	742	750	743.25	748.75	748.99	749.1	749.25	749.75	749.8
56	750	758	751.25	756.75	756.99	757.1	757.25	757.75	757.8
57	758	766	759.25	764.75	764.99	765.1	765.25	765.75	765.8
58	766	774	767.25	772.75	772.99	773.1	773.25	773.75	773.8
59	774	782	775.25	780.75	780.99	781.1	781.25	781.75	781.8
60	782	790	783.25	788.75	788.99	789.1	789.25	789.75	789.8
61	790	798	791.25	796.75	796.99	797.1	797.25	797.75	797.8
62	798	806	799.25	804.75	804.99	805.1	805.25	805.75	805.8
63	806	814	807.25	812.75	812.99	813.1	813.25	813.75	813.8
64	814	822	815.25	820.75	820.99	821.1	821.25	821.75	821.8
65	822	830	823.25	828.75	828.99	829.1	829.25	829.75	829.8
66	830	838	831.25	836.75	836.99	837.1	837.25	837.75	837.8
67	838	846	839.25	844.75	844.99	845.1	845.25	845.75	845.8
68	846	854	847.25	852.75	852.99	853.1	853.25	853.75	853.8
69	854	862	855.25	860.75	860.99	861.1	861.25	861.75	861.8

ANNEX 9.3

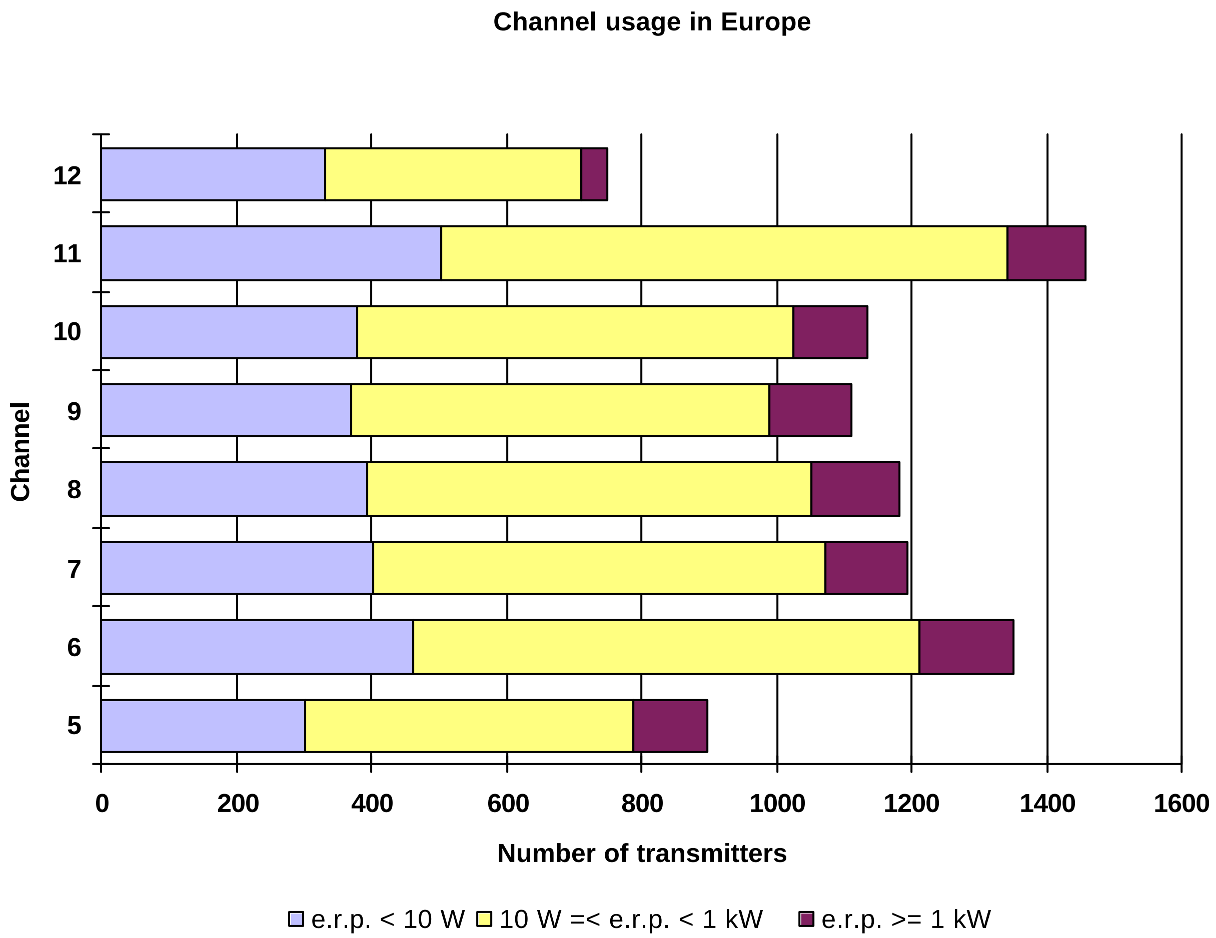


Figure 1: Number of transmitters in use per channel in VHF Band III (5 to 12)

Channel

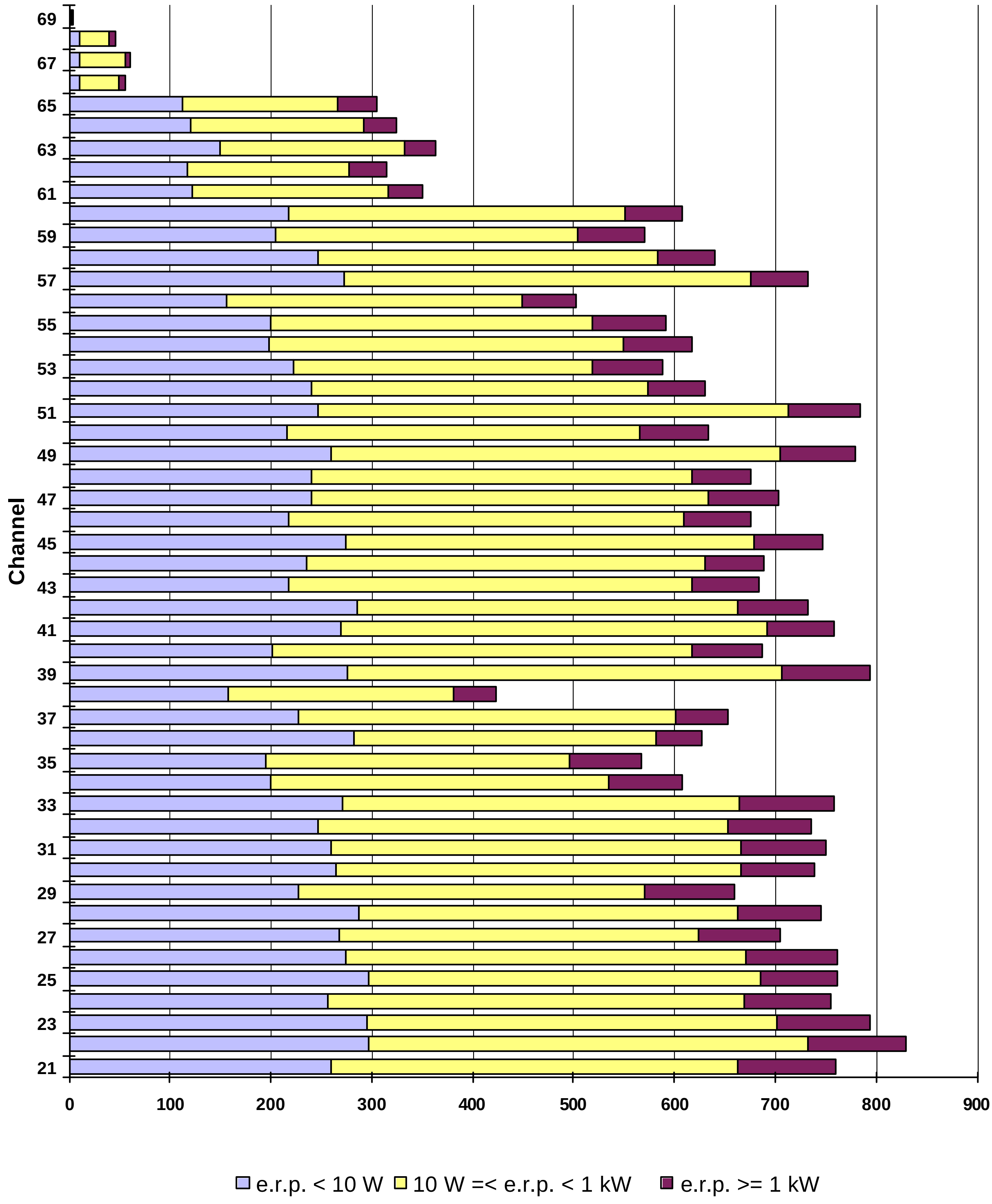


Figure 2: Number of transmitters in use per UHF channel (21 to 69)

10. TELEVISION TRANSMITTER DATA REQUIRED FOR PLANNING

10.1 Transmitter data

It is only possible to conduct planning studies if a suitable data base of existing television analogue stations is available. In order to facilitate the establishment and maintenance of a suitable transmitter data bases, a format for electronic data exchange has been designed and is in use within the EBU. The details for analogue stations are given in Annex 10.1.

The structures shown in Annexes 10.1 and 10.2 were used as the basis for CEPT database structures and the EBU structures were subsequently aligned, where necessary, to match those adopted by the CEPT.

Although such a detailed database of VHF and UHF television station information is available from some countries, for those countries which have not supplied information, EBU planning studies have relied on a database derived from the EBU List of VHF/UHF television stations. This list contains the television transmitters which are currently in operation in Europe. It does not include any transmitters which have been planned and co-ordinated between neighbouring countries but which have not yet been brought into operation. In some countries, transmitters in this category may be of high power and if an individual administration decides to implement any of these stations for analogue services, there could be a major impact on the planning of digital stations.

For the exchange of data on digital television stations, Annex 10.2 provides a digital television transmitter database structure. As the digital television system develops it may be necessary to make provision for additional information and some columns have been left unused for this purpose. As far as possible, the same columns are used for the same purposes in the analogue and digital television file structures.

ANNEX 10.1

EBU ANALOGUE TELEVISION TRANSMITTER DATABASE STRUCTURE
(EBU and CEPT structures have been aligned)

Field	Item	Start Column	Width	Type
1	File identifier, must be TVA1	1	4	A4
2	ITU code for administration responsible	5	3	A3
3	Identification code used by organization[1]	8	9	A9
4	Update code used by organization[1]	17	1	A1
5	Space reserved for serial number (e.g. ITU No.)	18	9	A9
6	Status code (**O**perating/**N**ot operating)	27	1	A1
7	Date of entry into operation (DDMMYY)	28	6	3I2
8	ITU code for country in which transmitter is sited[1]	34	3	A3
9	Station name	37	20	A20
10	Latitude (in degrees, **N**/**S**, min., sec.)	57	7	I2, A1, 2I2
11	Longitude (in degrees, **E**/**W**, min., sec.)	64	8	I3, A1, 2I2
12	Height of site[2] (m. asl; as sign followed by a number)	72	5	I5
13	Television system (**B**/**D**, ... etc.)	77	2	A2
14	Colour system (**P**al, **S**ecam, or **N**TSC	79	1	A1
15	Channel	80	3	A3
16	Vision offset value (in 1/12 line units; as sign followed by a number)	83	4	I4
17	Nominal vision carrier frequency in MHz (including decimal point)	87	9	F9.3
18	Vision offset value in Hz (as sign followed by a number)	96	8	I8
19	Offset type (**U**nspecified /**N**ormal/**P**recision/**S**ynchronized)	104	1	A1
20	Maximum vision e.r.p. of horizontally polarized component (in dBW; as sign followed by a number including a decimal point)	105	5	F5.1
21	Maximum vision e.r.p. of vertically polarized component (in dBW; as sign followed by a number including a decimal point)	110	5	F5.1
22	Nominal primary sound carrier frequency minus nominal vision carrier frequency in MHz (as a number including a decimal point; if value is negative, e.g. System L at VHF, include sign in first column of field)	115	4	F4.1
23	Primary sound carrier offset[3] value in Hz (for system L only)	119	7	I7
24	Vision to primary sound carrier power ratio (in dB)	126	2	I2
25	Nominal secondary sound carrier frequency minus nominal vision carrier frequency in MHz (as a number including a decimal point; if value is negative, e.g. System L at VHF, include sign in first column of field)	128	6	F6.2
26	Unused columns	134	6	
27	Secondary sound system (**F**M/**N**icam; leave blank if no secondary sound system)	140	1	A1
28	Vision to secondary sound carrier power ratio (in dB)	141	2	I2
29	Polarization (**H**/**V**/**M**)	143	1	A1
30	Height of antenna[2] (m. agl)	144	3	I3
31	Directional? (**D**irectional/**N**on-directional)	147	1	A1

Field	Item	Start Column	Width	Type
32	36 values of e.r.p. reduction (in dB) of the horizontally polarised component in the horizontal plane relative to the maximum e.r.p. of the horizontally polarised component (at 10 degree intervals, starting at North)	148	(36x2)	36xI2
33	36 values of e.r.p. reduction (in dB) of the vertically polarised component in the horizontal plane relative to the maximum e.r.p. of the vertically polarised component (at 10 degree intervals, starting at North)	220	(36x2)	36xI2
34	Elevation angle of the horizontally polarised component (in degrees, negative if above the horizontal)	292	4	F4.1
35	Unused columns	296	2	
36	Elevation angle of the vertically polarised component (in degrees, negative if above the horizontal)	298	4	F4.1
37	Unused columns	302	2	
38	Unused column	304	1	
39	Maximum effective antenna height (m)	305	5	I5
40	36 values of effective antenna height in m, at 10 degree intervals, starting at North	310	(36x5)	36xI5
41	Organization name or code[1]	490	5	A5
42	Programme identifier[1]	495	5	A5
43	Date of last change to data on file[1] (DDMMYY)	500	6	3I2
44	Designation of emission for the vision signal[1]	506	9	A9
45	Designation of emission for the primary sound signal[1]	515	9	A9
46	Designation of emission for the secondary sound signal[1]	524	9	A9

[1] Not needed for calculation purposes. These are items added for general information which may be found useful during a co-ordination process.

[2] Not needed for calculation purposes if ITU-R Rec. P.370 is used.

[3] Sound carrier offset is defined as co-ordinated or used sound carrier frequency minus (nominal sound carrier frequency + vision frequency offset). It is thus zero, unless a special sound offset is in use.

[4] All alphanumeric fields should start in the left-most column of the field.

[5] All numeric fields should finish in the right-most column of the field. If a sign is necessary, this should be given in the left-most column of the field.

[6] Fields whose value is not known or which are not relevant should be left blank.

[7] If no information is given concerning the performance of the antenna in the vertical plane, it will be regarded as having a uniform radiation pattern in that plane.

ANNEX 10.2

EBU DRAFT DIGITAL TELEVISION TRANSMITTER DATABASE STRUCTURE (EBU and CEPT structures have been aligned)

Field	Item	Start Column	Width	Type
1	File identifier, must be TVD1	1	4	A4
2	ITU code for administration responsible	5	3	A3
3	Identification code used by organization[1]	8	9	A9
4	Update code used by organization[1]	17	1	A1
5	Space reserved for serial number (e.g. ITU No.)	18	9	A9
6	Status code (**O**perating/**N**ot operating)	27	1	A1
7	Date of entry into operation (DDMMYY)	28	6	3I2
8	ITU code for country in which transmitter is sited[1]	34	3	A3
9	Station name	37	20	A20
10	Latitude (in degrees, **N**/**S**, min., sec.)	57	7	I2, A1, 2I2
11	Longitude (in degrees, **E**/**W**, min., sec.)	64	8	I3, A1, 2I2
12	Height of site[2] (m. asl; as sign followed by a number)	72	5	I5
13	Digital television system	77	2	A2
14	Carrier and guard interval	79	1	A1
15	Channel	80	3	A3
16	Unused	83	4	
17	Block centre frequency in MHz (including decimal point)	87	9	F9.3
18	Offset value in Hz (as sign followed by a number)	96	8	I8
19	Offset type (**U**nspecified/**N**ormal/**P**recision)	104	1	A1
20	Maximum e.r.p. of horizontally polarized component (in dBW; as sign followed by a number including a decimal point)	105	5	F5.1
21	Maximum e.r.p. of vertically polarized component (in dBW; as sign followed by a number including a decimal point)	110	5	F5.1
22	Identifier for SFN	115	5	A5
23	Relative timing of transmitter within an SFN (µsec)	120	6	I6
24	Unused	126	17	
29	Polarization (**H**/**V**/**M**)	143	1	A1
30	Height of antenna[2] (m. agl)	144	3	I3
31	Directional? (**D**irectional/**N**on-directional)	147	1	A1
32	36 values of e.r.p. reduction (in dB) of the horizontally polarised component in the horizontal plane relative to the maximum e.r.p. of the horizontally polarised component (at 10 degree intervals, starting at North)	148	(36x2)	36xI2
33	36 values of e.r.p. reduction (in dB) of the vertically polarised component in the horizontal plane relative to the maximum e.r.p. of the vertically polarised component (at 10 degree intervals, starting at North)	220	(36x2)	36xI2
34	Elevation angle of the horizontally polarised component (in degrees, negative if above the horizontal)	292	4	F4.1
35	Unused columns	296	2	
36	Elevation angle of the vertically polarised component (in degrees, negative if above the horizontal)	298	4	F4.1
37	Unused columns	302	2	
38	Unused column	304	1	
39	Maximum effective antenna height (m.)	305	5	I5
40	36 values of effective antenna height (in m, at 10 degree intervals, starting at North)	310	(36x5)	36xI5

Field	Item	Start Column	Width	Type
41	Transmission provider[1]	490	5	A5
42	Service provider[1]	495	5	A5
43	Date of last change to data on file[1] (DDMMYY)	500	6	3I2
44	Designation of emission	506	9	A9

[1] Not needed for calculation purposes. These are items added for general information which may be found useful during a co-ordination process.

[2] Not needed for calculation purposes if Rec. P.370 is used.

[3] All alphanumeric fields should start in the left-most column of the field.

[4] All numeric fields should finish in the right-most column of the field. If a sign is necessary, this should be given in the left-most column of the field.

[5] Fields whose value is not known or which are not relevant should be left blank.

[6] If no information is given concerning the performance of the antenna in the vertical plane, it will be regarded as having a uniform radiation pattern in that plane.

11. PLANNING STUDIES

11.1 General

11.1.1 Studies for single stations and networks

Planning studies have been carried out to investigate the coverage that could be achieved if use were made of the channels that are available in a given country. The coverage of a single digital television station depends on the restrictions necessary to protect existing or planned analogue stations and the C/N requirement for the digital service.

Also coverage achieved by networks have been investigated. Theoretical lattice networks are used to investigate the impact of certain parameters on the coverage, such as the guard interval in a SFN.

A number of studies show the coverage that could be achieved in practice. The studies include MFNs and SFNs. (MFN planning is sometimes also called conventional planning or interleaved planning.)

11.1.2 Portable reception

In Chapter 4 two reception modes were defined: fixed and portable reception. It has to be noted that portable reception is characterised (in planning terms) by a simple built-in or set-top antenna.

Portable reception is seen now by many organisations as a very important feature of terrestrial digital television, which cannot be achieved by digital television via satellite or cable. There is general agreement that planning of digital television must take account of portable reception. In particular SFNs may be particularly suitable for achieving a satisfactory portable coverage.

In the transition period, when analogue television still exists, the power of digital transmission will need to be restricted in many cases in order to protect the analogue services. Under these circumstances it will be difficult to achieve portable reception in the whole derived coverage area.

In planning digital television a balance has to be found between conflicting items such as high bit rate and large coverage on the one hand and limited power and limited access to the spectrum on the other hand. This becomes particularly important in planning for portable reception.

Some organisations plan for fixed reception and calculate the coverage area for portable reception to show the reception possibilities. Others plan to cover the main population centres for portable reception and calculate the coverage area for fixed reception in order to show where the signals can still be received.

11.2 Single station studies

A series of planning studies was carried out some years ago within the EBU Technical Department. While these studies are now somewhat outdated, they have been retained here as they give a reasonable indication of what should be fairly readily achievable in many countries. These studies considered the coverage which

Table 11.1

Coverage for a digital station complementing analogue station A

The digital service must protect all analogue stations above 100 watts

The average coverage of the analogue services on the same site is 10000 sq km

Summary of area (in sq km) covered by digital service on each channel
Case where polarization of the digital service is Horizontal

Results for a digital service C/N ratio of 8 dB

	0	1	2	3	4	5	6	7	8	9
20		470	6174	----	1036	5542	----	500	5100	3118
30	----	527	4020	----	7582	3296	----	7111	----	753
40	----	----	----	----	----	758	----	----	1830	----
50	----	----	----	----	1553	----	1262	----	----	1236
60	----	----	1990	----	----	----	----	----	----	----

Results for a digital service C/N ratio of 14 dB

	0	1	2	3	4	5	6	7	8	9
20		----	4178	----	617	3653	----	270	3319	1886
30	----	290	2420	----	5260	1952	----	4947	----	425
40	----	----	----	----	----	425	----	----	1115	----
50	----	----	----	----	941	----	1262	----	----	----
60	----	----	1214	----	----	----	----	----	----	----

Results for a digital service C/N ratio of 20 dB

	0	1	2	3	4	5	6	7	8	9
20		----	2705	----	----	2359	----	----	2105	1109
30	----	----	1385	----	3559	1074	----	3279	----	----
40	----	----	----	----	----	----	----	----	----	----
50	----	----	----	----	----	----	----	----	----	----
60	----	----	----	----	----	----	----	----	----	----

Results for a digital service C/N ratio of 26 dB

	0	1	2	3	4	5	6	7	8	9
20		----	1708	----	----	1449	----	----	1272	636
30	----	----	776	----	2318	570	----	2084	----	----
40	----	----	----	----	----	----	----	----	----	----
50	----	----	----	----	----	----	----	----	----	----
60	----	----	----	----	----	----	----	----	----	----

Note:

In Tables 11.1 and 11.2, the coverage area has been suppressed for any case in which:

- a channel is in use for an analogue service from the same site;
- the coverage area is too small to be calculated reasonably accurately;
- the relevant channel is in use by other services, for example, radio astronomy.

Table 11.2

Coverage for a digital station complementing analogue station B
The digital service must protect all analogue stations above 100 watts

The average coverage of the analogue services on the same site is 10000 sq km

Summary of area (in sq km) covered by digital service on each channel
Case where polarization of the digital service is Horizontal

Results for a digital service C/N ratio of 8 dB

	0	1	2	3	4	5	6	7	8	9
20		12538	19863	6421	10642	7738	7478	----	9090	2547
30	----	8600	1236	8474	6276	1194	----	5200	----	2091
40	19735	9950	2116	1035	4501	2513	2322	3003	4842	13764
50	1943	4876	18162	2337	3687	11202	12557	17818	14704	5318
60	19261	----	----	----	----	----	----	----	----	----

Results for a digital service C/N ratio of 14 dB

	0	1	2	3	4	5	6	7	8	9
20		9207	13568	4206	7747	5229	4965	----	6144	1458
30	----	6039	712	5692	4283	725	----	3483	----	1307
40	14271	6944	1342	607	2986	1622	1475	1889	3197	9835
50	1160	3231	13359	1436	2382	7691	8923	13066	10489	3467
60	14256	----	----	----	----	----	----	----	----	----

Results for a digital service C/N ratio of 20 dB

	0	1	2	3	4	5	6	7	8	9
20		6612	9129	2678	5541	3378	3150	----	4068	905
30	----	4057	384	3702	2758	406	----	2166	----	774
40	10101	4675	813	----	1860	979	918	1123	2013	6930
50	649	2113	9671	818	1472	5193	6224	9265	7421	2241
60	10278	----	----	----	----	----	----	----	----	----

Results of a digital service C//N ratio of 26 dB

	0	1	2	3	4	5	6	7	8	9
20		4677	6059	1679	3831	2084	2016	----	2592	518
30	----	2648	----	2339	1709	----	----	1295	----	454
40	6933	3121	471	----	1086	580	524	622	1214	4720
50	----	1313	6916	----	843	3404	4194	6622	5139	1377
60	7211	----	----	----	----	----	----	----	----	----

could be achieved by individual digital television stations, that is, excluding any consideration of mutual interference between digital television stations. The purpose of the studies was to investigate what coverage could be achieved if use were made of any of the channels currently available in any given country. Although the purpose of the exercises was primarily exploratory, a primary requirement was the protection of the existing analogue service areas. The method given in § 7.3.1 was used to establish these. A wide range of planning criteria was investigated and, in this context, the C/N ratio requirement for a specific digital system is particularly important. In order to simplify the results, however, only representative values of 8, 14, 20 and 26 dB have been used for the results presented here. In addition, because these calculations were made some time ago, the results represent 99% location coverage by the digital stations. As it is now generally assumed that a location coverage target of 95% is a more realistic target, it is necessary to accept that the results presented represent an underestimate of what is achievable.

Once the permitted e.r.p. on each of 36 bearings has been derived, the digital coverage radii on those bearings may also be calculated. The result for any given transmitter site varies with the channel under consideration and also with the system variant. Fig. 11.1 shows the results for Crystal Palace for system variants requiring C/N values of 14 dB and 26 dB and for the case of horizontally polarized digital signals. These results were obtained before channel 35 was proposed for analogue television use in the United Kingdom.

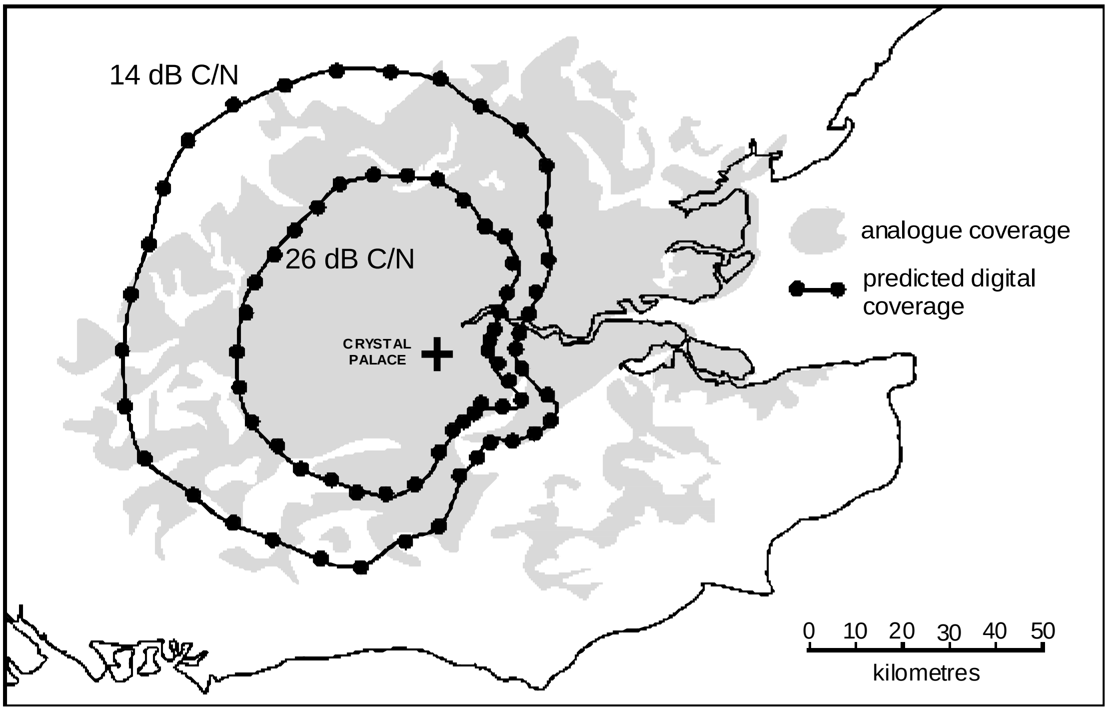


Figure 11.1: EBU predicted coverage of DVB-T from Crystal Palace (UK) on channel 35

It is clearly impractical to present results in the form of diagrams for all of the various options available and it is more useful to consider tabulated results such as those shown in Tables 11.1 and 11.2. These represent one case where only a few channels seem to be available for digital television and a case where there seems to be a large number of channels available, albeit with reduced coverage compared with the analogue services.

Each of these Tables shows the results obtained for theoretical digital transmissions from an existing analogue transmitter site. Each Table is sub-divided to show results for different C/N ratios (8, 14, 20 and 26 dB). Within each sub-division, values of coverage area are given corresponding to the use of horizontal polarization for the digital transmission.

In deriving these values, new optimized radiation patterns for the digital station transmitting antennas were synthesized. These patterns were intended to maximize the coverage of the digital service on a given channel and polarization. Precautions were taken to ensure that the resultant radiation patterns are reasonable from the point of view of being physically realizable for each channel considered separately. However, the antenna is unlikely to be realizable for several channels taken together. It also cannot be assumed that the masts and towers in use would be able to accommodate such antennas. In this sense, the results presented represent an optimistic view of what might be achievable.

It has to be made quite clear that these exercises were intended to explore the possibilities available for digital television services. As yet, there has been no attempt to synthesize a plan which would provide services in several countries or even any individual country. There is little reason to try to synthesize a plan until:

- one of the system variants has been chosen in each country;
- decisions about coverage philosophy have been reached in all countries;
- it is clear how many, if any, additional analogue stations are to be implemented in each country.

At present, it seems probable that the decisions on these three points will not be the same in all countries and, if so, this will represent a considerable complexity in the planning software and in the interpretation of the results.

It must be noted that there is also an inherent assumption in these results which may not be valid in all countries. It was assumed that analogue stations with a radiated power of 100 W or more must be protected against additional interference from digital stations. This meant that any increase in interference was limited to 0.5 dB. Analogue stations with radiated power of less than 100 W are not considered in this interference analysis. This means that if there is an increase in interference to an analogue station with a radiated power of less than 100 W, then either this interference must be accepted or a new channel for the analogue station must be found. The latter will not be at all easy in many cases.

One should not make too many generalizations on the basis of a limited sub-set of stations, but these and other studies suggest that channels can be found for some digital stations and that in a number of cases the coverage achieved could be a substantial fraction of that of the corresponding analogue station. This suggests that in many countries successful terrestrial digital stations could be introduced.

Of course, this is from a technical view point only. For such stations to be successful, it is also necessary for there to be reasons for the public to use them.

11.3 MFN Studies

11.3.1 Introduction

This section outlines the considerations which went into the studies carried out for the implementation of MFN terrestrial digital services under the general description of “conventional planning". This term is used to cover those cases in which digital television transmitters, in general, re-use the same sites as existing analogue television transmitters and the frequency planning approach adopted would be similar to that for analogue services.

It is not intended to imply that all existing analogue sites would be used in this way, nor is it intended to imply that some additional sites for digital service transmitters would not be implemented.

11.3.2 Protection of existing analogue services

This matter of protection of the analogue services is of great importance. When digital television was first being promoted, there were some claims that digital transmissions would have only a low interference impact on analogue television. The truth is much less optimistic. Digital signals behave rather like noise and their impact on analogue television is also similar to that of noise.

For the analogue television systems used in the European Broadcasting Area (EBA) the protection ratio against interference from a digital television signal is around 40 dB; slightly above 40 if the required analogue picture quality is Grade 4 (appropriate if the interference is continuous) and slightly below 40 for Grade 3 (appropriate if the interference is only present for a few percent of the time). Such figures are not dissimilar from those for the case of interference from another analogue television signal. Indeed, in the case where both analogue signals have precision control of their frequencies, the analogue-to-analogue protection ratios can be in the mid 20s (dB).

However, digital receivers can operate with lower values of input signal than can analogue receivers. The amount of the reduction depends essentially on the C/N requirement of the digital signal and this, in turn, depends on the complexity of the digital signal. Very rugged digital services, targeted essentially at portable receivers, may have a C/N requirement of around 8 dB. Multi-programme or HDTV services may have a C/N requirement in excess of 20 dB. The comparison with the signal level requirements of analogue systems is thus not easy. A simplification would be to say that the more complex digital systems require about the same minimum field-strength as analogue systems while the simplest and most robust digital systems can work with minimum signal levels some 20 dB lower than those required by analogue systems.

11.3.3 Achievable coverage for digital stations

The digital coverage achievable will be very dependent upon the degree of development of the analogue services. In a country with a large number of analogue programme chains and with a very extensive network of relay stations, it is to be expected that there will be less opportunity for digital stations and services. There will be fewer channels available for the digital services and for those channels which are available there will be more severe power restrictions on the digital service in order to protect the analogue services.

11.4 SFN studies

11.4.1 Guard interval requirements

From the studies which have been made, it can be seen that there are several factors which will affect the guard interval requirements.

These are:
- co-channel protection;
- transmitter separation distance;
- symbol duration.

At the time of writing, it is not entirely clear how to deal with signals which have delays only a little larger than the guard interval. In principle, such signals contribute both to the wanted signal and to the interfering signal. These contributions vary as a function of the amount by which the signal delay exceeds the guard interval. In practice, the contribution to the wanted signal may be reduced (and that to the interfering signal increased) by effects linked to the system and receiver implementation. In an extreme case, there could be an abrupt transition from wholly contributing to wholly interfering at the end of the guard interval.

In view of this uncertainty, current planning studies for SFNs are being made on the basis of a gradual transition and also on the basis of an abrupt transition. A choice between the two sets of results can be made when tests on hardware implementations of DVB systems become available. In the meantime, the two sets of results may be used to guide further investigations of system design.

Several organisations have carried out studies intended to show the impact of guard interval and symbol length on the coverage which could be achieved by an SFN of digital television transmitters using OFDM. However, different parameters and methodologies have been used by different organisations. In particular, different statistical methods have been used when making summations of wanted and interfering signals levels. In addition, it is obvious that key parameters such as the required C/N ratio values and the separation distance between transmitters in the networks will have a major impact on the results obtained. These differences lead to some difficulties when interpreting the results.

Nevertheless from the results available some general conclusions may be reached (at least for systems with a non-abrupt transition from wholly contributing to wholly interfering):
- the fraction of the symbol duration which is given to the guard interval may vary from 1/8 to 1/4 without having a <u>major</u> impact on the coverages. It is thus possible to simplify discussion on the coverage aspects to consideration <u>only</u> of the guard interval requirements;
- for a network with an inter-transmitter distance in the range 60 to 90 km (typical of many existing analogue television networks in the EBA) a guard interval in the range 200 to 300 µsec is required[1];

[1] Some studies have suggested that a guard interval as long as 500 µsec might be advantageous in the case of a very large area network and a digital television system with a C/N requirement of about 26dB. However, such a case may be better dealt with by means of a combination of a shorter guard interval and the use of different frequencies for SFNs in different parts of the area/country. Such a solution would require more spectrum than a single SFN, but would be much less onerous technically.

- for a network with an inter-transmitter distance in the range 30 to 60 km, a guard interval in the range 80 to 200 μsec is required;

- for a network with an inter-transmitter distance in the range 10 to 30 km, a guard interval in the range 30 to 80 μsec is required. The lower value of 30 μsec is proposed as much from consideration of likely reflections near to the reception point as from consideration of delayed signals from other transmitters;

- for any given value of guard interval, coverage will increase as the symbol length increases.

The values quoted above have been derived from studies relevant to reception using a fixed, roof-level receiving antenna and for OFDM systems requiring a C/N value of about 20 dB. For significantly lower C/N values and the same receiving antenna conditions, lower values of guard interval would be required.

Similar studies for reception using a non-directional receiving antenna (and thus more appropriate for portable receivers) have demonstrated that for a given C/N value, the guard interval requirements are longer than for fixed antenna reception. The values quoted above would remain valid for OFDM systems requiring a C/N value of about 8 dB.

11.4.2 Protection ratios

The protection ratios depend on the usable data rate to be transmitted (in the range 6 to 30 Mbit/s for the systems under consideration). A particular data rate may not have a fixed protection ratio but may vary depending on the coding system. However, it is convenient to have nominal protection ratios for the various data rates and figures of 8, 14, 20 and 26dB have generally been used. With the higher protection ratios, the signals from other transmitters in the SFN can become significant sources of interference, depending on the time delay in the arrival of their signals (this is known as self-interference).

12. IMPLEMENTATION STRATEGIES

12.1. Introduction

It is to be expected that there will be differences in the detailed terrestrial digital television implementation strategies adapted by different countries in the European Broadcasting Area (EBA). There are, after all, differences in the state of development of the analogue terrestrial networks, of the cable networks and of the use made of satellite based television services. In addition, there are differences in the political climates: how urgently politicians see the need for change in the broadcasting scene.

In spite of all of these differences, it seems that there are some common threads in the ways in which terrestrial digital television may be introduced, how it may develop and what its longer term uses may be. However, it has to be accepted that consideration of the long term situation is rather speculative as there are so many variables involved. This chapter attempts to provide a general overview rather than concentrating on the detail in individual countries. In this overview, a distinction is made between short to medium term scenarios (indicated as S1, S2 …) and long term scenarios (indicated as L1, L2 …).

12.2. What can be done now in the EBA?

Introducing digital terrestrial television in the immediate future (for example in the next five years) has a main constraint to start with: protection of the existing analogue services.

Countries in the EBA can be considered in two broad categories:

<u>Category 1</u>

Those countries which have access to unused assignments for television stations, or even networks, (at relatively high effective radiated power) which have been fully co-ordinated and are thus included in the updated Stockholm Plan. Countries which can obtain access to, for example, channels above 60 (where there have been many restrictions due to the presence of military tactical radio links) may also be considered to be in category 1;

<u>Category 2</u>

Those countries which do not have access to unused (relatively high power) television station assignments.

This separation is convenient because different implementation strategies are possible in the two cases. However, even countries in Category 1 will probably not have access to sufficient spectrum to satisfy all of their requirements and will thus come into Category 2 for some requirements.

12.2.1 Scenario S1: using existing or planned channel assignments

12.2.1.1 Assumptions

The first scenario (S1) is possible for those countries which have available unused or planned channel assignments (Category 1). Such countries are in a fortunate position with regard to the implementation of terrestrial digital television. In particular, if a complete network is available, this should provide spectrum capacity for at least one digital network.

There is one note of caution. It is commonly assumed that the interference impact of a digital service from a given station will be less than that of an analogue service from the same station, due account being taken of any difference in effective radiated power (e.r.p.) between the digital and analogue services. This is not necessarily true, in particular where precision offset has been employed in the planning of the analogue network or where digital services being planned require a high C/N ratio. It is essential that the relevant protection ratios and e.r.p. values for the digital and analogue services are considered on a case-by-case basis to ensure that an existing assignment can, in fact, be used to achieve the digital service required.

12.2.2 Scenario S2: using new channel assignments

12.2.2.1 General assumptions

Scenario (S2) applies to category 2 countries without free assignments and to category 1 countries having already used their free assignments for their first digital networks. It may be subdivided into two variants as described below.

The main features of Scenario S2 are:

<u>Protection of existing or planned analogue services</u>

Any new station, digital or analogue, causes some increase of interference to existing viewers and thus causes a coverage reduction. The constraints on the power of digital stations will be set by considerations of how much additional interference to analogue viewers is tolerable and for what percentage of the time. The size of the digital coverage areas will be determined by a combination of factors:

- the radiated power of the digital transmitter;
- the amount of interference from analogue or other digital transmitters;
- the required C/N ratio for the digital service.

<u>Fixed roof top reception and limited portable reception</u>

Most studies have shown that, at least during the transition period when analogue and digital services will have to coexist, the coverages achievable for portable reception are likely to be rather limited. However, useful portable coverage could be achieved if a transmitter is close to a population centre.

The implementation scenario where existing transmitter sites are used, may therefore take reception with fixed roof top antenna as a basis. Portable reception is subject to very variable conditions compared to fixed roof top reception and depends on receiving height, building penetration loss and local signal variations. Depending on the situation (indoor or outdoor, high or moderate location probability, bit-rate requirement), portable reception may be possible in up to a large proportion of the area for roof top reception.

It must be noted that in countries with high cable and satellite penetration, portable reception may be seen as the primary target for future terrestrial services;

Acceptance of some frequency changes or closures

It is clear that it will not be possible, in general, to change the channels used by the analogue transmissions because of the widespread disturbance to analogue reception which could be caused. However, some of the e.r.p. restrictions on digital stations may be caused by the need to protect low power (and low coverage) analogue stations. In such cases, analogue channel changes may be implementable and this could make a significant improvement to the digital coverage achievable. In this context, it has to be remembered that there are some 50,000 operating stations with less than 100 watts e.r.p. in the EBA in addition to the 30,000 stations above 100 watts (the numbers of stations will be subject to revision as more information becomes available).

12.2.2.2 Scenario S2a: using existing transmitter sites

12.2.2.2.1 Specific assumptions

Most homes already have a domestic receiving antenna which is both frequency selective and oriented with a particular direction and polarisation. In order to maximise the commercial attraction of digital transmissions, it is desirable that they should be easily receivable and this means that an existing receiving antenna system should also be usable to receive the digital services. The added cost of installing a new antenna system represents a significant disadvantage for most viewers - especially if there is no additional programme to be received, that is, where the digital service carries the same programme material as an existing analogue service.

In addition to the same transmitter sites, for maximum viewer and broadcaster convenience it is desirable that, where practical, the channels used for new digital services should be close to those used for existing analogue services and that the same antenna and polarisation should be used.

Generalisations with regard to choice of polarisation are not possible, but the use of the same polarisation for the digital and analogue services would at least mean that existing domestic receiving antennas could be used without change for the digital services. Because the services come from the same site and because the digital service power would be lower than that of the analogue service (for the reasons given earlier), there would be little risk of causing adjacent channel interference to the existing analogue service viewers.

It must be noted that many of the technical aspects related to the use of adjacent channel transmissions from the same site still need to be investigated. In addition, if a country wishes to prepare a long term future with SFN, the choice of adjacent channels may be incompatible with the SFN channel.

12.2.2.3 Prepare a long term future, Single Frequency Networks

SFNs offer the major advantage of requiring few channels to cover large areas. Indeed, in theory, only a single channel may be needed for a complete national network. Equally, regional SFNs may be possible in many countries preferring such coverages.

The use of SFNs, improves portable reception because of space diversity provided.

The SFN technique and its implications are discussed in chapter 6. The following discussion is limited to implementation possibilities in the short term, but the results of some SFN studies may be found in chapter 14.

One option which could be considered attractive by a country with one or more unused assignments available would be to re-plan these on a single frequency network basis. It is probable that such re-planning would not be possible nation-wide, because of interference to neighbouring countries, but it may be possible in the case of relatively isolated countries (those with few neighbours), or where two neighbouring countries both have unused networks and can co-ordinate channel changes with one another (and with any other potentially affected neighbours).

12.2.2.3 Scenario S2b: adding new transmitter sites

12.2.2.3.1 Assumptions

Scenario S2b is in fact a variation of scenario S2a. It is mainly based on the same assumptions for most areas with the addition of new low power stations in those areas where the protection of existing analogue services prevents enough coverage with digital signal from existing sites.

It covers two kinds of additional networks.

12.2.3.2 Mini SFNs

In principle, the idea is that an existing main station and many (perhaps all) of its relay stations (possibly with site changes) would share the same channel. This is an attractive concept in terms of channel economy but there is the question of how programmes to be re-transmitted would be sent to the relay station sties. At present, this is usually by direct reception of the signals from the main station followed by some form of frequency change. If there is no frequency change, it will not be easy to achieve the required output powers from the relay stations while maintaining equipment stability. To provide alternative programme feed arrangements may be expensive. In addition, there are likely to be viewers of the existing analogue transmissions from the main station who are situated close to the relay station sites. Such viewers are likely to experience interference from the digital transmissions from the relay station if these use channels adjacent to those of the analogue services. Finally, the receiving antennas used by the viewers of the analogue services from the relay stations are unlikely to be suitable for reception of the new digital services because of channel differences.

12.2.2.3.3 Dense networks

It is also possible to consider various forms of dense network with all of the transmitters using the same channel but with all transmitters having a lower e.r.p. than that required for a single transmitter serving the same area. In effect, this is one type of mini SFN. Such networks are likely to be more expensive to install than conventional networks because of the need for additional transmitter sites, but they can have the advantage of reducing the impact of co-channel interference from the digital network and thus the coverage areas may be increased in size. However, there is a significantly increased risk of causing interference to existing analogue viewers in the case that a channel adjacent to that of an analogue transmission is used for the digital service. This is simply because most of the transmitters in the digital mini SFN will not be co-sited with the analogue transmitters and this will lead to high level digital signals in areas where the analogue signal is relatively weaker.

Dense network configurations should be possible in some circumstances but they need careful study on a case-by-case basis to ensure that major interference to existing viewers is not caused.

12.3. What could be done in the long term?

Terrestrial digital television introduction requires not only good perspectives in the near future but needs also to be examined from the long term strategy point of view (typically 15 to 20 years from now and possibly even longer).

Scenarios L1 and L2 consider two different maximisation strategies, either maximise the amount of coverage or maximise the number of programmes. Compromises between these two extremes are not considered here. Scenario L3 is put in only to provide further thought.

12.3.1 Scenario L1: maximising size of coverage areas

Scenario L1 is based on Single Frequency Networks.

<u>Wide coverages</u>

As already stated, SFNs offer the major advantage of requiring few channels to cover large areas. Indeed, in theory, only a single channel may be needed for a complete national network. MFN planning would require several channels.

With an SFN a national coverage can be achieved on the same channel. As all countries will claim their equitable share of the spectrum not the whole band can be used. Experience in planning SFNs in DAB have shown that, at least in Western Europe, one fifth of the band is available for national coverage. Of course, channels from neighbouring countries can be re-used at a certain distance from the border, the distance being chosen sufficiently large that interference to the services in the neighbouring country is not caused.

For band IV/V, channels 21 to 60, there would be 8 channels available in each country for national coverage. In a digital mode with 4 programmes per channel this means 32 programmes. Re-use of other channels on a regional basis adds multiple of 32 programmes. Depending on the location viewers may have one hundred or at certain places even more programmes.

Therefore, even if some part of the UHF spectrum were to be made available to other services, terrestrial broadcasting has good perspective of capacity in the long-term;

Portable reception

As an alternative to large number of programmes, one can prefer portable reception over the wide area, the maximum bit rate in a channel being used with robustness instead of multiplying the number of programmes;

Analogue networks closure

In most cases, finding a clear channel all over a wide area needs the closure of existing analogue stations working on this channel. Therefore, scenario L1 is a straight forward scenario which implies the end of analogue transmissions at a given time and therefore needs a strong will and a good management of the transition period (see § 12.4).

12.3.2 Scenario L2: maximising number of programmes in limited areas

Scenario L2 applies when wide coverages, as in scenario L1, are not the main objective. Then, more possibilities become available. In particular, it may be reasonable to ask if full national coverage is a requirement for terrestrial digital television in the presence of alternative delivery media such as cable and satellite.

Therefore, one may not try to cover 100% of an area but rather urban areas which may limit investment costs. Elsewhere, people would receive the programme from satellite or by any other means.

The aim could then be to maximise the number of programmes available, especially for portable reception.

SFNs with wide areas (Scenario L1) require sharing of the available channels between neighbouring service areas, thus dividing the total possibilities in the available frequency range, as indicated above.

In scenario L2, concentrated over limited areas, possible interferences between separated service areas are of less importance. All channels can be used in these limited areas.

For the band IV/V channels 21 to 60 this means that 40 channels are available for local coverage. In a digital mode with 4 programmes per channel this means 160 programmes.

Therefore, even if some part of the UHF spectrum were to be made available to other services, terrestrial broadcasting has good perspective of capacity in the long-term.

12.3.4 Scenario L3: No terrestrial broadcasting

In this scenario, terrestrial digital television services will not start and the existing analogue services will eventually be phased out. Programmes are only delivered by satellite or cable.

12.4. The way from now to then

Between the short term start of digital terrestrial broadcasting and the long term situation, one has to manage a transition period (except in scenario L3). During that period, the constraints on digital transmission should decrease and the networks should be modified as appropriate, with frequency changes and site modifications if necessary.

12.4.1 Decrease protection of existing analogue services

The protection of the existing analogue transmission is controlled through three major parameters:

- Level of impairment of the analogue service due to the digital transmission;

  The level of interference is measured through the increase of "usable field strength". For example, an increase of 3 dB corresponds to an impairment of half a grade on the ITU-R quality scale;

- Percentage of time during which analogue transmission is protected, usually 99%;

- Percentage of locations where the analogue reception is protected in its service area, up to 90% of locations;

  By modifying progressively the above parameters, the implementation possibilities of digital terrestrial television may be increased. This could be measured, as a percentage increase of the covered population.

12.4.2 Disregard some analogue transmitters

As shown in some studies the digital implementation possibilities vary very much according to the set of analogue transmitters to be protected.

12.4.3 Automatic frequency changes

Some transition scenarios will certainly need some frequency adjustments of digital transmitters. This would be the case for a transmitter starting in an MFN and going in the long term towards integration in an SFN at a different frequency.

The technical specification of the terrestrial digital system should include this possibility in a transparent way for receivers.

Nevertheless, this may be difficult in cases where the receiving antenna is frequency selective.

13. PRACTICAL CONSIDERATIONS

13.1 General

This chapter is intended to act as collection point for a set of elements related to practical implementation considerations. Some of the practical elements have been incorporated in other chapters in those cases where this was directly relevant or where there were major issues involved. Examples of the latter would be the case of the spectrum masks, or re-use of existing transmitting antennas.

13.2 Digital transmitter linearity considerations

The required out-of-channel spectrum mask (see § 8.2) is directly related to the transmitter linearity and to the necessary filtering at the high power output of transmitters. Adjacent channel operation will be simplified for the case of a more linear transmitter than for the case of a less linear transmitter. This remains true even if the less linear transmitter is equipped with a better filter to achieve the same spectrum shape in the transition region because additional peaks arise in the out-of-channel range as the result of intermodulation caused by OFDM clipping within the channel.

13.3 Measurement of adjacent channel protection ratios

When measuring adjacent channel protection ratios for the case of interference from a digital television service, a high linearity source and amplifier should be used for the reasons given in § 13.2.

13.4 Measurement of protection ratios for analogue television

When measuring the interference from digital television into analogue television, the subjective comparison method (to be found in the Annex to ITU-R Rec. BT.655) should be used.

13.5 Measurement of the statistic of received signals

In the definition of a receiving location in Chapter 4, it is stated that the antenna can be moved “within a distance of 0.5 m”. This reflects the fact that during the installation of a fixed antenna it is easy to move the antenna such a distance, in order to optimise reception over a set of channels.

This concept needs to be taken into account when making signal level measurements for the purpose of establishing the standard deviation of digital television signals.

The purpose is to characterise the field strength distribution over a small area (generally 100 m by 100 m) by calculating the mean value and the standard deviation.

For fixed reception, two different ways of making these measurements can be identified:

A) Small movement of receiving antenna

Measurements are carried out at each fixed location at a height of nominally 10 metres above ground level. The maximum field strength can be found by changing the height of the antenna from 10 m to 9 m or by moving the antenna horizontally up to 1 m. The value to be retained for this location is the maximum measured. Numerous measurements (from 10 to 100) are needed in the small area considered in order to get good precision for the mean and the standard deviation of the field strength distributed related to this area.

B) Large movement of receiving antenna

Where the local environment is not cluttered, measurements can be made at very short regular horizontal intervals over a long distance with an antenna fixed at 10 m above ground level. "Long distance" should be understood here as being of the order of 1 km.

In this case, it is supposed that there is a significant number of measurements every metre and that these measurements are generally stored in a computer system. The required statistics are obtained in a two step process.

In a first step the values obtained will be filtered by calculating the moving average (or a moving quasi-maximum) for each metre of the measuring distance. While the moving average is a better-known process, a moving quasi-maximum is probably more closely related to the antenna installation process where it is to be expected that a search will be made for the "best" location within a small volume of space. The quasi-maximum could be represented by finding the field strength exceeded at 20% of the individual measurement values within each metre.

In a second step, the set of values obtained in the first step are used to calculate the mean values and the standard deviations. To get accurate statistics, it is necessary that a great number of values are used for example by making long distance runs or by adding the results of multiple "short" distance runs.

Because reception of digital signals exhibits a rapid failure characteristic, it is necessary to be especially careful about the way in which location statistics are derived. It is to be expected that there could be some variation of these statistics in different receiving environments and it is considered to be especially important that measurements should be made for a wide variety of such environments and that comparisons between these sets of measurements be carried out.

13.6 SFN Gap-fillers

13.6.1 Introduction

Gap-fillers have been an important part of most analogue television networks for a long time. In most cases a gap-filler has been established because the main transmitter provided insufficient field strength in a (populated) local area. There are, however, also many cases where gap-fillers have been built because the technical quality of the signal from the main transmitter was not satisfactory because of reflections from buildings or the terrain itself.

The latter case is not expected to play any important role with respect to DVB-T, because of the ability of the system to use the energy in such delayed signals in a constructive way. There will, however, still be some local areas which can not be served properly from a main transmitter and consequently the need for gap-fillers can be expected to persist.

Gap-fillers for analogue television normally require a separate channel for the transmissions in order to avoid interference with the signal from the parent transmitter in the local area to be covered, except for a small number of cases where the terrain provides enough shielding to allow for an active deflector. The need to convert the received signal to a different channel for transmission implies that a channel has to be found which is not always an easy task.

DVB-T (and T-DAB) offers the possibility to operate transmitters in an SFN covering the same area, provided that they radiate the same multiplex. This, of course, also applies to gap-fillers and thus avoids the need to find a new channel.

13.6.2 SFN gap-filler concept

The simplest version of an SFN repeater is an amplifier with its input connected to a receiving antenna and the output to a transmitting antenna. This implies an obvious risk for self-oscillation if the gain of the amplifier is higher than the attenuation of the circuit between output and input which is dominated by the attenuation (isolation) between the two antenna systems as illustrated in Figure 1 below.

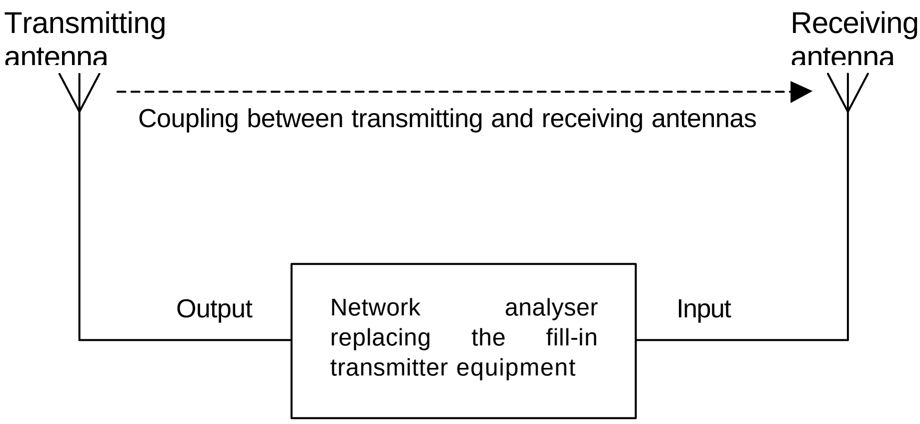


Figure 1: Measurement of isolation between antenna systems

In order to prevent self-oscillation the gain of the fill-in transmitting equipment must be lower than the isolation measured. This difference is here called the *safety-margin* and is measured in dB. It is clear that if a high safety-margin is chosen the radiated power will be lower than if a low safety-margin were chosen. The isolation between the antenna systems may not be constant over time as it can be expected to vary with the weather conditions. A reasonable safety-margin could be 10 dB.

Example calculation:

Measured:	Isolation between antennas: 75 dB
Measured:	Transmitting antenna cable loss: 2 dB
Measured:	Transmitting antenna gain: 10 dB
Assumed:	Safety margin: 10 dB
Calculated:	Max. Gain of equipment: (75 – 10) dB = 65 dB
Measured:	Input voltage to receiver: 60 dBμV = –77 dBW (in 50 Ω)
Calculated:	Max. Output power from equipment: (–77+65) dBW=–12 dBW
Calculated:	Max. E.r.p.: (–12 –2 + 10) dBW = –4 dBW

13.6.3 Measured values of isolation

In order to find representative values for the isolation between the transmitting and receiving antenna systems the members of the EBU Project Group B/MDT were invited to provide results from measurements on some of their existing (analogue) fill-in stations. Results were received from Austria, Denmark, Portugal, Sweden and the United Kingdom and are listed in Table 1 below.

Receiving polarisation	Transmitting polarisation	Distance between antenna systems	Measured frequency range	Minimum isolation	Maximum isolation
Horizontal	Horizontal	5 m	174 – 182 MHz	59 dB	70 dB
Horizontal	Horizontal	17 m	195 – 203 MHz	57 dB	68 dB
Horizontal	Horizontal	8.5 m	202 – 210 MHz	58 dB	64 dB
Horizontal	Horizontal	10.5 m	470 – 478 MHz	73 dB	78 dB
Horizontal	Horizontal	20.5 m	614 – 622 MHz	70 dB	72 dB
Vertical	Vertical	3 m	630 – 638 MHz	81 dB	89 dB
Horizontal	Horizontal	22 m	654 – 662 MHz	79 dB	81 dB
Horizontal	Horizontal	13.5 m	766 – 774 MHz	66 dB	70 dB
Horizontal	Vertical		170 – 220 MHz	60 dB	69 dB
Horizontal	Horizontal		170 – 220 MHz	85 dB	89 dB
Horizontal	Vertical	5.5 m	170 – 220 MHz	56 dB	65 dB
Horizontal	Vertical	5 m	170 – 220 MHz	52 dB	60 dB
Horizontal	Vertical	32 m	170 – 220 MHz	69 dB	73 dB
Horizontal	Circular		170 – 220 MHz	65 dB	83 dB
Horizontal	Circular		170 – 220 MHz	66 dB	75 dB
Horizontal	Vertical		170 – 220 MHz	55 dB	68 dB
Horizontal	Vertical		170 – 220 MHz	77 dB	84 dB
Horizontal	Vertical		170 – 220 MHz	76 dB	87 dB
Horizontal	Vertical		170 – 220 MHz	50 dB	60 dB
Horizontal	Vertical	43 m	470 – 800 MHz	81 dB	85 dB
Horizontal	Vertical	3 m	470 – 800 MHz	70 dB	75 dB
Horizontal	Vertical	4 m	510 – 520 MHz	73 dB	74 dB
Horizontal	Vertical	76 m	470 – 850 MHz	85 dB	95 dB
Horizontal	Vertical	86 m	470 – 800 MHz	80 dB	86 dB
Horizontal	Vertical	93 m	470 – 800 MHz	83 dB	86 dB
Horizontal	Horizontal	60 m [1])	704 – 724 MHz	>105 dB	
Horizontal	Vertical	18.3 m [2])	807.25 MHz	97 dB	
Horizontal	Vertical	18.3 m [3])	807.25 MHz	101 dB	
Horizontal	Horizontal		174 – 230 MHz	80 dB	83 dB
Horizontal	Horizontal		470 – 850 MHz	65 dB	72 dB
Horizontal	Horizontal		470 – 850 MHz	80 dB	83 dB
Horizontal	Horizontal		470 – 850 MHz	58 dB	65 dB
Horizontal	Horizontal		470 – 862 MHz	62 dB [4])	85 dB
Horizontal	Vertical	70 m	502 – 510 MHz	95 dB	101 dB
Horizontal	Vertical	70 m	758 – 766 MHz	100 dB	110 dB
Horizontal	Vertical	70 m	846 – 854 MHz	104 dB	110 dB

[1]) The two antennas are mounted on different parts of a building having no direct view to each other
[2]) Both receiving and transmitting antennas mounted on the same mast
[3]) Receiving and transmitting antennas mounted on two separate masts 18.3 m from each other
[2 + 3]) Both antennas are directional and pointing in bearings separated by 80 degrees
[4]) Minimum isolation may be masked by signals received from other transmitters and could be as high as 80 dB

Table 1: Isolation between transmitting and receiving antenna systems at fill-in stations

13.6.4 Overall considerations

The attenuation between the output and the input of the gap-filler transmitter equipment is determined by the following elements:

- cable loss between transmitter output and transmitting antenna;
- cable loss between the receiving antenna and the receiver input;
- the location of the two antenna systems relative to each other.

From the results listed in Table 1 it seems that there is no simple relation between the relative polarisations or gains of the antenna systems and the isolation achieved. It seems that there is, so far, no evidence that an increased gain of the transmitting or receiving antennas causes a similar and unambiguous change of the isolation. It thus remains necessary to carry out on-site tests to determine suitable antenna mounting arrangements for individual installations.

14. INTERACTION WITH OTHER SERVICES

14.1 General

Broadcasting does not have exclusive access to the frequency bands allocated to the broadcasting service. A number of sharing situations exist and these vary from one country to another, both in terms of the “other service” involved and its status in Radio Regulatory terms. Indeed, in some cases, the status may be in the process of change, for example from “permitted” to “primary”. Neither the status nor the right to protection are of direct concern here. However, it is clear that methods for calculating any potential interference either from or to the broadcasting service are required. This calculation process is complicated by the fact that it may be necessary to consider either assignments or allotments as the basis for digital television planning. This is also a difficulty which must be dealt with in the planning of television services (in other words, the interaction between television services) with no consideration of interference to or from other services.

14.2 Other service stations

Regardless of whether planning is done on the basis of digital television assignments or allotments, it is essential to have a clear definition of the other service requirements, in terms of their susceptibility to interference and their protection needs and also in terms of their potential to cause interference. In the case of a receive-only service, such as Radio Astronomy, the potential for it to cause interference to television may be regarded as zero.

14.2.1 Protection needs of other services

In addition to obvious elements:

- centre frequency;
- signal level to be protected;
- protection ratio as a function of frequency separation between other service and digital television centre frequencies;
- percentage time for which protection is required;
- other service receiving antenna orientation and discrimination (if relevant),

it is also necessary to determine the area or the locations for which the protection is required. The latter may conveniently be done by specifying a set of test point locations (as longitude, latitude and height above ground level) which represent either:

- the boundary of the area within which protection is required; or,
- the actual locations at which a receiving installation is, or may be, installed.

In order to avoid some ambiguities which have created difficulties in the past, special care needs to be taken when obtaining information about other service receiving antenna characteristics:

- in the case of mobile reception, is it realistic to assume that there is neither directivity nor polarisation discrimination and, if not, what values could be applied?

- in the case of fixed reception, in what direction is the receiving antenna oriented and what is its discrimination as a function of relative bearing for the cases of co- and cross-polarisation?

14.2.2 Interference potential of other services

Some elements which are needed to determine the interference potential of an other service transmission are obvious:

- centre frequency;

- protection ratio as a function of frequency separation between other service and digital television centre frequencies;

- radiated power as a function of azimuth angle and polarization;

- transmitting antenna location (longitude, latitude and height).

Other elements are less obvious, for example, in the case of rotating radar installations, is it reasonable to take account of the non-continuous nature of any interference? If so, it is necessary to know the rotation rate of the radar antenna. Can secondary effects, for example, signal scattering from aircraft, be neglected?

While it is reasonably easy to deal with transmissions from aircraft on the basis of test points representing potential transmitting locations, this is not directly applicable to satellite based transmissions and perhaps the latter need to be treated as a uniform, potentially interfering signal over the whole area. If so, what needs to be done with regard to location statistics? It can be argued that the values applicable to terrestrial reception should be applied because similar signal reflection and loss effects will occur (at least for low elevation angles) as for terrestrial paths, but it is not yet clear that this argument would be valid. However, it would seem to be valid to base propagation calculations on the free-space criterion and to assume that potential interference is continuous if in line-of-sight.

14.3 Digital television stations

14.3.1 Protection needs

Regardless of whether allotments or assignments are being considered, it will be necessary to have a definition of the area within which the television service is required to be protected. This can conveniently be done by means of a set of test points defined in terms of longitude, latitude and height (equal to 10 m for fixed antenna reception, but lower heights are relevant for portable reception).

In general, it is to be expected that these test points may be used to define a closed boundary to the area within which protection is needed. However, there may also be a need to add other test points for specific reception locations, for example re-broadcasting sites. It is desirable that such test points should be identified as being separate from those which can be assumed to constitute a boundary and it may also be necessary to define specific protection criteria for such sites.

14.3.2 Interference potential of assignments

In this case, the specific transmitting locations are known and may be dealt with as a set of identifiable elements:

- centre frequency (of television channel);
- radiated power as a function of azimuth angle and polarisation;
- transmitting antenna location (longitude, latitude and height).

14.3.3 Interference potential of allotments

In this case, it seems necessary to use some form of reference network (for SFNs) or nominal transmitting characteristics (for non SFNs). The interference potential may be specified as a distance versus field strength curve (or family of curves) or by means of an agreed calculation process. In addition, the centre frequency of the television channel is needed.

14.4 Other services in the broadcasting bands used for television

Table 1 in Appendix 9.3 indicates the other services in each of the bands used for television broadcasting in a number of countries in and around the European Broadcasting Area. A summary of the services in each of these bands is given below. More details of each of these services and their protection needs and interference potential are given in the subsequent sub-sections, where information is currently available. A full list of other services in Europe will be produced by the CEPT on the basis of information supplied by administrations and it will be necessary to obtain similar information for non-CEPT countries.

The following list may not be exhaustive. The country codes indicate where the services are located, but other countries may have restrictions imposed due to these services. Before calculation methods can be proposed the compatibility between these services and digital television, significantly more information will be needed.

Band I

Services include:	Land mobile	AUT, BEL, D, DNK, EST, HOL
	Radiometers	EST
	SAB/SAP	F
	Radio amateur	F, FIN
	Windprofiler radars	F
	Fixed services	HOL

Band III

Services include:	[T-DAB]	AUT, BEL, D, DNK, G, HOL, IRL, NOR, POR, ROU, S, SUI
	Land mobile	DNK, E, F, HOL, MCO
	Radiotelephone	F
	Remote control	F
	SAB/SAP	HOL
	Fixed services	HOL

Band IV-V

Services include:	SAB/SAP	AUT,EST,G, HOL, NOR
	Radio astronomy	BEL, G, HOL, D
	Land mobile	BEL, HOL, RUS
	Mobile	D, DNK, E, F, FIN, POL
	Aeronautical radionavigation	EST, G, HNG, RUS
	Military	G
	Fixed services	HOL, NOR
	Broadcast satellite	RUS

The above list indicates the current or planned usage of the bands. In addition wind profiler radars and Mobile Satellite Service (MSS) uses have been proposed in Band IV-V, at least by some countries.

14.4.1 Aeronautical radionavigation (Radar)

This service operates in channel 36 in the UK. There are about ten radars in operation on various centre frequencies in the band 590-598 MHz.

Protection needs

A protection ratio curve and other information for analogue television are given in Annex III to the Technical Data for the 1961 Stockholm Conference, but new information will be needed to deal with DVB-T.

For DVB-T the following planning assumption may be used:

The maximum interfering field strength at the radar receiver can be taken as -12 dBµV/m over the range ±600 kHz from the receiver centre frequency. (These values represent a reduction in the maximum interfering field strength value and a reduction in the bandwidth compared with the Stockholm 1961 Technical Data).

Interference Potential

In the UK, the radars operate with the following characteristics:

Peak transmitter power:	60-500 kW
Antenna gain:	31 dB
e.r.p.:	78 to 88 dBW PXi
Emission bandwidth:	±600 kHz at approx. 35 dB down (triangular shaped)

14.4.2 Radio astronomy

The frequency band 608-614 MHz (channel 38) is used for radio astronomy in Belgium, Germany, United Kingdom and the Netherlands. Applications include single telescope measurements and Very Long Baseline Interferometry (VLBI) measurements.

Protection needs

Protection criteria for these measurements are given in ITU-R Rec. RA.769. The harmful interference levels are as follows:

Single telescope measurements (Table 1 in RA 769):

Spectral power flux-density:	- 253 dB(W/m^2/Hz)
Input power:	- 202 dBW (this value relates to a defined category of receiving installation)

Within the UK, a value of -190 dBW is assumed for the input power.

VLBI (Table 3 in ITU-R RA.769):

Spectral power flux-density:	-211 dB (W/m^2/Hz)
Input power:	-160 dBW (this value relates to a defined category of receiving installation)

Interference potential

As this is a receive-only service, there is no potential for interference to DVB-T.

14.4.3 SAB/SAP

More information is needed.

14.4.4 Land Mobile Service

ITU-R Rec. IS.851 contains information about compatibility between analogue television and the land mobile service. Some of this information may be useful in deriving compatibility criteria for digital television services. It must be noted that military tactical radio services are also usually categorised as land mobile and it may be found that this type of service needs special attention (in one way or another) as it may be very difficult to protect because of its operational usage.

14.4.5 Fixed service

ITU-R Rec. 851 contains information about compatibility between analogue television and the fixed service. Some of this information may be useful in deriving compatibility criteria for digital television services.

14.4.6 Mobile Satellite Service

Some countries have proposed making additional spectrum available on a worldwide basis for non-GSO MSS systems operating below 1 GHz. Studies have been carried out on protection requirements for broadcast services near 216 MHz and in Bands IV and V. The results of these studies suggest that band sharing is unlikely to be possible. At the time of producing the second revision of this document, it seems probable that the proposals for mobile satellite services in the bands used for terrestrial television have been abandoned, primarily because of the sharing difficulties.

14.4.7 Wind profiler radar

Studies have been carried out on locating these systems in frequency bands around 50, 400 and 1000 MHz. Specifically, the range 470-500 MHz has been considered, at least, in a few countries. A decision on the band is expected at the WRC-97. Whilst the compatibility criteria have not yet been fully defined, it is expected that these systems will not be compatible with the current analogue television broadcast services in most countries.

14.5 Technical elements for compatibility calculations

- transmitting/receiving data are needed
- frequency
- bandwidth
- maximum radiated power
- horizontal radiation pattern
- three dimensional radiation pattern in the case of radio-astronomy
- polarisation
- polarisation discrimination
- site co-ordinates and height information
- protection ratio as a function of frequency separation
- minimum signal level to be protected
- time percentage to be protected
- coverage area defined by calculation test points (up to 36)

14.6 Compatibility calculations required

14.6.1 Protection of other services

A calculation should be made for each of the calculation test points used in the definition of the other service. This calculation should take into account:

- the minimum signal level for the other service, being considered;
- the protection ratio for the frequency difference between the other service and the digital television service;
- the signal level from the interfering assignment or allotment;
- other service receiving antenna discrimination (polarisation and directivity), where relevant.

From the above information, the protection margin (at each of its boundary test-points) may be calculated for the other service. These margins may be used to provide guidance during any necessary co-ordination discussions.

Note: The calculation of the interfering signal level is dependent upon the other service being considered. ITU-R Rec. P.370 may be used for terrestrial other services, taking into account the relevant % of time. However, free-space calculations will be needed for aeronautical (or satellite) services if a line-of-sight condition between other service receiver and interfering transmitter exists.

14.6.2 Protection of digital television

A calculation should be made for each of the calculation test points used in the definition of a digital television coverage area. This calculation should take into account:

- the minimum signal level of the digital television service;
- the protection ratio for the frequency difference between the other service and the digital television service;
- the signal level from the other service transmitter;
- the digital television service receiving antenna discrimination (in the case of fixed antenna reception).

From the above information, the protection margin (at each of its boundary test-points) may be calculated for the digital television service. These margins may be used to provide guidance during any necessary co-ordination discussions.