Australian
Broadcasting
Authority

Digital Terrestrial Television Broadcasting Planning Handbook

INCLUDING TECHNICAL AND GENERAL ASSUMPTIONS

Australian Broadcasting Authority
Canberra

March 2005

ISBN 0 642 27070 8

First published 1999

Revised 2002

Second edition 2005

Published by the Australian Broadcasting Authority
Benjamin Offices
Chan Street
Belconnen ACT 2616

FOREWORD

The *Digital Terrestrial Television Broadcasting Planning Handbook* (*DTTB Planning Handbook*) provides broadcasters and planners with:

- the technical assumptions to which the ABA must have regard when considering whether the transmission of a commercial or national television broadcasting service will achieve the same level of coverage and potential reception quality as is achieved by the transmission of that service in analog mode
- other general technical assumptions to which the ABA will have regard when preparing a digital channel plan under the commercial and national television conversion schemes and
- an explanation of the technical planning processes involved in the planning of new digital television services as well as the conversion of existing analog television services

for the introduction of digital terrestrial television in metropolitan and regional areas of Australia. The *DTTB Planning Handbook* is intended as a companion document to the following publications:

- the *ABA's General Approach to Digital Terrestrial Television Broadcasting Planning*
- terrestrial television digital channel plans (DCPs) for Australia and
- the discussion and explanatory papers accompanying the draft and final DCPs.

Comments on the DTTB Planning Handbook

The Australian Broadcasting Authority (ABA) welcomes feedback on the content or format of its publications.

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1 INTRODUCTION

Schedule 4 to the *Broadcasting Services Act 1992* (‘the Act’) sets out arrangements for the conversion, over time, of the transmission of television broadcasting services from analog mode to digital mode. Under these arrangements, the ABA is required to formulate two schemes for conversion – a commercial television conversion scheme, and a national television conversion scheme. Each scheme is divided into two parts. Part A deals with digital conversion for the metropolitan and regional areas. Part B deals with digital conversion for remote areas.

The ABA formulated the Commercial Television Conversion (CTC) scheme in March 1999. The scheme commenced on 9 June 1999. The ABA formulated the National Television Conversion (NTC) scheme in December 1999. It was approved by the Minister for Communications, Information Technology and the Arts on 2 February 2000, and commenced on that date. Both the commercial and national conversion schemes may be varied from time to time.

Under Part A of both conversion schemes, the ABA must prepare digital channel plans that allot additional channels to broadcasters to enable them to transmit programs in analog and digital modes during a simulcast period. The DCP will determine which channels are to be allotted in each area, the channels assigned to each broadcaster; and the characteristics and technical limitations (if any) applicable to those channels.

In preparing the DCP, one of the ABA’s objectives, as required by Schedule 4 of the Act, is to plan the channel allotments to enable a broadcaster to plan its digital service to achieve the same level of coverage as its analog service as soon as practicable.

1.1 Purpose of this document

The *DTTB Planning Handbook* has been prepared for the purpose of sections 6(1) and 6(2) of the CTC and NTC schemes and deals with digital conversion in metropolitan and regional areas (Part A of the schemes). The document explains:

(a) the technical assumptions to which the ABA must have regard when considering whether the transmission of a commercial or national television broadcasting service in standard definition television (SDTV) digital mode will ‘achieve the same level of coverage and potential reception quality as is achieved by the transmission of that service in analog mode'. The ABA is required under the CTC and NTC Schemes to publish these assumptions[1]

(b) other general technical assumptions to which the ABA will have regard when preparing a DCP under the CTC and NTC conversion schemes and

(c) the technical planning processes involved in planning of new digital television services as well as the conversion of existing analog television services.

Section 2 of this document sets out the principal requirements and technical planning assumptions on which digital terrestrial television planning is based. Section 3 discusses the assumptions and methods used in the development of DCPs (i.e. 'channel planning'), and section 4 provides the planning parameters and requirements for planning of individual services (i.e. 'service planning').

It should be noted that, unlike the ABA's *Technical Planning Guidelines*, the *DTTB Planning Handbook* is not a legislative instrument. It should be further noted that the assumptions set out in this Handbook reflect those used in current planning work. As planning parameters for digital television mature the Handbook will be revised to reflect any necessary changes to planning assumptions or practices.

1.2 Legislative background

Schedule 4 to the Act provides a set of policy objectives to which Part A of the conversion schemes must be directed towards achieving. These objectives include that:

- additional channels for digital transmissions should occupy the same amount of bandwidth as channels used for analog transmissions
- as soon as is practicable after the start of the simulcast period for an area, the transmission of a television broadcasting service in SDTV digital mode in that area should achieve the same level of coverage and potential reception quality as the analog transmission and
- during the simulcast period for an area, the broadcaster should, as far as is practicable, co-locate the transmitter used to transmit the service in digital mode in that area and the transmitter used by the broadcaster to transmit that service in analog mode in that area.

In addition, Schedule 4 to the Act requires that the broadcaster:

- in addition to transmitting a version of the television broadcasting service in SDTV digital mode in the area concerned, transmit another version of the service in high definition television (HDTV) digital mode in that area;[2] and

[1] Section 6(1) of the CTC and NTC Schemes.

[2] This requirement must be met as soon as practicable after the licensee begins to transmit the service in SDTV digital mode in the area concerned but, in any event, within the phase–in period specified in clause 37E (2A) and 37F (2A) of Schedule 4 to the Act.

- meet specified quotas in relation to the extent to which high definition television programs, or specified kinds of high definition programs, are transmitted in HDTV digital mode on the HDTV version of that service in that area.

In preparing DCPs, the ABA must have regard to the policy objectives set out in clauses 6(3) and 19(3) of Schedule 4 to the Act, including the matters mentioned in sections 9 of both the CTC and NTC Schemes (see the *ABA's General Approach to Digital Terrestrial Television Broadcasting Planning*)**.**

1.3 Consultative processes

Once a draft DCP is prepared, the ABA is required, under section 10 of both the CTC and NTC Schemes, to publish a notice stating where the draft DCP can be obtained and inviting comments on the draft within a specified period. The ABA must have regard to any comments it receives.

To assist in the preparation of draft DCPs the ABA consults with broadcasting industry representatives through a body known as the Digital Television Channel Planning Consultative Group (DTCPCG). The DTCPCG is comprised of representatives from the ABA, metropolitan and regional commercial and national broadcasters, as well as a range of other stakeholders including the Australian Communications Authority (ACA), FreeTV Australia, subscription television operators and transmission facility service providers.

Subgroups of the DTCPCG may be convened to develop planning options for DCPs in each area. In determining DCPs, the ABA will have regard to the views and preferences of the DTCPCG, its members and its subgroups.

2 DIGITAL TELEVISION PLANNING PRINCIPLES

The technical planning for digital terrestrial television in metropolitan and regional areas of Australia is based on a number of key requirements and assumptions.

- Planning must accommodate the conversion of existing broadcasting services in analog mode to digital mode over time. It is a requirement of this conversion that broadcasters achieve the same level of coverage in SDTV digital mode as soon as practicable after the commencement of the simulcast period so that viewers who currently receive the service will continue to have access to television services after the end of the simulcast period.
- Broadcasters will be required to transmit a HDTV version of the service in digital mode. This leads to a high data rate requirement, which means planning must be based on a digital broadcasting system and operational mode that can achieve the required data rate.
- Digital planning is based, in part, on the analog planning assumptions regarding the reception environment, including the use of outdoor receive antennas placed 10 m above ground level.[3]
- Digital television is planned for operation within existing allocated broadcasting services bands (i.e. Bands III, IV and V) and in accordance with the current channel arrangement shown at appendix E.
- The ABA must have regard to the need to plan the most efficient use of the spectrum for broadcasting services or other uses, including the need for spectrum to be made available for allocation for the purposes of the transmission of datacasting services under, and in accordance with the conditions of, datacasting licences.

2.1 Same level of coverage

Objectives 6(3)(f) and 19(3)(f) to Schedule 4 to the Act require a digital service provided by an existing analog broadcaster who is converting to digital mode to

[3] In recognition of the fact that many viewers place their antennas at lower heights, an additional margin has been added to the required minimum median field strengths for suburban and urban reception environments. This margin equates to the difference in received field strength at 10 m and 5 m above ground level.

achieve the same level of coverage, in SDTV digital mode, as is achieved by their analog service as soon as practicable after the start of the simulcast period and throughout the remainder of that period. In addition, objectives 6(3)(g) and 19(3)(g) require broadcasters, as far as practicable, to co-locate their digital transmitters with their existing analog transmitters during the simulcast period.

In preparing DCPs, the ABA has proceeded on the basis that the same level of coverage will be achieved by co-locating digital transmitters at the main transmitter sites of the analog service and at some existing translator sites.

However, the legislation recognises that the co-location objective will not always be feasible and the CTC and NTC Schemes make provision for broadcasters to locate their digital transmitters at other approved locations, if the ABA is satisfied that an alternative location is appropriate having regard to the criteria set out in the schemes[4].

A subgroup of the DTCPCG that was convened to address the technical issues of achieving the same level of coverage developed two different approaches to determining the necessary effective radiated power (ERP) level for a digital transmitter operating in the same band as an analog transmitter. These approaches are termed the 'ratio method' and the 'first principles method' and in certain situations give different results. The report of the subgroup can be found in appendix A of this document.

This Handbook adopts the first principles methodology and results for service planning, as this approach can be applied to planning of digital services by both converting analog broadcasters and (future) new digital broadcasters. Service planning parameters and methods, consistent with the first principles approach, can be found in section 4 of this Handbook.

As DCPs are macro level plans that are to be completed before the micro level detail of service planning is undertaken, certain assumptions need to be made concerning the ERP levels of digital services. The assumed ERP levels need to be such that the same level of coverage objective, addressed during the service planning stage, can be achieved. As knowledge of digital television transmission performance is continuing to develop, it is necessary to make conservative assumptions regarding the ERP levels to be used in DCPs and err towards higher power levels. The method for determining the ERP level of digital services in DCPs is set out in section 3.2.

The legislation requires broadcasters to achieve the same level of coverage in SDTV digital mode as is achieved by their analog service. However, the ABA recognises that it may be desirable to go beyond this minimum objective in cases where one analog service in an area has a smaller coverage area than other analog services. This will ensure that consumers can receive all digital services operating in their area. For this reason, the maximum ERP levels catered for in the DCP attempt to provide all broadcasters, irrespective of operating band, the opportunity to achieve equal coverage in the same area. Where, however, the ERP of a particular channel is restricted to prevent interference (for example to an analog service) the ABA will not

4 Section 30 of the CTC Scheme and section 29 of the NTC Scheme.

restrict the ERP of the other digital services, as to do so would be contrary to the legislative objective to achieve the same coverage as soon as practicable.

2.2 Standards and operating modes

Planning for DTTB is based on the Australian Standard AS4599-1999, *Digital television – Terrestrial broadcasting – Characteristics of digital terrestrial television transmissions.* This standard is based on the European standard for terrestrial Digital Video Broadcasting[5] (DVB-T), but includes a number of variations specific to Australia.

2.2.1 Modulation schemes

There is a legislative requirement that television broadcasters must transmit a certain minimum amount of high definition television (HDTV) programming. To meet the service objectives, a bit rate of approximately 20 Mbit/s has been assumed for planning. The modulation mode to achieve this data rate leads to a necessary carrier-to-noise ratio (C/N) requirement of 20 dB as explained below.

For the reference modulation defined in table 2.1, the DVB-T system has a theoretical C/N threshold of 16.5 dB in a Gaussian channel. Tests of early receiver prototypes have shown that an implementation margin of 2.5 dB is required, resulting in a 19 dB C/N threshold in a Gaussian channel. For fixed antenna reception, a Ricean channel profile will generally be experienced, resulting in an increase in the theoretical C/N requirement for demodulation of 0.6 dB. For operation through a practical RF transmission system, an additional C/N allowance of 0.4 dB has been made. Combining these figures, for planning purposes, the notional threshold C/N requirement is taken to be 20 dB.

Table 2.1: Reference modulation for planning purposes

Modulation	*Code Rate*	*C/N*	*Guard Interval*	*Carrier Mode*
64-QAM	2/3	20 dB	1/8	8k

DVB-T offers flexibility in the use of transmission mode by supporting a range of modulation schemes, code rates and guard intervals to accommodate different broadcasting requirements. For the purpose of digital channel planning the reference modulation in table 2.1 has been employed. Subject to the same level of coverage requirement, broadcasters have the option of using other modulation schemes to improve DTTB coverage or data capacity as outlined in appendix B.

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5 Standard ETSI EN 300 744, Digital Video Broadcasting; Framing structure, channel coding and modulation for digital terrestrial television.

2.2.2 Carrier mode and guard interval

The DVB-T transmission standard allows for the use of either 1705 carriers (known as ‘2 k’ mode), or 6817 carriers (‘8 k’ mode). Consistent with Australian Standard AS4933.1-2000, *Digital television - Requirements for receivers – Part 1: VHF/UHF DVB-T television broadcasts*, DVB-T receivers are expected to be capable of receiving both 2 k and 8 k modes.

Based on current evidence, it is assumed that the carrier mode does not have an effect on the protection ratios outlined in appendix C. However, it is recognised that the selection of carrier mode will impact on the ability to implement single frequency networks (SFNs). The 2 k mode is suited to small SFNs with limited transmitter separations. The 8 k mode is suitable for SFNs requiring larger transmitter separations. To ensure maximum flexibility in the implementation of SFNs, ABA channel planning is based on 8 k operation.

2.3 Notional receiving system

Digital television planning for Australia is based, in part, on the analog planning assumptions regarding the notional receiving system, including the use of outdoor receive antennas placed 10 m above ground level. The characteristics of the receiver, referred throughout the Handbook as the ‘notional receiving system’, are specified in appendix D.

2.4 Frequency bands employed for digital television planning

Analog television services in Australia operate on VHF channels 0 to 12 and UHF channels 28 to 69. However, not all of these channels will be used for digital television as the following table illustrates:

Table 2.2: Television channels suitable for digital television

VHF Band I	Channels 0, 1 and 2	Not suitable for digital broadcasting transmissions as these channels are prone to interference from electrical noise.
VHF Band II	Channels 3, 4 and 5	Internationally used for FM radio and thus no new television services in Australia will be planned using these channels.
VHF Band III	Channels 5A - 12	Suitable for digital transmissions, although no new television services in Australia will be planned using channel 5A as it has been allocated internationally to other services.
UHF Band IV	Cannels 28 - 35	Suitable for digital transmissions.
UHF Band V	Channels 36 - 69	Suitable for digital transmissions.

Note: The ACA has indicated an interest in the clearance of broadcasting services from channels 68 and 69 to accommodate trunked land mobile services.

The radio frequency (RF) channel arrangement for television services in the broadcasting services bands is reproduced in appendix E.

2.5 Efficient use of the spectrum

Under section 9(2) of the CTC Scheme the ABA must have regard to the need to plan the most efficient use of the spectrum for broadcasting services or other uses, including the need for spectrum to be made available for allocation for the purposes of the transmission of datacasting services under, and in accordance with the conditions of, datacasting licences. Section 9(2)(a) of the NTC Scheme also provides that the ABA must have regard to the most efficient use of the spectrum.

Digital television provides for more efficient use of the spectrum than analog television as adjacent channels can be used in the same area and the re-use distance between co-channel services is less than for analog services with the same coverage. The use of SFN networks with multiple transmitters operating on the same frequency within the same region is another way of improving the spectrum productivity of television services.

In developing DCPs the ABA is constrained by the need to avoid interference to existing analog services as well as other operating or proposed digital services. This may limit the opportunity to take advantage of the spectrum efficient properties of digital television, such as SFNs. Additionally, the requirement to plan the spectrum efficiently needs to be balanced against other policy objectives such as minimising costs and disruption for viewers and broadcasters, and achieving the same coverage objective.

2.6 Single frequency networks (SFN)

The broadcaster or its agent is responsible for detailed planning and implementation of the digital television service. Where an SFN is proposed in a DCP, the ABA will undertake studies to confirm the feasibility of the network based on the reference modulation (see section 2.2.1). However, within the framework of the DCP technical specifications, selection of planning values for parameters such as guard interval, modulation mode, transmitter signal delay and, to some extent, transmitter siting is the responsibility of the broadcaster. The parameter values selected will often entail trade-offs which the broadcaster or its agent is best placed to determine.

References [7], [8] and [11] include information relevant to SFN planning which may assist broadcasters and others involved in the detailed planning and implementation of single frequency networks.

3 CHANNEL PLANNING

The purpose of this section is to describe the technical assumptions used in the development of DCPs for digital terrestrial television broadcasting in metropolitan and regional areas of Australia.

3.1 Planning constraints

In order to plan channel allotments for digital television some assumptions need to be made. Key transmission parameters need to be assumed in advance of the detailed service planning so that interference levels between services can be assessed. The primary objectives in developing DCPs are to:

- avoid or minimise interference and disruption to analog television reception
- identify the channels that can be used for digital services at sufficient ERP levels to achieve the same level of coverage, from the same transmission sites, as the analog services
- plan the most efficient use of the spectrum and
- minimise cost to viewers and broadcasters.

Within this framework, a number of issues need to be considered, including:

- suitability of existing transmission facilities for the transmission of digital television services and
- technical characteristics of the existing population of receive antennas.

3.2 Maximum ERP levels for digital television services

The DCP will specify for each channel allotment a maximum ERP level on which interference calculations have been based. Broadcasters will not necessarily be expected to operate at these levels, and in many cases it may not be desirable for them to do so, as this may create unnecessary interference levels or result in excessive overspill of signal outside their licence area. The ERP level to achieve the required coverage for each service in each area should be determined as a separate process using the first principles approach described in section 4.2.2.

The basis on which the maximum ERP levels in DCPs are derived is explained in section 3.2.1 and 3.2.2. These guidelines may be varied depending on the particular circumstances.

3.2.1 VHF analog television services

In areas where one or more analog VHF Band III service operate, the ERP of the highest power analog VHF Band III service will serve as the reference for the purpose of developing the DCP. The ERP level assumed for digital VHF Band III services will be 6 dB below that of the reference analog service. The ERP level assumed for digital UHF Band IV services will be the same as that of the reference analog service and the ERP level assumed for digital UHF Band V services will be 4 dB above that of the reference service. These ratios of –6 dB, 0 dB and +4 dB equate to the differences between the rural minimum median field strengths for the digital services in their respective bands (i.e. 44, 50 and 54 dBμV/m) and the rural minimum median field strength of the analog VHF Band III service (i.e. 50 dBμV/m).

If the above yields an ERP for digital UHF Band IV or V services that is more than 6 dB below the highest power analog UHF service in the corresponding band, then the ERP will be specified to be 6 dB below that of the Band IV or V analog UHF service. That is, whichever approach yields the higher ERP for UHF services will be adopted.

Where there is no analog service operating in VHF Band III, the ERP of the highest power VHF Band I or II service may be substituted for the reference ERP.

3.2.2 UHF analog television services

If no VHF services exist, the ERP level assumed for the UHF digital services, for the purpose of developing the DCP, will be 6 dB below that of the highest power analog service in the band. The ERP level assumed for digital services in UHF Band V will be 4 dB above that assumed for UHF Band IV and vice versa. The 4 dB difference between UHF Bands IV and V will not be applied where the channels are grouped at frequencies adjacent but either side of the Band IV/Band V frequency boundary.

Note: Power levels for DTTB services are mean levels. For analog services the power level is the root mean square (RMS) power of the vision signal during the line synchronisation interval (often referred to as ‘peak sync’ power).

3.3 Channel planning methodology

Channel allotments in DCPs are determined by assessing the compatibility of the proposed digital service(s) with other operating or proposed services in the same or surrounding regions. For the area under consideration, wanted and unwanted signal levels are evaluated and the wanted signal level 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 served. The method for assessing compatibility is described in the following sections.

3.3.1 Propagation predictions and use of statistical methods

A range of propagation models are available to predict wanted and unwanted field strengths or signal levels. These vary from empirical models, such as those described in Recommendation ITU-R P.1546 and the former recommendation ITU-R P.370, through to diffraction-based models such as Millington, Deygout and Epstein-Peterson. An understanding of the assumptions underlying each model, together with an assessment of the propagation paths over which predictions are to be made, will assist in identifying the most appropriate model(s) for use in calculations.

It should be noted that all propagation models are subject to some degree of uncertainty because of simplifying assumptions in the models and limitations in the accuracy of topographic and other data used in the calculations. Also, importantly in broadcast planning, the characteristics of the propagation channel are generally not well known (for example, the levels of clutter in the vicinity of any one receive location). For these reasons it is usual to employ statistical methods in the prediction and modelling of signal coverage and interference.

3.3.2 Antenna height

Antenna heights are critical parameters in any propagation prediction model. For the purpose of preparing DCPs, the transmit antenna height is assumed to be the same as that of the analog service.

The receive antenna height is assumed to be 10 metres above ground level, consistent with the notional receiving system.

3.3.3 Notional receiving system

The notional receiving system assumed for the purpose of developing DCPs is described in appendix D.

3.3.4 Wanted signal considerations

Where use is made of statistical field strength prediction methods, such as those described in Recommendation ITU-R P.1546, the wanted field strength (E_w) is to be calculated on the basis of 50% location and 50% time availability. Such a field strength is referred to as a median field strength and is represented by the notation $E(50, 50)$.

3.3.5 Unwanted signal considerations

In the case of a wanted digital service, the field strength of the interfering signal (E_i) for the purpose of interference assessment is that exceeded at 50% of locations for more than 1% of the time i.e. $E_i(50, 1)$.

In the case of a wanted analog service, the field strength of the interfering signal (E_i) for the purpose of interference assessment is the greater of:

- the sum of the field strength exceeded at 50% of locations for more than 50% of the time i.e. $E_i(50, 50)$ and the protection ratio for continuous interference and

- the sum of the field strength exceeded at 50% of locations for more than 10% of the time i.e. $E_i(50, 10)$ and the protection ratio for tropospheric interference.

The use of continuous and tropospheric protection ratios in television planning is explained in section 3.3.12.

3.3.6 Location variation

Within a small area, of the order of 100 m by 100 m, there will be a more or less random variation of signal level with location due to local clutter effects (i.e. surrounding buildings, vegetation etc). The statistics of this signal variation are characterised by a log-normal distribution of the received signal levels. For wide band digital signals the standard deviation (σ) of the field strength distribution has been shown to be of the order of 5.5 dB depending, to some extent, on the reception environment. This figure is assumed for fixed outdoor reception.

For the purpose of assessing interference to digital services, the standard deviation of unwanted analog signals, is also assumed to be 5.5 dB.

3.3.7 Location availability

Due to the abrupt failure characteristic of digital systems there is need for greater reliability in the reception of digital television services. The location availability for analog television has traditionally been set at 50% (the median value). In contrast, planning for digital television is based on location availabilities in the range of 80% to 95% (see section 5.2 of appendix A).

In order to secure reception at greater percentages of locations a higher median field strength is required. This is achieved through the addition of a margin to the minimum median field strength. The margin is known as the location correction figure, and is given by the relationship:

$$C_L = \mu \times \sigma \qquad \text{Equation (1)}$$

where:

μ normal distribution factor, being 0.00 for 50%, 0.84 for 80%, 1.28 for 90% or 1.64 for 95% of locations; and

σ standard deviation, which is taken as 5.5 dB for fixed outdoor reception.

The minimum median field strengths in table 4.1 include a location correction figure to ensure reliable reception of the wanted digital signal.

3.3.8 Nuisance field

The nuisance field describes the quantitative interference effect of a transmitter on the coverage of the wanted transmitter. It is derived from the predicted field strength of the interfering transmitter, the applicable protection ratio and the receive antenna directivity and polarisation discrimination.

The nuisance field is given by the expression:

$$E_n = E_i + PR + L_{cm} + A_d + A_p$$ Equation (2)

where:

E_n nuisance field strength (dBμV/m);

E_i predicted field strength of the interfering transmitter (dBμV/m);

PR applicable protection ratio (dB);

L_{cm} location correction margin (dB);

A_d antenna directivity discrimination (dB) where $A_d \leq 0$; and

A_p antenna polarisation discrimination (dB) where $A_p \leq 0$.

The location correction margin (L_{cm}) in equation (2) represents the additional margin required to take account of the statistical variation between the wanted and interfering signal. If wanted and unwanted signals are both log-normally distributed, are un-correlated and have identical standard deviations (σ), the location correction margin is given by:

$$L_{CM} = \sqrt{2} \times \mu \times \sigma$$ Equation (3)

where the symbols μ and σ are as defined for equation (1).

Note 1: In the case of a wanted digital service, the field strength of the interfering signal (E_i) is that exceeded at 50% of locations for more than 1% of the time i.e. $E_i(50,1)$.

Note 2: In the case of a wanted analog service, the field strength of the interfering signal (E_i) is the greater of:

(a) the sum of the field strength exceeded at 50% of locations for more than 50% of the time i.e. E_i (50,50) and the protection ratio for continuous interference; and

(b) the sum of the field strength exceeded at 50% of locations for more than 10% of the time i.e. E_i (50,10) and the protection ratio for tropospheric interference.

Note 3: The location correction margin (L_{cm}) is equal to 0 dB in the case of a wanted analog service.

3.3.9 Polarisation discrimination

The antenna polarisation discrimination defined in *Technical Planning Parameters and Methods for Terrestrial Broadcasting* is to be used in determining the nuisance field strength contribution of the unwanted transmitter.

3.3.10 Antenna directivity

The antenna directivity discrimination defined in *Technical Planning Parameters and Methods for Terrestrial Broadcasting* is to be used in determining the nuisance field strength contribution of the unwanted transmitter.

3.3.11 Required protection ratios

The required analog and digital television protection ratios for the different interference mechanisms and channel relationships are listed in appendix C. The protection ratios for digital television are based on the reference modulation defined in section 2.2.1. Different protection ratios may apply to other modulation schemes.

The protection ratios in appendix C represent current international planning values as defined in Recommendation ITU-R BT.1368 and are derived from measurements on prototype and early generation consumer receivers. These protection ratios will be reviewed in light of further ITU-R studies.

3.3.12 Continuous and tropospheric interference

Different protection ratios are specified for the protection of analog television services depending on whether the interference is continuous or tropospheric. Where a source of potential interference does not vary markedly with time it is said to be continuous. In situations where the potential interference is not continuous in nature, whether as result of long distance propagation effects or other intermittent conditions, it is said to be tropospheric.

The acceptable level of tropospheric interference corresponds to impairment grade 3 (slightly annoying) on the ITU-R five-point picture assessment scale, while the acceptable level of continuous interference corresponds to impairment grade 4 (perceptible, but not annoying). By specifying protection ratios for continuous and tropospheric conditions it is possible to take into account the subjective annoyance of interference that, on one hand is present the entire time and, on the other hand, is present occasionally. For small percentages of the time a higher level of interference (i.e. tropospheric) can be tolerated than would be acceptable on a continuous basis.

When applying protection ratios in analog television planning, it is therefore necessary to determine, for a given interferer, whether the interference should be treated as continuous or tropospheric. This may be achieved by comparing the nuisance fields for the two conditions.

From section 3.3.8, the nuisance field contribution for continuous interference can be expressed as:

$$E_{nc} = E_i(50, 50) + PR_c + A_d + A_p \qquad \text{Equation (4)}$$

and for tropospheric interference:

$$E_{nt} = E_i(50, 10) + PR_t + A_d + A_p \qquad \text{Equation (5)}$$

where:

$E_i(50,50)$	predicted field strength (dBμV/m) of the interfering transmitter, exceeded at 50% of locations for greater than 50% of the time;
$E_i(50,10)$	predicted field strength (dBμV/m) of the interfering transmitter, exceeded at 50% of locations for greater than 10% of the time;
PR_c & PR_t	protection ratio for continuous and tropospheric interference (dB), respectively;
A_d & A_p	antenna directivity and polarisation discrimination (dB), respectively; and
E_{nc} & E_{nt}	continuous and tropospheric nuisance fields (dBμV/m), respectively.

The protection ratio for continuous interference is applicable when the resulting nuisance field is stronger than that resulting from tropospheric interference $(\text{i.e. } E_{nc} > E_{nt})$. Similarly, the protection ratio for tropospheric interference is applicable when the corresponding nuisance field is stronger than that arising from continuous interference $(\text{i.e. } E_{nt} > E_{nc})$.

This means the interference is considered continuous and the protection ratio PR_c should be used in cases where:

$$E_i(50, 50) + PR_c > E_i(50, 10) + PR_t \qquad \text{Equation (6)}$$

and the interference is considered tropospheric and the protection ratio PR_t should be used in cases where:

$$E_i(50, 10) + PR_t > E_i(50, 50) + PR_c \qquad \text{Equation (7)}$$

In the case of a wanted digital service, no distinction is made between continuous and tropospheric interference due to the abrupt failure characteristic of digital television systems.

3.3.13 Summing interference levels from multiple sources

Where there are multiple nuisance fields due to other co-channel or adjacent channel services operating in the same or adjacent areas, the sum interference level is determined using one of the summation methods described in appendix F. The selection of summation model may vary depending on the wanted service (analog or digital), the particular signal configuration (multiple interferers or a single dominant signal) and the desired accuracy.

3.4 Local oscillator and image interference

In developing DCPs, the ABA does not give detailed consideration to local oscillator and image interference mechanisms as the congestion of television channels in metropolitan and surrounding regional areas make it impractical to avoid the use of these channels.

Australian Standard AS4933.1-2000, *Digital television – Requirements for receivers – Part 1: VHF/UHF DVB-T television broadcasts,* includes performance requirements for image signal rejection and spurious signals which should afford sufficient protection to both interference mechanisms in the current planning environment.

The required protection ratios at appendix C for a wanted analog television signal interfered with by an unwanted digital service on the image channel of the analog service suggest that image channel interference could be a problem if wanted and unwanted services are not co-sited. The potential for image interference to analog television services may, therefore, need to be considered on a case by case basis.

3.5 Channel assignment guidelines

In the DCPs, channels have been assigned to broadcasters in accordance with the following channel assignment guidelines. These guidelines are intended as a starting point and may be varied depending on particular circumstances.

CHANNEL ASSIGNMENT GUIDELINES

The guidelines will be applied in the order given below:

- If the lower adjacent channel to an analog service is available for digital use, then that channel is to be assigned to the broadcaster operating the analog service. If this channel is not available, then:
- If the upper adjacent channel to an analog service is available for digital use, then that channel is to be assigned to the broadcaster operating the analog service. If neither the lower nor the upper adjacent channels are available, then:
- Remaining channels are then assigned by assigning the lowest available digital channel to the broadcaster operating the analog service with the lowest channel and each channel is then assigned in turn by increasing channel number.

In the special case of a SFN, the ABA will give consideration to a range of factors in assigning digital channels, including applying the above steps where appropriate.

The adoption of the above guidelines does not preclude the ABA from deciding on different assignments in any given market on a case by case basis.

3.6 Frequency offsets

The use of frequency offsets, as a means of reducing protection ratios for co-channel services, is well known in analog television planning and implementation. Although no comparable benefit has been identified for digital television, implementation issues such as combiner constraints, that may limit a broadcaster's ability to use the same transmission antenna for an adjacent channel digital service, may be overcome through use of a frequency offset.

The use of channel offsets is not normally considered in the development of DCPs. However, the ABA will consider as part of the implementation plan process and on a case by casebasis, broadcaster proposals for use of ±125 kHz offsets, provided the use of such offsets is not detrimental to channel allotments in the same or adjacent markets or to long term digital planning.

3.7 Ancillary devices

The RF signals generated by ancillary devices (such as VCRs, video cameras, subscription television set-top units and electronic games) are not taken into account in the development of the DCPs.

Manufacturers of these devices have generally adopted RF output frequencies within the Australian television broadcasting service bands, with at least two channel selection options to avoid interference to/from operating analog broadcasting services. With the introduction of digital television, on the adjacent analog television channels, ancillary devices will require a larger channel selection range than has previously been necessary.

Australian Standard AS4542.1-1999, *Consumer television interfaces – PAL RF*, is relevant to this issue. The standard addresses the parameters and requirements for interfacing of ancillary equipment with television receivers, to ensure compatibility and acceptable operational performance. The standard recommends a preferred frequency tuning range for locally generated signals (RF output), from 470 to 862 MHz (UHF Channel 25 to 75), which extends beyond the broadcasting services bands. A minimum tuning range of 14 channels (or 98 MHz) is specified by the standard.

It is worth noting that VHF television channels 0 and 1, currently used by some ancillary devices, are not being considered for digital television broadcasting. Although now discouraged by the Australian Standard, there are some ancillary devices using channels 3 and 4. These channels are also not being considered for digital television, as the frequencies in question are allocated to VHF-FM radio broadcasting services.

4 SERVICE PLANNING

The purpose of this section is to provide sufficient information for broadcasters to plan their digital television services to achieve adequate coverage of their licence and coverage area and, in the case of services converting from analog mode, to achieve the same level of coverage and potential reception quality in digital mode as is achieved by that service in analog mode.

4.1 Field strengths

4.1.1 Minimum field strength targets

The minimum median field strengths required for digital television services in each frequency band and noise environment are listed in table 4.1. The derivation of the minimum median field strengths is explained in appendix A.

To achieve the same level of coverage, the rural minimum median field strength for the digital service should be achieved at the same distance from the transmitter as the corresponding rural minimum median field strength of the analog service.[6] In assessing the coverage of an analog UHF service, improvements in receiver noise figure should be taken into account. This allowance of 3 dB for Bands IV and V is reflected in the analog minimum median field strengths listed in table 4.2.

Note that in the case of translators in built up areas, it is the suburban or urban minimum median field strength that should be matched between the analog and digital services and not the rural field strength.

Table 4.1: DTTB minimum median field strength

Median field strength E(50,50) in dBuV/m			
Environment	**Band III**	**Band IV**	**Band V**
Urban	66	71	74
Suburban	57	63	67
Rural	44	50	54

Note: In rural areas with high electrical noise levels, higher field strengths may be required.

6 Comparison of analog and digital coverage should be made on a like to like basis. For example, digital field strength predictions should be compared to analog field strength predictions and not to analog field measurement.

Table 4.2: Analog minimum median field strength

Median field strength E(50,50) in dBuV/m					
Environment	**Band I**	**Band II**	**Band III**	**Band IV** [1]	**Band V** [1]
Urban	75	75	75	77	77
Suburban	65	65	65	69	73
Rural [2]	50	50	50	59	64

Note 1: For the purpose of achieving 'same coverage' in digital planning, the minimum median field strengths for Band IV and V analog television have been reduced by 3 dB to take account of improvements in receiver noise figure. These median field strengths should not be confused with the current analog television planning values specified in *Technical Planning Parameters and Methods for Terrestrial Broadcasting*.

Note 2: In rural areas with high electrical noise levels, higher field strengths may be required.

4.1.2 Field strength prediction

In principle, any propagation model appropriate to the frequency and propagation path(s) under consideration may be used to assess the coverage of a transmitter. However, prediction models are subject to varying degrees of uncertainty, depending on the simplifying assumptions made and the accuracy of topographic and other data used in the calculation. An understanding of the assumptions underlying the available models, together with an assessment of the propagation paths over which predictions are to be made, will assist in identifying the most suitable model for a given situation.

In predicting coverage it should be noted that the characteristics of the propagation channel give rise to random variations in received field strength. In any given small area, at any given time, the field strength varies from location to location. For any given location, within this small area, it may also vary with time. The variation with location is due to local clutter effects (i.e. buildings, trees and other obstructions). The variation with time is caused by changes in the refractive index of the troposphere, and is usually more prevalent over long propagation paths.

Detailed service planning should therefore give consideration to the variability of the signal level with time and location. Some prediction methods such as Recommendation ITU-R P.1546 incorporate time statistics and permit the field strengths exceeded, for different percentages of time, to be readily determined. In the absence of statistical data, an alternative method to assess the increase in field strength due to anomalous atmospheric conditions is to increase the effective earth radius (k-factor) to simulate the higher refractivity expected for small percentages of time.

The variation of signal level with location may be dealt through the use of location statistics as described in section 3.3.6 and 3.3.7. In case of an SFN or where there are multiple interference sources, the individual signals, which are described by statistical quantities, have to be combined statistically in order to determine the sum wanted and unwanted field strengths. Methods to perform the statistical summation are described in appendix F. The impact of signal summation effects on planning methods and coverage prediction is discussed further in the following section.

The *ITU-R Handbook on terrestrial land mobile radiowave propagation in the VHF/UHF bands* provides a useful overview of radio propagation mechanisms and describes several techniques and models that may be suited to prediction of digital coverage in the VHF/UHF bands. Studies are also in progress within the ITU-R on improved prediction methods for digital broadcasting.

4.1.3 Coverage probability targets

Section 3.3 explains the role of coverage (i.e. location) probability targets as planning parameters for digital television services. These target figures are related to the field strength signal distribution i.e. mean and standard deviation. The 50% coverage probability is determined by the mean value of the distribution. For the calculation of higher (and lower) coverage probabilities, knowledge of both the mean value and standard deviation of the signal distribution is required.

In the case of a single signal, the distribution parameters are known in advance. Using the standard treatment described in section 3.3.7, the location correction figures to cater for higher coverage probabilities required of digital services are readily calculated. The same also applies to location correction margins when one wanted and one unwanted signal is involved.

However, in a multi-signal situation, such as an SFN, the parameters of the resulting sum signal distribution are not known in advance. Mean value and, in particular, standard deviation strongly depend on the particular signal configuration, and have to be determined for each location by means of statistical procedures. As a consequence, minimum median field strengths and location correction margins no longer have fixed values, but rather become variables dependent on the number, strength, and spread (i.e. standard deviation) of the individual signal fields.

Notwithstanding the dependency on the individual signal distributions, signal summation effects are characterised by two trends. Firstly, the mean value of the sum signal is larger than the arithmetic sum of the individual means and, secondly, the standard deviation of the sum signal is smaller than that of the individual signals. Both factors contribute towards improving the service availability. As a consequence, coverage estimates based on the standard approach are likely to be conservative and result in higher ERP levels, which is appropriate for initial planning (i.e. channel allotment planning) when detailed information about the transmitter network configuration is not available. On the other hand, detailed planning of the service may need to take account of the signal summation effects. Location correction figures (for minimum field strengths) and location correction margins (for protection ratios) then no longer form suitable planning parameters and have to be replaced by the more basic coverage probability targets. Their relation to the distribution parameters of the wanted and unwanted sum fields is described in appendix G.

4.1.4 Time availability

In the Australian planning environment, coverage areas with radii in excess of 60 km are not uncommon. Over these path lengths, there will be some variation of received signal level with time. Section 4.2 of the subgroup report on 'same level of coverage and potential reception quality' suggests the use of 95% (corrected) time availability for situations where an allowance is considered as warranted. The report can be found at appendix A.

In practice, it may be more cost effective to provide translators to distant communities to improve the signal availability, rather than increase the ERP of the main station.

4.1.5 Receive antenna height

As field strength generally increases with height above ground level, it is necessary to adopt a reference height for the receive antenna. Field strength predictions and measurements are to be based on a fixed external antenna at a receive height 10 metres above ground level. This is the reference height adopted in Recommendation ITU-R P.1546. This height is also assumed to be typical of a receiver installation near the edge of the licence (coverage) area.

4.1.6 Field strength measurements

If the coverage of a DTTB service is to be determined, the field strength measurements are to be performed at a receive height of 10 metres above ground level using appropriately calibrated equipment. To permit comparison with planning values and to minimise the effect of local disturbances, several measurements should be made within an area of the order of 100 m by 100 m and the median field strength derived.

4.2 Transmission parameters

The transmission parameters for a digital television service discussed below should be determined in order to best meet the same level of coverage objectives.

4.2.1 Transmission facility siting

In determining the location of a transmission facility site, a licensee should refer to Australian Standard AS3516.2-1998, *Siting of radiocommunication facilities – Guidelines for fixed, mobile and broadcasting services operating at frequencies above 30 MHz*. The standard provides guidance on the siting, installation and operation of radiocommunications facilities for fixed, mobile and broadcasting services. In addition:

- transmission facility sites should be chosen so that field strengths consistent with table 4.1 are provided in the licence (coverage) area

- the site(s) and the effective radiated power(s) proposed shall be such as to comply with the transmitter siting, maximum ERP and maximum field strength provisions of the Technical Planning Guidelines, as well as the applicable regulatory requirements dealing with electromagnetic radiation (refer to sections 4.3 and 4.5)

- the proposed site(s) shall not represent a hazard to air navigation and have a minimum intrusion on the environment. The broadcaster is responsible for obtaining all necessary site approvals from the relevant federal, state/territory and local government planning authorities
- wherever practicable, a new transmission facility should co-locate with existing television services. Sharing of facilities (tower, antenna etc) is preferred where the services are intended to serve the same region. Where stations are co-located, but do not share antennas and/or support structures, the spacing, orientation and height of the support structures and the mounting of the transmitting antenna shall be such as to limit reflection, re-radiation and obstruction of signals of other services and
- a transmission facility should be located so that, for a particular broadcasting band, viewers within population centres of the licence (coverage) area of the service are able to receive all television services licensed to serve that area by means of a single outdoor antenna appropriate for that band. Note that in an SFN, signals of a particular service may arrive at a receiver from different directions.

4.2.2 Effective radiated power

The ERP of a transmitter, in a given direction, is the product of the power supplied to the antenna system and its gain relative to a half-wave dipole in that given direction.

As discussed in section 3.2, the ERP shown in the DCP is an assumed figure used for the purpose of developing the DCP. It is not an automatic entitlement for a broadcaster to operate their service at that ERP level. In undertaking service planning and in preparing their implementation plans, broadcasters are expected to determine the ERP required to adequately serve their licence (coverage) area and to achieve same level of coverage.

In determining the appropriate ERP level, broadcasters must have regard to the potential for interference to other services and for overspill of signal into adjacent licence areas. In addition, where the modulation scheme that is to be implemented is different to the reference modulation scheme described in section 2.2.1, the ERP should be adjusted by the $\Delta C/N$ factor in appendix B.

Prior to the cessation of analog services, the ERP of some digital services may be restricted to minimise the possibility of unacceptable interference. Due to this requirement the DCP may specify a restricted ERP level. The restricted ERP must be complied with until such time as the analog service ceases operation, is moved to an alternative channel, or viewers affected by any potential interference from the digital service are provided with a suitable alternative service. Notwithstanding these limitations, broadcasters are required to take steps that will allow removal of the ERP restriction in order to achieve same coverage as soon as practicable. Those services with restricted ERPs may be able to achieve the same coverage as other digital services not so restricted by trading off data rate for improved C/N, noting however the impact this may have on a broadcaster's ability to meet the HDTV quota standards.

The preparation of a table such as the following hypothetical example will assist the ABA in evaluating implementation plans and issuing transmitter licences with the appropriate ERP levels specified.

Table 4.3: Coverage/ERP calculations for: area served, transmitter site name

Town or Locality	Population	Dist (km)	Bearing	Analog median field strength (predicted or measured)	Target digital median field strength (VHF Band III)	Predicted digital median field strength (per kW)	Prediction Model	Required ERP to achieve target field strength
Areas within licence area:								
Black stump	3	40	34º	50 dBuV/m	44 dBuV/m	30 dBuV/m	Rec 370 land	25 kW
Suburbia	3000	5	100º	67 dBuV/m	57 dBuV/m	47 dBuV/m	BBC model	10 kW
Areas outside licence area:								
Timbuktu	250	55	50º	49 dBuV/m	<44 dBuV/m	29 dBuV/m	Rec 370 land	30 kW max.

4.2.3 Transmit antenna height

The height of the transmit antenna should be determined so that good coverage of the licence (coverage) area can be achieved.

4.2.4 Transmit antenna radiation pattern

The design of an antenna may provide for either an omnidirectional or directional radiation pattern in the horizontal plane.

A directional antenna may be useful in providing the required ERP in given directions for coverage purposes, while at the same time avoiding interference to other services by restricting the ERP in the direction of those services. A directional antenna may also assist to conserve transmitter power, with subsequent cost saving to the broadcaster, as well as contribute to improved spectrum efficiency

4.2.5 Beam tilt

Beam tilt may be required for an antenna with a relatively narrow vertical radiation pattern to ensure the axis of the main vertical lobe is optimum for coverage of the designated licence (coverage) area. The beam tilt angle specified may need to be varied somewhat to suit the width of the vertical radiation pattern and the expected tower stability.

For the purpose of determining DCPs, antenna beam tilt is not a consideration. Broadcasters will need to consider the requirement for beam tilt during detailed implementation planning.

4.2.6 Null fill

Null fill is necessary if reception is required at depression angles where a null or minimum exists in the vertical radiation pattern of the transmit antenna, and is generally for areas close to the transmitter.

For the purpose of determining DCPs, null fill is not a consideration. Broadcasters will need to consider the requirement for null fill during detailed implementation planning.

4.2.7 Polarisation

Television services may operate with either horizontal or vertical polarisation. In the absence of other planning considerations, it is preferred that main stations employ horizontal polarisation.

The use of mixed (orthogonal) polarisation is not being considered in Australia for digital television.

4.2.8 Frequency offsets

As noted in section 3.6, the use of channel offsets is not normally considered in the development of DCPs. Where implementation issues may warrant the use of a frequency offset, the ABA will consider as part of the implementation plan process and on a case by casebasis, broadcaster proposals for use of +125 kHz or –125 kHz offsets, provided the use of such offsets is not detrimental to channel allotments in the same or adjacent markets or to long term digital planning.

4.3 Technical planning guidelines

Section 33 of the Act requires the ABA to develop in writing guidelines for the technical planning of individual broadcasting services that use the broadcasting services bands as a means of delivery. These Technical Planning Guidelines (TPGs) contain procedures that must be followed and limits that must be observed by licensees when planning new transmission facilities or making alterations to existing transmission facilities.

In undertaking service planning and in preparing their implementation plans, broadcasters must have regard to the requirements contained in the TPGs. These requirements deal with a range of matters, including:

- location of the transmitter site
- maximum ERP of a transmitter
- maximum field strength within the licence area or datacasting service area;

- maximum field strength beyond the licence area or datacasting service area;
- interference to broadcasting and other radiocommunications services
- operation of single frequency networks (SFNs)
- establishment of additional co-channel transmitters and
- radiated signal characteristics of a transmitter.

4.4 Interference management scheme for digital television

The interference management scheme (IMS) for digital television is included as part of the Technical Planning Guidelines. The scheme applies to digital television broadcasters and is designed to ensure a viewer's analog television service is protected from interference from digital transmissions, and where such interference does occur, that resolution is achieved in a timely manner.

The IMS specifies the procedures to be followed on start up of digital television services, licensee obligations to maintain a log of technical operating specifications and the process for management and resolution of complaints arising from interference to analog television services.

4.5 Electromagnetic radiation

Holders of apparatus (transmitter) licences are required to comply with Australian Communications Authority (ACA) regulatory requirements dealing with human exposure to electromagnetic radiation. These requirements are aimed at ensuring radiofrequency electromagnetic radiation (EMR) limits from the licensee's transmitter are not exceeded at locations accessible to the general public.

Information on the EMR regulatory framework and how it applies to licensees of broadcasting transmitters is available from the ACA website (www.aca.gov.au).

4.6 Site compatibility assessment

Site compatibility refers to the ability of a transmitter to operate without causing unacceptable interference to other broadcasting or radiocommunications services operating at, or in the vicinity of, the transmitter site. A site compatibility assessment must take into account possible interference occurrences due to intermodulation, harmonic and out-of-band modulation products.

The ABA in developing DCPs does not perform site compatibility assessments, as these checks are specific to each transmitter site. Prior to commencement of the service, the broadcaster or its agent will need to perform compatibility checks to identify possible interference to existing operating services that may result from the introduction of the digital transmitter at the proposed site. The broadcaster or its agent will be required to resolve cases of unacceptable interference to broadcasting and other radiocommunications services unless it can be shown that the interference occurs as a result of poor installation or maintenance practices on the part of the operator of the affected service. Australian Standard AS3516.2 provides guidance on recommended practices for the installation and maintenance of broadcasting and radiocommunications facilities.

As a minimum, interference checks should be performed for intermodulation products up to the fifth order for two frequency mix products, and up to the third order for three frequency mix products. Harmonic products up to the fifth order should also be checked.

To minimise interference to other co-sited analog or digital television services, broadcasters must comply with the spectrum emission mask contained in Australian Standard AS4599-1999, *Digital Television – Terrestrial Broadcasting – Characteristics of digital terrestrial television transmissions.* The mask is applicable to digital transmitters that are co-located and operating on a channel immediately adjacent to an analog or digital television transmitter. Where a digital transmitter is to operate at frequencies near the broadcasting services band edge, specific steps may be required to ensure compatibility with radiocommunications services operating in the adjacent band.

5 REFERENCES

1 *Broadcasting Services Act 1992*.

2 Commercial Television Conversion Scheme 1999 (as amended).

3 National Television Conversion Scheme 1999 (as amended).

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5 *Technical Planning Parameters and Methods for Terrestrial Broadcasting*, Australian Broadcasting Authority, reprint April 2004.

6 *Technical Planning Guidelines*, Australian Broadcasting Authority, December 2003.

7 *Planning and Introduction of Terrestrial Digital Television (DVB-T) in Europe*, Joint ERC/EBU Report, Izmir, December 1997.

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12 Recommendation ITU-R P.370-7 (withdrawn), *VHF and UHF Propagation Curves For The Frequency Range From 30 MHz to 1000 MHz*, International Telecommunication Union, Geneva.

13 *Recommendation ITU-R P.1546, Method for Point-To-Area Predictions for Terrestrial Services in the Frequency Range 30 Mhz To 3000 Mhz*, International Telecommunication Union, Geneva.

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17 Australian Standard AS4599-1999 (incorporating Amendment No. 1) *Digital Television - Terrestrial Broadcasting – Characteristics of Digital Terrestrial Television Transmissions*.

18 Australian Standard AS4933.1-2000 (incorporating Amendment No.1), *Digital Television - Requirements For Receivers – Part 1: VHF/UHF DVB-T Television Broadcasts.*

19 Australian Standard AS4542.1-1999, *Consumer Television Interfaces - PAL RF*.

20 Australian Standard AS3516.2-1998, *Siting of Radiocommunications Facilities - Guidelines for Fixed, Mobile And Broadcasting Services Operating at Frequencies Above 30 MHz.*

Appendix A:

Subgroup report on ‘Same level of coverage and potential reception quality’

NOTE: This appendix is the report of a DTCPCG subgroup on the same coverage issue and is provided for information only. This appendix may contain minor errors or may be inconsistent with the main body of the Digital Terrestrial Television Broadcasting Planning Handbook. *Text in the main body of the Handbook takes precedence over the text in this appendix.*

Executive summary

This report provides a technical definition of the phrase ‘same level of coverage’ which appears in the Television Services (Digital Conversion) Act.

The key element of the report is the idea that the point where existing analog systems become un-watchable should be matched, in terms of the percentage of unserved locations, to the point where reception of the digital signal would just ‘fail’. In this way the gradual failure characteristic of the analog signal is matched to the more sudden failure of the digital signal. In applying this definition the subgroup considered that the point where the analog signal is un-watchable is approximately grade 1.5, which for the Band III rural case is 43 dB(μV/m) or 7 dB below the point at which analog services are planned.

In developing this reasoning two different approaches to deriving planning values for defining the field strengths at the limit of digital coverage where studied. These were a ‘ratio approach’ and a ‘first principles approach’. The ratio approach determines field strength values by applying a set of adjustments to the current analog minimum median field strength values. The first principles approach calculates minimum median field strength values from knowledge of the failure point of the digital receiver and the propagation and other factors that affect reception of digital signals. The results obtained using both methods are broadly similar, though not always identical. Generally speaking, the ratio method gave higher minimum median field strength values.

For the important Band III rural case both methods gave an identical result of 6 dB below the current analog minimum median field strength values. For other reception environment and Band conditions the results were not always identical. However, when allowance is made for the 3 dB improvement in noise figures that is assumed in Band IV and V digital planning, it is proposed that Band IV and V minimum median field strength values of 10 dB below the current analog values could be adopted as reasonable compromise values.

It is strongly recommended that practical measurements be conducted on early start up transmissions to confirm the suitability of these values.

Some cautions

Several important cautions should be noted when attempting to apply these values:

(1) the 'same level of coverage' guarantee is strongest where same band-same transmitting antenna situations apply. If different bands are used for the analog and digital services there could be some situations where a digital signal may not be received even though an analog signal is received, even though if taken over a service area the total percentage of viewers receiving coverage is the same for analog and digital

(2) the 'same level of coverage' concept is not compatible with co-channel, adjacent area operation of digital and analog services (at least). In such cases the requirement to provide 'same level of coverage' may need to be balanced against a requirement to limit the power of the digital service to avoid interference to neighbouring analog services. (Alternatively more detailed translator planning might, in theory at least, allow both requirements to be satisfied at once, assuming that suitable translator frequencies are available).

Further work

The subgroup recognised that its work was inhibited by limited information on certain key parameters (e.g. allowances to be added for man-made noise, time availability). In section 6 of the report it is strongly recommended that the ABA take action to initiate studies to provide further information to validate (or otherwise) the 'best available information' assumptions which were made by the subgroup.

1 General

1.1 Terms of reference

The *Television Broadcasting Services (Digital Conversion) Act 1998*, clause 6(3)(f) and 19(3)(f) of Schedule 4 of the *Broadcasting Services Act 1992* (the Act) specifies that:

> … a, and throughout the remainder of that period, the transmission of a commercial television broadcasting service in digital mode in that area should achieve the 'same level of coverage' and potential reception quality as is achieved by the transmission of that service in analog mode in that area …

Note: For national services similar wording applies except that 'licence area' is replaced with 'coverage area'

The new digital terrestrial television transmissions to be introduced in year 2001, should provide 'same level of coverage and potential reception quality' to be able replicate the existing analog coverage achieved by terrestrial television services. Initially, a definition is required to identify the boundaries of the analog coverage that need to be replicated. For the purpose of this study group it is assumed that the digital service to be provided extends to the existing analog services rural contour within each broadcaster's licence area. Secondly, the group is required to determine the parameters, which achieve the required digital service coverage. In this regard, two major scenarios are considered in the report. They are:

(1) Same band introduction

(2) Different band introduction.

1.2 Membership

A subgroup was formed to consider the *Same level of Coverage and Potential Reception Quality* draft paper produced by ABA engineering for discussion at the Channel Planning Consultative Group meeting held on 9 February 1999. The members of the subgroup were Murray Delahoy (DCITA), Ray Treloar (DCITA), Stephen Farrugia (NTA), Wayne Dickson (Network TEN), Colin Roberts (Capital), Fred Gengaroli (ABA), Shanthilal Nanayakkara (ABA). Geoff Tomes (GTV-9) and David Soothill (SBS) also participated as corresponding members of the group.

1.3 Meetings

Three meetings were held; 19 February 1999, 3 March and 12 March 1999 at ABA Planning and Licensing Branch, Canberra.

2 Overview

The group studied the derivation of the minimum median field strength values which apply for current analog planning. It has also investigated how these assumptions used in the existing analog planning need to be adapted for use in a digital planning context.

It found that the available documentation on the derivation of the current analog field strength values does not provide full details on how the quantitative allowances that were made for each of the items that lead to the determination of the minimum required field strength values were obtained.

Against this background the group considered two different ways of arriving at a technical interpretation of 'same level of coverage'.

The 'ratio method', determines the digital ERP level (or the minimum median field strength) by finding a suitable ratio relative to the ERP of the existing analog service to provide the same level of coverage. This ratio is determined by considering only those planning factors for which digital planning differs from that of analog. The ratio determined by this method can be applied where the digital service operates in the same band as the existing analog service. It may also be applicable when a digital service is required to match the already existing analog service and hence digital services in that band.

The factors which were considered by the subgroup in determining the ratio were:

(1) the C/N requirements of analog systems

(2) the C/N requirements of digital COFDM (64QAM, FEC 2/3)

(3) the difference in receiver IF bandwidths of analog and digital systems

(4) the use of the equivalent location availabilities (via ITU Rec. 370-7) between Analog and Digital over all environments

(5) the increasing C/N needs of COFDM (64QAM, FEC 2/3) as the environment increases in complexity

(6) the increased sensitivity of COFDM (64QAM, FEC 2/3, 2K) to man made noise compared to analog VSB.

The 'first principles derivation method', determines a minimum required median field strength by a line by line addition of all the factors that contribute to the minimum field strength. This method can be applied for the digital service in a 'green fields' situation or with an existing analog service. When there is an existing analog service to which the digital service is required to match, knowledge of the existing analog contours is required. The method may also be applicable where the same coverage is required as that of an analog service in another band, to that of the new digital service.

The factors that were considered by the subgroup in determining the minimum median field strength were:

(1) an allowance for location availability

(2) an allowance for man made noise

(3) an allowance for the digital receiver's threshold performance in the presence of multipath

(4) an allowance for antenna height effects and

(5) an allowance for interference (but not for co-channel adjacent area interference).

In situations where a broadcaster moves to a different band and joins other broadcasters (which have analog and companion digital services in the same band), there is a policy issue as to whether the broadcaster should satisfy the 'first principles' minimum field strength or whether he should use the 'ratio method' to provide the same coverage requirements as other broadcasters operating in the same band.

The structure of this report is as follows. Section 3 gives a proposed derivation of 'same level of coverage', this is equally applicable to the 'ratio' and 'first principles' methods. Section 4 considers the items that may be needed to derive the required ratios or the minimum median field strength values. Section 5 presents tables showing the required minimum field strength values obtained by both the ‘ratio’ and by the ‘first principles’ methods.

The information contained in this report represents the best information that could be obtained by the group given the resources and time available for its work. In several areas there is a clear need for more information. Section 6 itemises several areas of further work. The subgroup suggests that the Digital Channel Planning Group should draft recommendations for the ABA Board to request that these studies be undertaken. In this light, the minimum median field strength values presented in this report should be treated as provisional and subject to revision when this further data is available.

One further important qualification should noted. The ‘ratio’ or ‘first principles’ minimum median field strength values have both been derived based on an assumption that there is no significant interference from neighbouring services. However, some of the channel planning scenarios currently being considered by the DCP group may not meet this condition. For example, during the analog-digital transition phase co-channel, adjacent area digital and analog services may operate where the level of terrain shielding is relatively low (e.g. less than 30 dB). Under such conditions it will not be possible to satisfy the ‘same level coverage’ requirement while at the same time avoiding interference to existing analog services. This will mean that, either, the initial operation of the digital service may not satisfy the ‘same level of coverage’ requirement, or more complex/costly multiple transmitter service area coverage arrangements may be required. This would appear to be a matter requiring further consideration by the ABA.

3 Definition of same level of coverage

3.1 Current analog planning

Current PAL planning at VHF provides 50 dB(µV/m) at the limit of rural coverage. This will provide a signal that has ‘... “acceptable” picture quality, using a receiving installation typical of outlying or fringe areas, in the absence of man-made noise or interference from other stations’.[1]

The planning guidelines state that ‘... For television services, the minimum median field strength for which protection against interference is to be planned are shown the table below. The values refer to the field strength at a height 10 metres above ground level.

Band	**I**	**II**	**III**	**IV**	**V**
dB(µV/m)	50	50	50	62	67

The field strengths cited above are those exceeded at 50% of the receiving locations for 50% of the time.’

[1] This quote comes from the earlier October 1982 Draft Planning Guidelines VHF/UHF Television DOC document number GS3/4.

Although the current planning guidelines do not clearly define what ‘acceptable’ picture quality means in terms of a picture grading on the 5 point impairment scale[2] at locations near the edge of coverage, it can be inferred that the requirement, at the edge of rural coverage at least, is to provide a grade 3 picture.

This requirement can be equated to a requirement for a video signal-to-noise ratio (luminance unweighted) of 26 dB.[3] This can be equated to a C/N (carrier-to-noise) requirement of approximately 33 dB.

3.2 Matching location availability of analog and digital systems

As stated above current analog planning is based on producing a grade 3 picture a median field strength of 50 dBµV/m value. The planning guidelines require that at the edge of coverage this field strength will be provided to 50% of locations for 50% of the time. Since field strength is subject to statistical variation, the actual field strength at a specific locations near the edge of coverage could be somewhat more or somewhat less than the median 50 dBµV/m value.

Noting this statistical variation with location, and also noting that at some sufficiently low field strength the existing analog signal can be said to have failed, it is possible to derive a ‘same level of coverage’ definition for digital television that will match the failure point of the existing analog television service. This approach aims to ensure that any viewer who currently receives a grade 3 analog signal will receive a digital signal, and also that viewers who are within the coverage area, but who receive signals which are watchable, but below grade 3, will also receive a digital signal.

The following paragraphs explain the method used to arrive at the location variability allowance that is thought necessary to provide a digital service with the ‘same level of coverage’ as the existing analog service.

CCIR Report 409-3 ‘Boundaries of the television service area in rural districts having a low population density’ states that:

> In such areas, without [PAL] co-channel interference, field strengths in the order of 40 dB(µV/m) in Band I and 43 dBuV/m in Band III can give good quality pictures; however, it is generally observed that the public begin to lose interest in installing television reception equipment when the field strength falls much below these levels.

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2 The ‘impairment’ scale should be used here rather than a ‘quality’ scale. Our interest is in the amount of impairment due to noise that the picture, assumed to be perfect on leaving the transmitter, has suffered by the time it is received.

The impairment scale is as follows

Grade	Description of impairment
5	Imperceptible
4	Perceptible, but not annoying
3	Slightly annoying
2	Annoying
1	Very annoying

3 This value is obtained from DOC556, ‘Technical Specification for the Australian Reference Television Receiving System’, Deparment of Communications, Canberra, June 1986. However the value can be derived mathematically from the required field strength value.

Two conclusions can be drawn from this. Firstly, viewers are not watching analog Band III services with field strengths below 43 dB(μV/m). Secondly, this point of 'unwatchability' is 7 dB below the edge of service median field strength level which, in turn, equates to an unweighted VSNR value of 19 dB. The impairment level of such a picture would be described as being somewhere between 'annoying' and 'very annoying'. Observation of pictures with unweighted VSNR at 19 dB confirms that this is a reasonable assumption.

Now, when the field strength distributions of figures 5 and 12 of ITU-R Rec. P.370-7 are considered, a 7 dB difference between the target grade of service and an 'unwatchable' picture implies that approximately 20% of locations at the limit of the PAL coverage contour will not receive a 'watchable' picture and therefore should not be considered as needing to be served by a digital signal under the 'same level of coverage' principle. When applied to the wideband digital curves in the same figures this leads to ≈4 dB adjustment to the 50/50 prediction curves for VHF and ≈4.5 dB correction to the 50/50 prediction curves for UHF.

It is important to note that the percentage of locations at the *edge of coverage* that receive a watchable picture is NOT the same as the total percentage of locations *within a service area* that receive a watchable picture. The latter number is considerably higher. For example, a simplistic calculation using free space propagation will show that if a location availability percentage of 80% is provided at the outer perimeter of a coverage area covering a radius of 100km from a transmitter, then the total availability at all locations within a coverage radius of the transmitter will be greater than 90%.

3.3 Other comments

This definition provides a reasonable basis for providing a technical interpretation of the words of the Act which require 'same level of coverage' where the analog and digital services are operated in the same band, and desirably from the same antenna (this can be done by means of a ratio between analog and digital transmitter powers, or by using the method to derive a minimum median field strength requirement for digital).

However, in cases where different bands are to be used for the analog and digital services, it will be important to derive a minimum median field strength requirement for digital in order to assess the extent to which the 'same level of coverage' can be met. This will ensure, as far as is possible given the statistical nature of point-to-area television propagation predictions, that the percentage of locations not receiving digital signals will be the same as that which currently does not receive analog signals. It should be understood however that because the processes involved are statistical in nature that where the analog and digital services are operated in different bands, there could be some locations where a digital signal may not be received even though an analog signal is receivable.

The above definition is also predicated on an assumption that existing analog coverage is based on a rural coverage field strength. The group received an input paper that argued that in some cases (e.g. SBS, Sydney) this may not have been done. Such situations seem to raise policy questions which seemed to be outside the scope of the same coverage group.

4 Factors used in deriving ratios and minimum field strength values

4.1 Location availability

Received field strength will vary depending upon the placement of the receive antenna in its local environment. Multipath effects, due to reflections from the ground, buildings and other objects, creates standing waves resulting in rapid field strength variations as the receive antenna is moved distances comparable to the signal wavelength. Shadowing from local terrain, buildings and vegetation gives typically larger and slower variations in the received field strength as the receive antenna is moved within a region significantly larger than a wavelength, but not so large that the unobstructed field strength would vary across it. A region of 100m to 200m square is typically considered for location variability in the VHF and UHF bands.

The location variability of received field strengths in a region can be statistically described by a log-normal distribution with a standard deviation and a mean. ITU Recommendation P.370-7 contains figures showing this distribution for narrow and wideband signals at VHF, figure 5, and UHF, figure 12. The figures give the ratio, in dB, of the field strength for a given percentage of the receiving locations to the field strength for 50% of the receiving locations. Wideband systems like digital television have a lower standard deviation than analog systems as they are less subject to frequency dependent location variation.

Note: The subgroup discussed whether or not to add separate allowances for location variability, height gain effects and clutter. Although there was some disagreement about the definition of each of these terms, it was accepted that it was sufficient to add allowances for location availability and height gain in each of the environment types.

4.1.1 Location availability allowance for rural environments

Section 3 of this document describes a method for equating the ‘failure point’ of analog and wideband digital systems. The analog planning criteria of 50 dBuV/m at 50% of locations implies 80% of locations will have a field strength of greater than 43 dBuV/m, the assumed failure point of PAL. Therefore a minimum location availability of 80% is required for digital services when failure points are equated. ITU Rec. P.370-7 figure 5 shows that, for VHF digital services, 80% of locations will have a field strength 4 dB less than the median 50% location field strength. Similarly, figure 12 shows that for UHF digital services, 80% of locations will have a field strength 4.5 dB less than the median 50% location field strength.

A location variability margin of 4 dB at VHF and 4.5 dB at UHF is therefore required. This will ensure that the field strength predicted at 50% of locations will be sufficient to ensure that the analog and digital services will have an equivalent service with at least 80% of the locations receiving ‘watchable’ signals.

4.1.2 Location variability allowance for Suburban and Urban environments

Due to the limitations on antenna placement in each of the different environments different location availability percentages are proposed for rural, urban and urban environments. A very high location availability of 95 % is considered necessary at the limit of the urban environment because there is little opportunity to optimise the location of the receive antenna. At the limit of the suburban environment a location availability of 90% is proposed, this recognises that suburban rooftops offer limited possibilities for antenna placement. Using Rec.P.370 is can be found that an addition margins of approximately 3 dB and 5 dB, respectively, are required at both VHF and UHF to achieve the desired 90% and 95% location availabilities in suburban and urban environments.

4.2 Time availability and/or fading allowance

4.2.1 Background

PAL services in Australia are currently planned for 50% time availability. ITU-R Recommendation 370-7 provides data on radiofrequency propagation in the broadcasting bands. The Recommendation provides correction information for wideband digital signal location variability, however, it is silent on the difference between narrowband and wideband-digital time variabilities.

Using a similar process to that of location variability and assuming that the time and location variabilities are independent, we can consider what the appropriate time correction (or desired time availability) is.

As stated previously, there is a 7 dB difference between the nominal edge of coverage field strength and an ‘unwatchable’ PAL picture.

The two ‘Narrowband’ tables below show the difference between the 50% time curves and the 10%, 5% and 1% time curves in Recommendation 370. It is assumed that the signal distribution is symmetrical (as it is with locations) and hence the difference between the 50% time and the 10% time curves is the same as the difference between the signal availability of 50% time and that of 90% time.

For most high-power transmission facilities, the rural contour would be between 100 and 150 km from the transmit site.

From the tables below it can be seen that, for an effective antenna height of 600 m and a receive antenna at 100 km, the PAL picture is above the ‘unwatchable’ level for greater than 95% of the time.

Narrowband			Band - VHF						
Distance from Tx (km)	Effective Tx Ant Height = 300m			Effective Tx Ant Height = 600m			Effective Tx Ant Height = 1200m		
	Time availability			Time availability			Time availability		
	90%	95%	99%	90%	95%	99%	90%	95%	99%
50	0.7	2.2	3.0	0.0	0.6	2.0	0.0	0.0	0.0
100	5.9	9.2	10.0	3.2	6.8	8.3	3.2	5.0	7.0
150	9.0	13.0	14.0	6.7	10.2	12.0	5.9	8.7	11.5

Narrowband			Band - UHF						
Distance from Tx (km)	Effective Tx Ant Height = 300m			Effective Tx Ant Height = 600m			Effective Tx Ant Height = 1200m		
	Time availability			Time availability			Time availability		
	90%	95%	99%	90%	95%	99%	90%	95%	99%
50	0.5	2.5	6.0	0.0	1.5	4.2	0.0	0.0	0.0
100	4.8	7.2	12.0	3.2	6.2	11.8	1.0	3.8	8.2
150	7.2	10.0	15.5	5.7	9.0	16.3	4.2	7.0	13.2

It is expected that signal fading will comprise both frequency selective fading affecting a small part of the 7MHz channel and whole channel (‘flat’) fading. As analog signals were dependent upon a single dominant carrier, it is likely that both these factors are reflected in the time variabilities shown in the above tables. Due to the robustness of a DTTB signal to frequency selective fading within the channel, it is likely that the time variability would be less than for analog systems. The following ‘Wideband’ tables have used a 0.6 factor on the narrowband figures (as per the location variation – analog to digital ratio) to take account of the expected reduced variability of the DTTB signal. It is recommended that a program of measurements be undertaken to determine the accuracy or otherwise of this assumption (see section 6.2).

Wideband (Scaled 0.6 x Narrowband)								Band - VHF	
Distance from Tx (km)	Effective Tx Ant Height = 300m			Effective Tx Ant Height = 600m			Effective Tx Ant Height = 1200m		
	Time availability			Time availability			Time availability		
	90%	95%	99%	90%	95%	99%	90%	95%	99%
50	0.4	1.3	1.8	0.0	0.4	1.2	0.0	0.0	0.0
100	3.5	5.5	6.0	1.9	4.1	5.0	1.9	3.0	4.2
150	5.4	7.8	8.4	4.0	6.1	7.2	3.5	5.2	6.9

Wideband (Scaled 0.6 x Narrowband)							Band - UHF		
Distance from Tx (km)	Effective Tx Ant Height = 300m			Effective Tx Ant Height = 600m			Effective Tx Ant Height = 1200m		
	Time availability			Time availability			Time availability		
	90%	95%	99%	90%	95%	99%	90%	95%	99%
50	0.3	1.5	3.6	0.0	0.9	2.5	0.0	0.0	0.0
100	2.9	4.3	7.2	1.9	3.7	7.1	0.6	2.3	4.9
150	4.3	6.0	9.3	3.4	5.4	9.8	2.5	4.2	7.9

From the ‘wideband’ tables above, to equate to the current 95% time availability for an effective antenna height of 600 m and a receiver 100 km from the transmit antenna, a margin of approximately 4 dB would be required.

Following the assumption of ITU Report 485-1 that the location variation and the time variation are independent, the total affect of the two margins (approximately 4 dB each) is an approximate increase of 6 dB (i.e. 2 dB more than the value for location variability allowance).

4.2.2`Conclusions concerning time availability allowance

The subgroup discussed the conditions under which this allowance should be applied. It concluded that this allowance should be treated as a planning tool that would be applied for particular situations but that it would not be assumed as a general planning principle. It also noted that other planning tools such as the use of translators may be more appropriate in particular situations. Therefore no general ‘time availability allowance’ has been added in the indicative link budgets presented in section 5.

In particular planning situations where it is determined that an allowance for time availability should be added the following guidelines are suggested. To match analog and digital availabilities at distant reception situations it is provisionally suggested that 95% time availability should be used. But this provisional conclusion should be confirmed by further studies (refer to section 6.2). Also in applying the 95% time availability it should be noted that a provisional scaling factor of 0.6 should be applied to the data in Recommendation 370-7 to account for the wideband nature of the digital signals. Furthermore, any time availability allowance should be combined with the location availability allowance according to the combination rule given in ITU-R Report 485.

4.3 Man made noise allowance

ITU-R Recommendation PI.372-6 provides data on median values of man-made noise. The data is summarised in two different frequency dependent formulas which cover different, but overlapping, frequency ranges. The results of the different formulas at various frequencies of interest are shown below. The values are given in dB above kT_0.

Environment	Band III (170 MHz)	Band III (230 MHz)	Band IV (550MHz)	Band V (800 MHz)
Business	15.0	11.4 /15.3	10.6	8.6
Residential	10.7	7.1		
Rural	5.4	1.8		

Notes:

1. For the business case the two formulas give slightly different results in the frequency range where they overlap.

2. The ITU-R Recommendation does not provide data for the 'residential' or 'rural' environments at Band IV or Band V.

3. The ITU-R Recommendation only provides median noise data. Further study is required to determine if median noise is the most appropriate metric of the failure performance of COFDM television systems.

The Communications Laboratory has attempted to find data in the literature to confirm the suitability or otherwise of these values. Only a limited amount of data has been obtained, however, on the data currently available seems to agree fairly well with the ITU-R data at 230 MHz.

Therefore the following set of man-made noise values are provisionally proposed for use in calculations for digital television planning, subject to further data becoming available (refer section 6.1)

Environment	Band III	Band IV	Band V
Urban	14	10	8
Suburban	7	5	4
Rural	2	0	0

The group also considered how these values of man made noise should be treated in DTTB link budget calculations. It considered that man-made noise was a noise source which was not coherent and should be added in an r.m.s. fashion to the noise contributed by the receiver (which is represented by Noise Figure in the link budget). Therefore, it was concluded that rather than quoting a simple 'Man-Made Noise' value, a 'man-made Noise *Allowance*' should be quoted. This Allowance is the additional number of dB, over and above the allowances for receiver Noise Figure and cable loss, that should be included in the link budget to allow for the net effect of man-made noise.

Provisional recommended values for 'Man made noise allowance'

(i.e. increment to be added for man-made noise after receiver noise figure and cable loss are considered)

Margin	Band III	Band IV	Band V
Receiver noise figure (dB above kT)	6.0	7.0	8.0
Cable loss* (rural/suburban/urban) (15m/10m/10m)	3/2/2	4/2.7/2.7	5/3.4/3.4
Effective noise figure of receiver and cable	9/8/8	11/9.7/9.7	13/11.4/11.4
Urban	7	3	2
Suburban	3	1	1
Rural	1	0	0

* refer to section 4.2.5

The following additional allowances have been applied in deriving the 'ratio' values given in section 5.1. These are the amounts that digital is more sensitive to man made noise compared to analog reception.

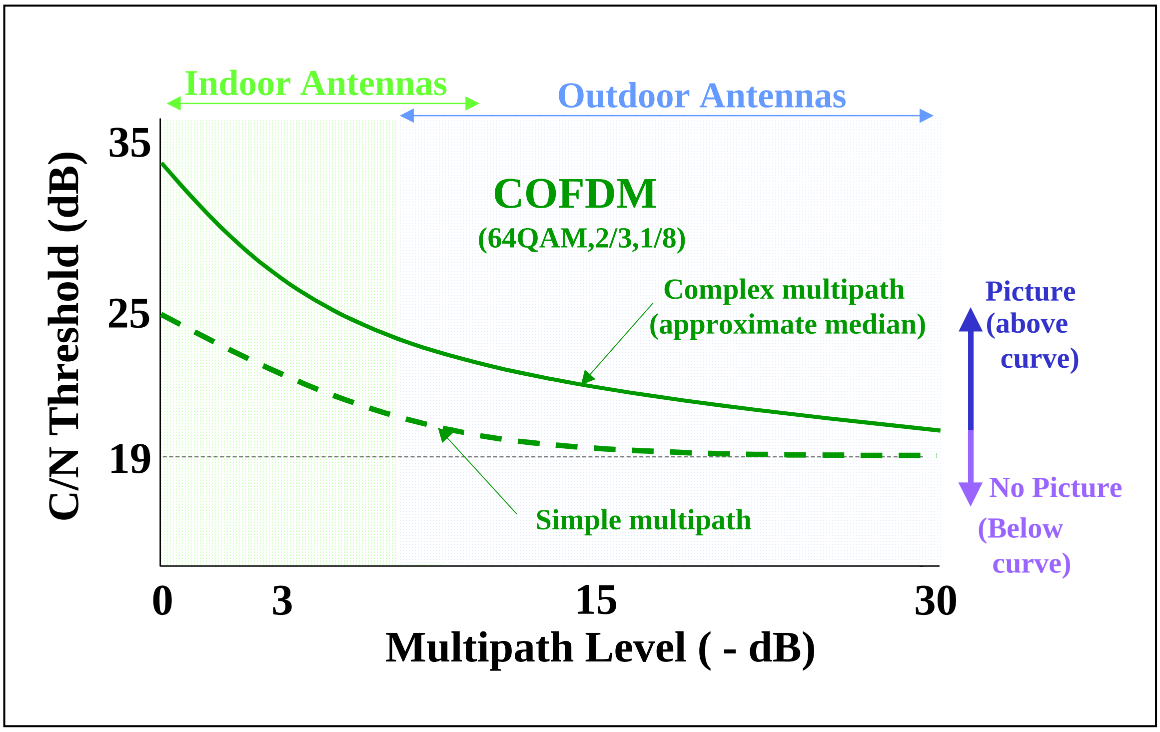
Man made noise allowance (diff. D to A) (dB)			
Environment	**Band III**	**Band IV**	**Band V**
Rural	0.5	0	0
Suburban	1	0	0
Urban	1.5	0.5	0

It is noted that Communications Laboratory measurements of the impulse noise sensitivity found that the COFDM system was 10 dB *more* rugged than PAL. On the basis of these measurements this implies that COFDM systems operated at power levels of up to 10 dB below PAL levels should not experience impulse problems. However, there have been several reports of apparently contrary anecdotal evidence. It is a clear that when interpreting such results there is a need to be careful about the relative levels of the wanted signals with respect to noise levels. It also further reinforces the need for additonal investigation of the performance of COFDM systems in the presence of noise.

The above values are provisionally proposed for use in Australian DTTB planning, however it is strongly recommended that measurements should be performed in Australia to confirm the suitability of these values. (Measurements of the effects of urban noise at Band III and impulse (ignition) noise are thought to be the most important areas where this confirmation is required).

4.4 Receiver threshold performance allowance

Reception of COFDM with 64QAM at FEC rate 2/3 modulation demands different C/N thresholds dependent primarily upon the level and timing of the multipath portion of the signal. This is illustrated in the graph below which shows the requirements in the field with complex multipath require C/N compared to the singe echo case. From this graph it has been estimated that a further 2 dB and 4 dB is required in the Urban and Suburban environments to cater for this extra C/N demand (for the case of outdoor antennas which is the basis for current analog planning).



Note: The graph has been generated from multiple sources of laboratory and field trials. The indoor portion of the complex multipath curve is an extrapolation and requires verification.

Threshold C/N (dB)			
Environment	**Band III**	**Band IV**	**Band V**
Rural	20	20	20
Suburban	22	22	22
Urban	24	24	24

4.5 Antenna height allowance

Field strength predictions using ITU-R Recommendation 370-7 are based upon a standard receive antenna height of 10 m. The method does allow for corrections for other receive antenna heights in the range 1.5 m to 40 m.

In the case of rural reception, the assumption of a 10 m receive antenna is considered reasonable.

For suburban and urban reception, it is reasonable to assume that a lesser receive antenna height will be (is currently) used. Assuming a 5m receive antenna height for these zones, the correction factors (margins) are as follows:

	VHF (dB)	UHF (dB)
Suburban	5	6
Urban	6	8

That is, the required minimum receive field strength requirements for urban and suburban environments should be increased by the margins above to allow for the expected use of lower receive antenna height.

With the antenna height reduced to 5 m a subsequent reduction in cable length would reduce the above margins by 1 dB, 1.3 dB and 1.6 dB for Bands III, IV and V respectively.

Note: The inclusion of an allowance for the negative height gain of antennas at heights lower than 10 m could alternatively be seen as inclusion of an allowance for clutter.

4.6 Interference allowance

As already noted in section 2, possible co-channel operation of digital channels in first-adjacent markets have not been considered in this report. Further studies on digital-digital and analog-digital protection ratios may be needed to ascertain the protection ratio values to be recommended for use in digital channel planning.

It has been suggested that an [provisional] allowance of 1 dB be used for terrestrial transmissions to derive the required field strength and determine the required protection ratio which corresponds to this degradation in Carrier/Noise+Interference (C/N+I). This allowance could lead to a review of currently used protection ratios in digital planning and could have an impact on planned digital channels for use in the proposed digital channel plan (DCP) by the Australian Broadcasting Authority. It has been suggested that an existing protection ratio of 20 dB (digital-to-digital) may change to 27 dB because of this allowance; a 7 dB difference in protection ratio.

In current planning, the interferer level is based on E(50,10) prediction for tropospheric interference and E (50,50) for continuous to be radio broadcasting. However, if the E (50, 1) is interferer level is to be used instead for tropospheric interference, some compensation for the increase in protection ratio may be possible. This compensation is dependent on the effective antenna height, transmission distance and the transmission band. Critical cases, however, may need to reviewed on a case by case basis.

5 Recommended ratios and minimum F/S for planning

5.1 Ratio method

The following table provides a summary of the derivation of the ratio required between a digital service and an analog service to provide the same level of coverage.

Parameters	Band III			Band IV			Band V			*Note*
	R	S	U	R	S	U	R	S	U	
Base threshold C/N requirement (dB)	20			20			20			
Multipath margin (dB)	0	2	4	0	2	4	0	2	4	
Loc. availability margin (80%/90%/95%)	4	6.5	8.5	4.5	7.0	9.0	4.5	7.0	9.0	
Differential allowance for environmental noise (dB)	0.5	1	1.5	0	0	0.5	0	0	0	
Interference margin (dB)	1	0	0	1	0	0	1	0	0	1
Total digital C/N requirement (dB)	25.5	29.5	34	25.5	29	33.5	25.5	29	33	
Base C/N requirement for analog (dB)	26			26			26			
Loc. availability margin (80%/90%/95%)	7	11	13.5	7	12	15.5	7	12	15.5	
Total analog C/N requirement (dB)	33	37	39	33	38	41.5	33	38	41.5	
Bandwidth difference allowance (dB)	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	2
Resultant ratio (dB)	6.2	5.7	4.2	6.2	6.7	5.7	6.2	6.7	6.2	3

A 1 dB interference allowance has only applied to rural for a simple planning scenario of rural environments near the licence area boundaries.

As the receiver bandwidths for analog are 5 MHz and for digital 6.7 MHz a difference of 1.3 dB exists between the noise floors.

The resultant ratio is equal to: (Total Analog C/N) – (Total Digital C/N) – (Bandwidth Allowance)

The allowance for time variability is to be applied where required or justified. In the case where a time variability allowance has already been added to the existing analog service planning, as the equivalent margin for digital is less, the ratio can increase. That is, there is less power needed for the digital service to achieve the same coverage in a time variable environment if it has already been allowed for in the Analog service planning.

The figures above may be rounded to provide:

Ratio within the same Band (dB)			
Environment	**Band III**	**Band IV**	**Band V**
Urban	4	5	6
Suburban	6	7	7
Rural	6	6	6

5.2 Minimum median field strength values derived by 'first principles' derivation method

Parameters	**Band III**			**Band IV**			**Band V**		
	R	**S**	**U**	**R**	**S**	**U**	**R**	**S**	**U**
Minimum field strength (dBuV/m)	**37.6**	**39.6**	**39.6**	**44.6**	**46.3**	**46.3**	**48.6**	**49.9**	**49.9**
Loc. availability margin (80%/90%/95%)	4	6.5	8.5	4.5	7.0	9.0	4.5	7.0	9.0
Time availability margin (dB)	0	0	0	0	0	0	0	0	0
Multipath margin (dB)	0	2	4	0	2	4	0	2	4
Height gain allowance (dB)	0	5	6	0	6	8	0	6	8
Additional allowance for environmental noise (dB)	1	3	7	0	1	3	0	1	2
Interference margin (dB)	1	1	1	1	1	1	1	1	1
Resultant operating F/S (dBuV/m)	43.6	57.1	66.1	50.1	63.2	71.2	54.1	66.9	73.9

The figures above may be rounded to provide:

DTTB 'First Principles' Planning Minimum median field strength in dBuV/m			
Environment	**Band III**	**Band IV**	**Band V**
Urban	66	71	74
Suburban	57	63	67
Rural	44	50	54

The differences to the current Analog planning figures are shown below.

Difference between planning guidelines **Difference to current analog F/S (dB) (1)**			
Environment	**Band III**	**Band IV**	**Band V**
Urban	9	9 (6)	6 (3)
Suburban	8	9 (6)	9 (6)
Rural	6	12 (9)	13 (10)

CAUTION : These figures are a record of planning differences NOT the ratios between analog and digital Services.

Note: The bracketed figures show the difference if a correction is made to allow for the differences in noise figure assumptions in digital planning and current analog planning. The receiver noise figures in the current analog planning guidelines for Bands IV and V are 3 dB higher than those proposed which have been proposed for digital planning. However it is expected that in practice the noise figures of digital receivers will be similar to current analog receivers.

6 Further work

6.1 Environmental noise (man-made noise) and its effect of COFDM reception

Further work is necessary to validate (or otherwise) the numbers provided in section 4.2.3 for the Australian environment. It will also be important to consider whether the median man-made noise level is the most appropriate metric of the failure of COFDM television systems.

6.2 Time variabilities

ITU-R 370-7 deals with propagation of signals in the broadcasting bands. Corrections have been made for the differences in location variability between analog and digital wideband signals, however, it is silent on time variability differences between analog and digital signals.

A measurement program is required to determine the affect of time variabilities on a COFDM television system. This program should include a range of effective transmit antenna heights (from approximately 150 m to 600 m) and distances (from 50 km to 200 km) to determine appropriate corrections for time variability.

6.3 Indoor reception parameters

Whilst planning is done based on a 10 m receive antenna height, it is acknowledged that a significant number of viewers in urban and suburban environments do not use outdoor antennas.

This work is not fundamental for the technical definition of same coverage, however, it is likely that viewers will continue to use indoor antennas where practical.

Therefore, work that quantified variables such as building penetration loss, indoor dynamic multipath (due to human movement) and indoor man-made noise would assist the implementation of DTTB in Australia.

6.4 Multipath affects

The C/N requirements used in this report are estimates derived from Laboratory testing and Field Trials conducted to date. Further collection of data is requirement to either support or change these estimates.

6.5 Network gain

Initial work in Europe has found that Single Frequency Networks can have network gains of 4 to 6 dB. This may be a more cost-effective and spectrum efficient way of increasing the location availability of DTTB signals.

Work on this issue could potentially help to reduce the power required in those areas using SFN planning.

6.6 Protection ratios for interferers to DTTB

Currently, the protection ratios for interference into a DTTB signal relate to the quasi-error free BER level of 2.1×10^{-4} errors after Viterbi decoding (or 1×10^{-11} after Reed Solomon) of the DTTB signal.

It has been suggested that a (provisional) 1 dB allowance for interference be added to the minimum required field strength. The protection ratios for interference into DTTB signals would therefore need to be recalculated to account for this change in definition.

Annex 1

Derivation of Minimum Field Strength for Planning

DVB-T 7 MHz notional receiver

Parameters	Band III	Band IV	Band V	*Note*
Frequency [f (MHz)]	230	582	820	1
Equivalent noise bandwidth [b(MHz)]	6.7	6.7	6.7	2
Receiver noise figure [F(dB)]	6	7	8	
Receiver noise input voltage [V_r(dBμV)] 75Ω, 290K, 6.7MHz	9	10	11	
Required threshold C/N (dB)	20	20	20	3
Minimum receiver input voltage [V_{min}(dBμV)]	29	30	31	

Notional receiving system (R = Rural, S = Suburban, U = Urban)

Parameters	Band III			Band IV			Band V		
	R	S	U	R	S	U	R	S	U
Antenna gain relative to half wave dipole [G_d(dBd)]	8	5	5	11	8	8	12	9	9
Feeder loss [L(dB)] RG59 @ 15m (rural), 10m (suburban / urban)	3	2	2	4	2.7	2.7	5	3.4	3.4
Antenna factor [K(dB)]	8.5	10.5	10.5	14.6	16.3	16.3	17.6	19.0	19.0
Antenna height (m)	10	5	5	10	5	5	10	5	5
Minimum field strength (dBuV/m)	37.6	39.6	39.6	44.6	46.3	46.3	48.6	49.9	49.9

Note 1: The Band III figures are applicable to channel 12 whereas previous figures are valid for channel 11 (channel 11 was the highest channel that was used in analog planning).

Note 2: The noise need only be measured over the COFDM spectrum bandwidth as the FFT decoding mechanism in the receiver effectively provides a digital filter with a width of the COFDM spectrum. Single carrier systems and analogue systems would use the IF bandwidth.

Note 3: For the ITU M3 modulation to be used, the DVB-T system (ref. ETSI EN 300 744) has a theoretical threshold carrier to noise figure of 16.5 dB in a Gaussian channel, based upon perfect channel estimation and perfect receiver implementation. Current receiver implementations have shown that an additional 2.5 dB is required, resulting in 19 dB threshold C/N performance in a Gaussian channel environment, that is in an environment with no multipath. For fixed antenna reception, a Ricean channel multipath profile will generally be experienced, which increases the C/N requirement for demodulation theoretically by 0.6 dB. For the use through a practical RF transmission system, an additional 0.4 dB C/N degradation shall be allowed. Combining these figures therefore, for planning purposes, the notional threshold C/N requirement shall be taken to be 20 dB.

Note 4: Appropriate formulas are at annex 2.

Annex 2

Formulas used to calculate receiver minimum field strength requirements

Formula	In decibel
$p_t = k.T_o.b$	$V_n = F + B + R - 203.98$ or in typical units $V_n\,[\text{dB}\mu\text{V}] = F + B\,[\text{dBMHz}] + R - 23.98$
$v_t = \sqrt{p_t.r} = \sqrt{k.T_0.b.r}$	
$v_n = \sqrt{n.k.T_0.b.r}$	
$v_{min} = v_n\sqrt{C/N}$	$V_{min}\,[\text{dB}\mu\text{V}] = C/N + V_n = C/N + F + B\,[\text{dBMHz}] + R - 23.98$
$p_r = \phi.A = \dfrac{\varepsilon^2}{120.\pi}\ \dfrac{g_i.\lambda^2}{4.\pi}$	
$v_r = \sqrt{p_r.r} = \varepsilon\sqrt{\dfrac{1.64.g_d}{480.\pi^2}\left(\dfrac{3.10^8}{f}\right)^2.r}$	
$\varepsilon_{min} = v_r z$ where $z = \sqrt{\dfrac{480.\pi^2}{1.64.g_d}\left(\dfrac{f}{3.10^8}\right)^2.\dfrac{1}{r}}$	$\text{E}_{min} = V_r + Z$ where $Z = Fr - G_d - R + L - 134.94$ or in typical units $\text{E}_{\text{min}}[\text{dB}\mu\text{V/m}] = V_r\,[\text{dB}\mu\text{V}] + Z$ where $Z = Fr\,[\text{dBMHz}] - G_d - R + L - 14.94$
	$\text{E}_{op} = \text{E}_{min} + M_l + M_t + M_m + M_h + M_e + M_i$

p_t = thermal noise power [W]
v_t = thermal noise voltage [V]
v_n = receiver noise input voltage [V]
k = Boltzmann Constant = $1.38\ x\ 10^{-23}$ [J/K]
T_o = temperature [K] = 290
b = equivalent noise bandwidth [Hz]
r = input resistance [Ω]
n = receiver noise factor
v_{min} = minimum receiver input voltage [V]
C/N = RF Carrier to Noise ratio
p_r = received power [W]
ϕ = power flux density
A = effective antenna aperture
v_r = receiver terminal voltage [V]
ε_{min} = minimum field strength [V/m]
z = antenna factor
g_i = antenna gain over an isotropic radiator
g_d = antenna gain over a dipole $= g_i/1.64$
λ = wavelength [m]
f = RF frequency [Hz] $= 3.10^8/\lambda$

$V_n = 20\log(v_n)$
$F = 10\log(n)$
$B = 10\log(b)$
$R = 10\log(r)$
$-203.98 = 10\log(kT_o)$
$V_{min} = 20\log(v_{min})$
$\text{E}_{min} = 20\log(\varepsilon_{min})$
$V_r = 20\log(v_r)$
$Z = 20\log(z)$
$G_d = 10\log(g_d)$
L = cable loss (dB)
$Fr = 20\log(f)$
E_{op} = Operating Field Strength
M_l = Location Availability Margin (dB)
M_t = Time Availability Margin (dB)
M_m = Multipath Margin (dB)
M_h = Height Gain Allowance (dB)
M_e = Environmental Noise Allowance (dB)
M_i = Interference Margin (dB)

Appendix B:

DVB-T modulation schemes

Table B.1: Net data rates in the DVB-T 7 MHz system (Mbit/s)

Modulation	Code Rate [1]	Guard Interval				Required C/N Ricean Channel	ΔC/N [2]
		1/4	1/8	1/16	1/32		
QPSK	1/2	4.354	4.838	5.123	5.278	3.6	-13.5
	2/3	5.806	6.451	6.830	7.037	5.7	-11.4
	3/4	6.532	7.257	7.684	7.917	6.8	-10.3
	5/6	7.257	8.064	8.538	8.797	8.0	-9.1
	7/8	7.62	8.467	8.965	9.237	8.7	-8.4
16-QAM	1/2	8.709	9.676	10.246	10.556	9.6	-7.5
	2/3	11.612	12.902	13.661	14.075	11.6	-5.5
	3/4	13.063	14.515	15.369	15.834	13.0	-4.1
	5/6	14.515	16.127	17.076	17.594	14.4	-2.7
	7/8	15.240	16.934	17.930	18.473	15.0	-2.1
64-QAM	1/2	13.063	14.515	15.369	15.834	14.7	-2.4
	2/3	17.418	19.353 [3]	20.491	21.112	17.1	0
	3/4	19.595	21.772	23.053	23.751	18.6	+1.5
	5/6	21.772	24.191	25.614	26.390	20.0	+2.9
	7/8	22.861	25.401	26.895	27.710	21.0	+3.9

Guard Time: (μsec)					
	‘2K’	64	32	16	8
	‘8K’	256	128	64	32

Note 1: Net bit rates increase with higher inner code rates, shorter guard intervals and higher states of subcarrier modulation.

Note 2: The ΔC/N figures are approximate, as slightly different implementation margins may be required for different modulation schemes.

Note 3: Reference modulation scheme for planning of digital television services.

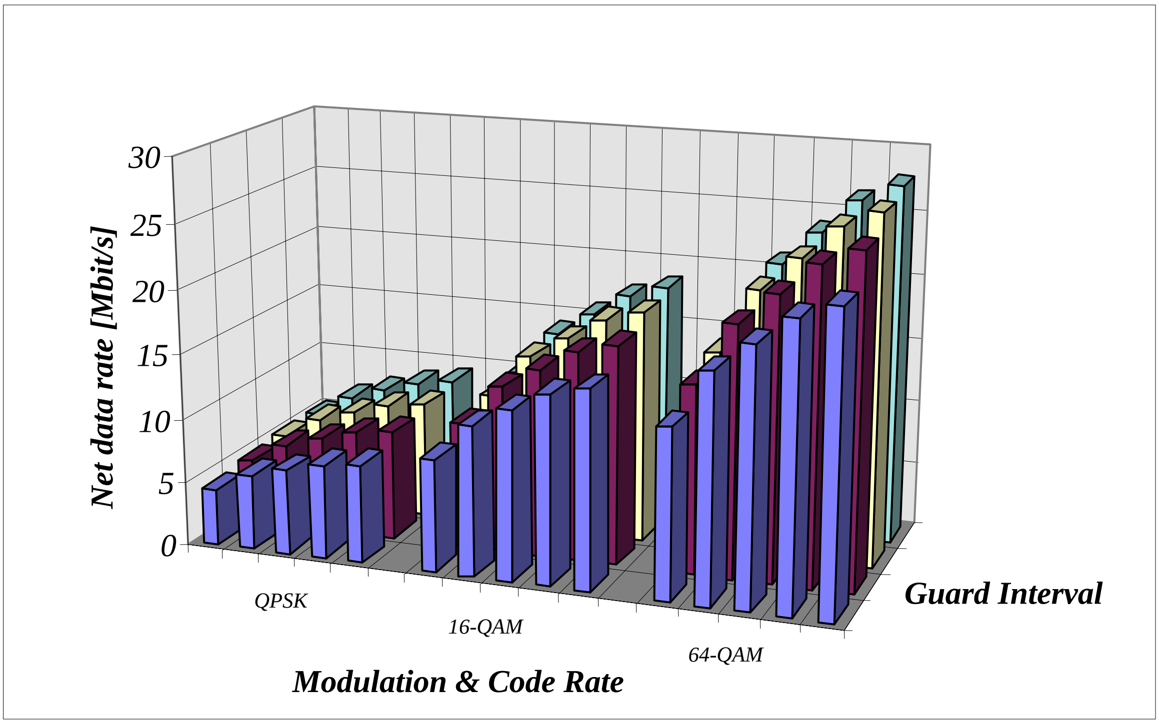


Figure B.1: Net data rates in the DVB-T 7 MHz system

Appendix C:

Protection ratios

The protection ratios shown in the following tables have been extracted from ITU-R Recommendation BT.1368-4, entitled *Planning Criteria for Digital Terrestrial Television Services in the VHF/UHF Bands* and are applicable to the reference modulation defined in section 2.2.1. Recommendation BT.1368-4 should be referenced directly for protection ratios associated with other modulation schemes.

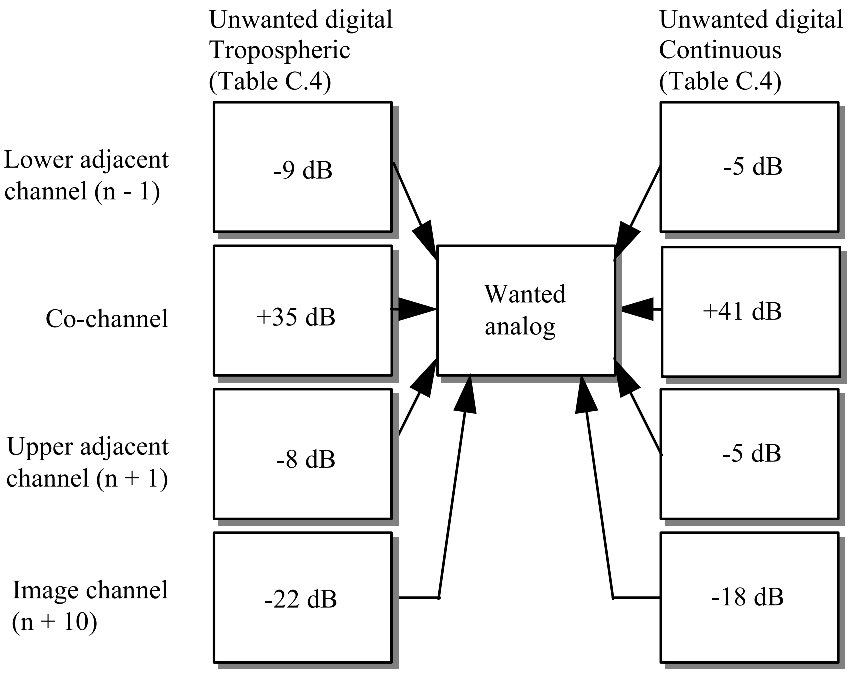


Figure C.1: Analog protection ratios for continuous and tropospheric interference

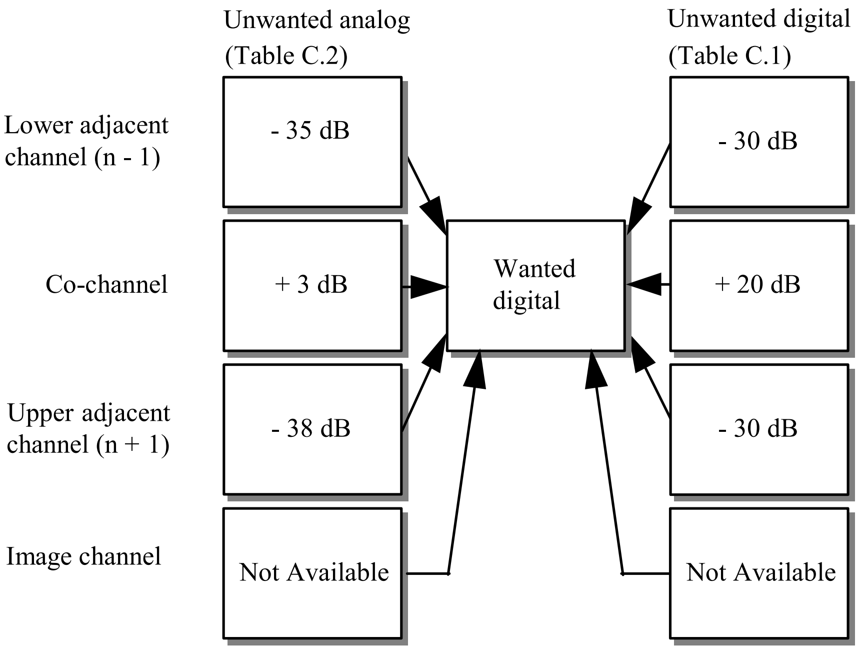


Figure C.2: Digital protection ratios for continuous and tropospheric interference

Table C.1: Protection ratios (dB) for a DVB-T 7 MHz signal interfered with by a DVB-T 7 MHz signal

Parameter	Δf	Tropospheric/Continuous	ITU Table
Lower Adjacent (n – 1)	-7	-30	Table 15
Co-channel (n)	0	+20	Table 14 [1, 2]
Upper Adjacent (n + 1)	+7	-30	Table 15
Local Oscillator			Not Available
Image Channel			Not Available

The frequency difference (Δf) is the centre frequency of the unwanted DVB-T signal minus the centre frequency of the wanted DVB-T signal in MHz

Note 1: Table 14 of ITU-R Recommendation BT.1368-4 provides co-channel protection ratios for three types of propagation channels (Gaussian, Ricean and Rayleigh). For fixed antenna reception, a Ricean channel profile will generally be experienced.

Note 2: For overlapping channels, in absence of measurement information, and if the overlapping bandwidth between the wanted and unwanted signals is less than 1 MHz, the protection ratio, PR, should be extrapolated from the co-channel ratio figure as follows:

$PR = 20 + 10*Log_{10}[Overlap (MHz)/6.7 (MHz)]$

PR= -30 dB should be used when the above formula gives PR < -30 dB.

Table C.2: Protection ratios (dB) for a DVB-T 7 MHz signal interfered with by an overlapping PAL B TV signal including sound

Parameter	Δf	Tropospheric/Continuous	ITU Table
Lower Adjacent (n-1)	-9.25	-35	Table 17/20
	-8.75	-12	Table 20
	-8.25	-11	Table 20
	-7.75	-5	Table 20
	-6.25	-3	Table 20
	-3.45	-1	Table 20
	-3.25	+4	Table 20
Co-channel (n)	-2.25	+3/+1	Table 16/20
	-1.25	0	Table 20
	0	+2	Table 20
	1.75	-5	Table 20
	2.75	-5	Table 20
	4.25	-36	Table 20
Upper Adjacent (n + 1)	4.75	-38	Table 18/20

The frequency difference (Δf) is the vision carrier of the analog television signal minus the centre frequency of the DVB-T signal in MHz

Table C.3: Protection ratios (dB) for a DVB-T 7 MHz signal interfered with by a T-DAB signal

Parameter	Tropospheric/Continuous	ITU Table
Lower Adjacent (n – 1)	-30	Table 25
Co-channel (n)	+24	Table 24 [1]
Upper Adjacent (n + 1)	-30	Table 25

Note 1: Protection ratio is based on four equal interfering T-DAB signals within the DVB-T channel.

Table C.4: Protection ratio (dB) for an analog (PAL B) vision signal interfered with by a DVB-T 7 MHz signal

Parameter	Δf	Tropospheric	Continuous	ITU Table
	-7.75	-16	-11	Table 33
Lower Adjacent (n-1)	-4.75	-9	-5	Table 29/33
	-4.25	-3	+4	Table 33
	-3.75	+13	+21	Table 33
	-3.25	+25	+31	Table 33
	-2.75	+30	+37	Table 33
	-1.75	+34	+40	Table 33
	-0.75	+35	+41	Table 33
Co-channel (n)	2.25	+35	+41	Table 28/33
	4.25	+35	+40	Table 33
	5.25	+31	+38	Table 33
	6.25	+28	+35	Table 33
	7.25	+26	+33	Table 33
	8.25	+6	+12	Table 33
Upper Adjacent (n + 1)	9.25	-8	-5	Table 30/33
	12.25	-8	-5	Table 33
Image Channel (n+10)		-22	-18	Table 32

The frequency difference (Δf) is the centre frequency of the DVB-T signal minus the vision carrier frequency of the analog television signal in MHz

Table C.5: Protection ratios (dB) for FM sound signal of an analog (PAL B) system interfered with by a 7 MHz DVB-T signal (overlapping channel)

	DVB-T below FM		DVB-T above FM		
Δf	**Tropospheric**	**Continuous**	**Tropospheric**	**Continuous**	**ITU Table**
-500	0	+9	+5	+15	Table 36
-250	0	+9	+5	+15	Table 36
-50	0	+9	+4	+14	Table 36
0	+5	+14	+3	+12	Table 36
50	+5	+14	-9	-6	Table 36
250	+6	+15	-22	-16	Table 36
500	+6	+16	-32	-27	Table 36

The frequency difference (Δf) is the frequency of the 3 dB point of the DVB-T signal minus the FM carrier frequency in kHz

Table C.6: Protection ratios (dB) for T-DAB signal interfered with by a DVB-T 7 MHz signal

Parameter	Δf	Tropospheric/Continuous	ITU Table
Terrestrial DAB	-4.5	-49	Table 39
	-3.7	0	Table 39
	-3.5	+1	Table 39
	-2.5	+2	Table 39
	0	+2	Table 39
	2.5	+2	Table 39
	3.5	+1	Table 39
	3.7	0	Table 39
	4.5	-49	Table 39

The frequency difference (Δf) is the centre frequency of the DVB-T 7 MHz signal minus the centre frequency of the T-DAB signal in MHz

APPENDIX D:

DTTB notional receiving system

Table D.1: DVB-T 7 MHz notional receiver

Parameters	Band III	Band IV	Band V
Frequency [f(MHz)]	230	582	820
Equivalent noise bandwidth [1] [b(MHz)]	6.7	6.7	6.7
Receiver noise figure [F(dB)]	6	7	8
Receiver noise input voltage [V_r(dBμV)] 75Ω, 290K, 6.7MHz	9	10	11
Required threshold C/N [2] (dB)	20	20	20
Minimum receiver input voltage [V_{min}(dBμV)]	29	30	31

Table D.2: Notional receiving system (R = Rural, S = Suburban, U = Urban)

Parameters	Band III			Band IV			Band V		
	R	**S**	**U**	**R**	**S**	**U**	**R**	**S**	**U**
Antenna gain relative to half wave dipole [G_d(dBd)]	8	5	5	11	8	8	12	9	9
Feeder loss [L(dB)] RG59 @ 15m	3	3	3	4	4	4	5	5	5

Note 1: The noise bandwidth is equal to the COFDM spectrum bandwidth as the FFT decoding mechanism in the receiver effectively provides a digital filter with a width of the COFDM spectrum.

Note 2: For the reference 64 QAM modulation, 2/3 code rate and 1/8 guard interval, the DVB-T system has a theoretical C/N threshold of 16.5 dB in a Gaussian channel. Tests of early receiver prototypes have shown that an implementation margin of 2.5 dB is required, resulting in a 19 dB C/N threshold in a Gaussian channel. For fixed antenna reception, a Ricean channel profile will generally be experienced, resulting in an increase in the theoretical C/N requirement for demodulation of 0.6 dB. For operation through a practical RF transmission system, an additional C/N allowance of 0.4 dB has been made. Combining these figures, for planning purposes, the notional threshold C/N requirement is taken to be 20 dB.

Appendix E:

RF channel arrangement for television services in the broadcasting services bands

Table E.1: Australian television broadcasting bands – Television channel numbers and frequency limits (MHz)

VHF		UHF			
BAND I [1]		**BAND IV**		47	659-666 MHz
0	45- 52 MHz	27 [5]	520-526 MHz	48	666-673 MHz
1	56-63 MHz	28	526-533 MHz	49	673-680 MHz
2	63-70 MHz	29	533-540 MHz	50	680-687 MHz
		30	540-547 MHz	51	687-694 MHz
		31	547-554 MHz	52	694-701 MHz
BAND II [1]		32	554-561 MHz	53	701-708 MHz
3	85-92 MHz	33	561-568 MHz	54	708-715 MHz
4	94-101 MHz	34	568-575 MHz	55	715-722 MHz
5	101-108 MHz	35	575-582 MHz	56	722-729 MHz
				57	729-736 MHz
		BAND V		58	736-743 MHz
BAND III		36	582-589 MHz	59	743-750 MHz
5A [2]	137-144 MHz	37	589-596 MHz	60	750-757 MHz
6	174-181 MHz	38	596-603 MHz	61	757-764 MHz
7	181-188 MHz	39	603-610 MHz	62	764-771 MHz
8	188-195 MHz	40	610-617 MHz	63	771-778 MHz
9	195-202 MHz	41	617-624 MHz	64	778-785 MHz
9A [3]	202-209 MHz	42	624-631 MHz	65	785-792 MHz
10 [4]	208-215 MHz (superseded)	43	631-638 MHz	66	792-799 MHz
	209-216 MHz (current)				
11 [4]	215-222 MHz (superseded)	44	638-645 MHz	67	799-806 MHz
	216-223 MHz (current)				
12 [3]	223-230 MHz	45	645-652 MHz	68 [6]	806-813 MHz
		46	652-659 MHz	69 [6]	813-820 MHz

Note 1: Television Band I (channels 0, 1 & 2) and Band II (channels 3, 4 & 5) are not being considered for the introduction or ongoing transmission of digital television services.

Note 2: VHF channel 5A is currently within the broadcasting services bands (BSB) and has been recommended for clearance by the ABA and ACA to allow for the introduction of low earth orbiting (LEO) satellites. Channel 5A is not being considered for the introduction or ongoing transmission of digital television services.

Note 3: Clearance of radiocommunication services from 202-208 MHz and from 222-230 MHz has allowed a revised channel arrangement to be implemented. The current channel arrangement has two new channels (channels 9A and 12). To accommodate channel 9A, channels 10 and 11 were shifted up in frequency 1 MHz.

Note 4: The majority of existing services on channels 10 and 11 were assigned using the superseded channel arrangement. Services on channels 10 and 11 may be required to shift in frequency to align with the current channel arrangement. Any such requirement will be considered on a case by casebasis. New services on channels 10 and 11 will be assigned according to the current channel arrangement i.e. channel 10 (209-216 MHz) and channel 11 (216-223 MHz).

Note 5: UHF television channel 27 has a bandwidth of 6 MHz and therefore is not currently suitable for digital television services. The ABA and ACA are considering ways of making use of channel 27 as a 7 MHz channel.

Note 6: The ABA and ACA are considering spectrum that may be re-allocated for non-broadcasting purposes due to the increased spectral efficiency with digital television. In particular the use of part, or the entire frequency band 806-820 MHz is under consideration. Where practicable the ABA will endeavour to avoid the use of channels 68 and 69.

Appendix F:

Summing signal levels for coverage assessment

In the planning of analog and digital television services, consideration must usually be given to potential interference from multiple sources e.g. other co-channel or adjacent channel services operating in the same or adjacent areas. In the case of a single frequency network (SFN), there may also be multiple wanted or 'useful' signals. To assess the resultant wanted and unwanted field strengths, these individual signals have to be combined.

Where signal strengths are described by statistical quantities they have to be combined statistically. Although this is true for both location and time statistics, it is usual practice to treat them differently. Time statistics are taken account of using field strength propagation curves for the appropriate time percentages. Location statistics are dealt with through field strength distributions.

A description of the more commonly used methods for summation of individual field strength distributions, in order of increasing complexity, is provided below.

Power sum method

In this method, the sum signal level is calculated by a non-statistical summation of the individual signal powers. For the unwanted signal, the powers of the median values of the individual nuisance fields, as described in section 3.3.8, are added to the power of the minimum median field strength (representing the noise contribution), and the usable field strength determined. For the wanted signal in an SFN, the powers of the median values of the useful fields are added. The required field strength of the wanted signal is then given by:

$$E_r = 10 \times \log_{10}\left(10^{\frac{E_{min}}{10}} + \sum_{i=1}^{n} 10^{\frac{E_{ni}}{10}} \right)$$

where:

E_r required sum field strength of the wanted signal (dBμV/m)

E_{min} minimum median field strength (dBμV/m) of the wanted signal as given in *Technical Planning Parameters and Methods for Terrestrial Broadcasting* in case of a wanted analog signal and table 4.2 in case of a wanted digital signal

E_{ni} nuisance field strength of the i-th unwanted signal (dBμV/m) and

n number of interferers in the analysis.

The power sum method gives acceptable results for median values (i.e. 50% locations) but shows poor correlation at higher percentages due to its non-statistical nature. Estimates of digital coverage using this method should be considered as indicative only.

Simplified multiplication method

The simplified multiplication method is a statistical computation procedure developed initially for assessing the coverage probability of analog services in the presence of multiple interferers.

The method is prefaced on the following assumptions:

- wanted and nuisance signals are log-normally distributed with known means and standard deviations
- no correlation exists between the wanted and nuisance signals
- one nuisance field dominates at the reception location and
- the influence of noise, represented by the minimum median field strength of the wanted signal, can be neglected.

Using this method the usable field strength can be calculated by iteration from:

$$P_c = 100 \times \prod_{i=1}^{n} L(x_i)$$

with

$$x_i = \frac{E_r - E_{ni}}{\sigma\sqrt{2}}$$

where:

P_c desired coverage probability in the presence of *n* nuisance fields

$L(x_i)$ coverage probability in the presence of the single (i-th) nuisance signal, given by the probability integral for the normal distribution

E_{ni} nuisance field strength of the i-th unwanted signal (dBμV/m)

E_r required field strength of the wanted signal (dBμV/m) for the desired coverage probability and

σ standard deviation (dB) of the wanted and nuisance signals.

As the effect of noise is not taken into account in this method, over-estimation of the coverage can be expected when the nuisance fields of the interferers are low. It should also be noted that the method is not able to deal with multiple useful signals, and is therefore not applicable to SFNs.

The simplified multiplication method is explained in detail in ITU-R Report 945 [15] and in O'leary and Rutkowski [16].

Log-normal and simplified log-normal methods

The log-normal method (LNM) is an approximation method for the statistical calculation of the sum distribution of several log-normally distributed signals. The method is based on the assumption that that the resulting sum distributions of the wanted and nuisance fields are also log-normally distributed. To some extent, the LNM is able to deal with different standard deviations of the single field distributions.

The procedure is comprised of several steps. First, the composite wanted and unwanted nuisance fields are calculated. Then the corresponding carrier-to-interference and carrier-to-noise distributions are evaluated. Finally, the coverage probability is determined by the combination of the two distributions.

To improve the accuracy of the LNM in the high probability region (i.e. high location values) a correction factor (k) can be introduced. The value of k varies depending on the number, mean power and standard deviation of the nuisance fields involved. In practice, an average value is adopted in order to simplify the calculation. This version of the LNM is known as k-LNM. Algorithms for both the standard LNM and k-LNM are given in EBU document BPN 005 [8].

A further variant of the LNM is described in ITU-R Report 945. This method seeks to further simplify the calculation of usable field strength by treating the minimum median field strength of the wanted signal (representing the noise contribution) as an additional interferer. This 'simplified LNM' is only applicable to 50% location probability and is therefore not suited to digital coverage assessment.

t-LNM method

The t-LNM is a numerical approximation method for the statistical calculation of the sum distribution of several log-normally distributed signals. It is similar in structure to the LNM and is prefaced on the same principle assumption i.e. that the sum distribution of two log-normal signals is also log-normal. However, the parameters of the sum distribution are calculated differently from those of the standard LNM.

This approach leads to improved accuracy in the high probability region (i.e. high location availabilities) compared to the standard and k-LNM approaches, although at the expense of additional complexity. The t-LNM is able to deal with different standard deviations of the single fields with relatively few restrictions.

A description of the method is also provided in EBU document BPN 005.

Appendix G:

Evaluation of coverage probability

In a receiving situation where signal summation effects become important (e.g. SFNs), minimum median field strengths and location correction margins for protection ratios are no longer suitable planning parameters. These parameters have to be replaced by the more fundamental system values for minimum field strengths, protection ratios and coverage probability targets, and a statistical evaluation of the signal configuration performed.

In assessing coverage and compatibility, the same basic procedure is applied as in the standard case. At each 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 served. However, the way this result is derived differs between the two approaches.

The statistical approach performs the evaluation (field strength prediction and statistical summation) of the wanted and unwanted signals at **each** location taking account of the individual signal variation effects, whereas the standard approach shifts all statistical effects into a **single** value which is reflected in the location correction figure (for minimum median field strength) and the location correction margin (for the protection ratio).

The statistical procedure is as follows:

- evaluate, using an appropriate prediction method, the median field strengths of the individual wanted and unwanted fields at the receiving location
- add to each unwanted field the appropriate protection ratio and receive antenna directivity & polarisation discrimination values to obtain the respective nuisance fields. The applicable protection ratios may be obtained from appendix C
- noise may be treated as an additional interfering field. This is achieved by taking the system value of the minimum field strength as the 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 the ‘minimum field strength’ listed in the table of section 5.2 of appendix A, increased by the ‘multipath margin’, ‘height gain allowance’, the ‘additional allowance for environmental noise’ and ‘interference margin’

- evaluate the distribution parameters (i.e. mean and standard deviation) of the wanted and unwanted sum fields by means of a statistical summation method (see appendix F). The mean value and standard deviation of the respective sum fields F_{Σ}^{w} and F_{Σ}^{u} are denoted by $\overline{F}_{\Sigma}^{w}$, σ_{Σ}^{w} and $\overline{F}_{\Sigma}^{u}$, σ_{Σ}^{u} ('w' for wanted, 'u' for unwanted)
- the coverage probability at the considered location is given by

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

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

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

  and the function I is given by

  $$\mathrm{I}(\mathrm{F},\sigma) = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{-\mathrm{F}}{\sigma\sqrt{2}}\right)\right], \text{ where } \sigma = \sqrt{\left(\sigma_{\Sigma}^{w}\right)^2 + \left(\sigma_{\Sigma}^{u}\right)^2} \text{ and } \mathrm{F} = \overline{\mathrm{F}}_{\Sigma}^{w} - \overline{\mathrm{F}}_{\Sigma}^{u}$$

  The error function erf is equal to twice the integral of a normalised Gaussian distribution between 0 and $\mathrm{F}/\sigma\sqrt{2}$ and is readily calculated with use of tables (see ITU-R Report 945) or by numerical approximation.

Appendix H:

Implementation plans

The implementation plan is a key step in the digital conversion process. It is a broadcaster's binding commitment to:

- provide transmission of a commercial or national television broadcasting service (whichever is applicable) in digital mode from specified sites
- cover specified areas by specified dates and
- achieve the same level of coverage and potential reception quality in SDTV digital mode as is achieved by the transmission of that service in analog mode.

Commercial television broadcasting service

Each holder of a commercial television broadcasting licence for a licence area will be required to submit to the ABA at least one implementation plan, dealing with important technical and administrative aspects of conversion to digital transmission in that area.

The holder may submit a single, comprehensive, plan for the area or the ABA may allow the holder to submit a series of plans that develop the holder's digital transmission arrangements for the area in stages.

The ABA will assess the implementation plan (or a plan that is part of a series), and approve or refuse to approve the plan.

An approved implementation plan is the basis on which the holder will convert to digital transmission. However, as conversion proceeds, the holder may arrange for an approved implementation plan to be varied to reflect changed circumstances or needs that arise.

National television broadcasting service

Each national television broadcaster that broadcasts in a coverage area will be required to submit to the Minister at least one implementation plan, dealing with important technical and administrative aspects of conversion to digital transmission in that area.

The national broadcaster may submit a single, comprehensive, plan for the area or a series of plans that develop the national broadcaster's digital transmission arrangements for the area in stages.

Before deciding whether to approve an implementation plan (or a plan that is part of a series), the Minister may direct the ABA to provide a report on the matter.

An approved implementation becomes the basis on which the national broadcaster will convert to digital transmission. However, as conversion proceeds, the national broadcaster may ask for the approved implementation plan to be varied to reflect changed circumstances or needs that arise.

ABA application forms

The following are the application forms required for an implementation plan:

Form ABA 46 – *Form B – Application for approval of a commercial television implementation plan* (to be submitted with an implementation plan).

Form AB 47 – *Form C – Commercial television implementation plan* (proforma).

Form AB 48 – *Form D – Application for variation of an approved commercial television implementation plan*.

Form ABA 49 – *Form E – Application for approval to transmit in a regional licence area before start of simulcast period*.

Forms can be obtained from the ABA's website (http://www.aba.gov.au/forms/index.htm).