The conventional planning approach applied to digital terrestrial television

K.J. Hunt (EBU)

This article continues and expands upon the discusion started in [3]. It is becoming ever more clear that the future of broadcasting, and that of television in particular, is digital. The transfer to digital is already taking place in the studio; many contribution circuits are already digital; the final stage in this process involves the transmission and reception part of the overall chain.

The potential benefits are considerable. The greater spectrum economy of digital signals will provide the capacity for more services, while also providing higher technical quality for the pictures displayed in viewers' homes.

The main difficulty lies in finding the spectrum in which to introduce the digital services, while maintaining the existing analogue services in operation for what could be an extended transition period.

1. Introduction

This article outlines the studies being carried out for the implementation of terrestrial digital services under the general description of "conventional planning". This term is used to cover those cases in which digital television transmitters, in general, re–use the same sites as existing analogue television transmitters and the frequency planning approach adopted would be similar to that for analogue services.

It is not intended to imply that all existing analogue sites would be used in this way, nor is it intended to imply that some additional sites for digital service transmitters would not be implemented.

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

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

Another aspect of conventional planning is that it makes an inherent assumption that the existing

Original language: English
Manuscript received 22/6/94.

analogue services, which currently serve more than 98% of the population in most European countries, will remain in use for many years and that relatively few changes to the analogue stations will occur in that time. In particular, there are likely to be no generally–applied channel or site changes within the analogue networks.

However, it may be found desirable to introduce a limited number of channel, or even site, changes at some of the lower power analogue stations where this can be shown to have a significant impact on the implementation opportunities for digital stations and services. In this context, it is important to remember that there are some 40,000 analogue television transmitters already in use in Europe and that the resultant channel usage is very intensive.

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

Even though no choice has yet been made in Europe of the system which will be used for terrestrial digital television, it seems reasonably clear that the future will involve a transition to all digital services. It is also reasonably clear that digital television can and will be implemented in channels of about the same width as those used for analogue television – although such a channel may well contain more than one television programme. Because of this similarity of bandwidth between analogue and digital systems, it is obvious that attempts should be made to accommodate the new digital services within the same spectrum as that already used by analogue television.

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

Of course the fact that an *attempt* is made to re–use analogue television spectrum does *not* give a guarantee of success. We have some 40,000 television transmittersin use in Europe and the philosophy of national coverage which applies in virtually all countries means that these stations are supposed to be protected against interference, whether this comes from analogue or digital stations.

2. Protection of existing analogue services

This matter of protection of the analogue services is of great importance. When digital television was first being promoted, there were some claims that digital transmissions would have only a low interference impact on analogue television. Indeed, there were some claims that there would be no interference at all! The truth is much less optimistic. Digital signals behave rather like noise and their impact on analogue television is also similar to that of noise.

For the analogue television systems used in Europe the protection ratio against interference from a digital television signal is around 40 dB; slightly above 40 if the required analogue picture quality is Grade 4 (appropriate if the interference is continuous) and slightly below 40 for Grade 3 (appropriate if the interference is only present for a few percent of the time). Such figures are not dissimilar from those for the case of interference from another analogue television signal. Indeed, in the case where both analogue signals have precision control of their frequencies, the analogue–to–analogue protection ratios can be in the mid 20s (dB). The implication is that it may not really be easier to plan for new digital services than for new analogue ones.

However, the last point is an over–simplification. Digital receivers can operate with lower values of input signal than can analogue receivers. The amount of the reduction depends essentially on the C/N requirement of the digital signal and this, in turn, depends on the complexity of the digital signal. Very rugged digital services, targetted essentially at portable receivers, may have a C/N requirement of around 8 dB. HDTV would have a C/N requirement in excess of 20 dB.

To complicate this point, it has to be noted that there are many quality levels under discussion and many proposals for multiple programmes in a single channel. At present, there are system proposals with C/N requirements ranging from less than 8 dB to more than 30 dB. The comparison with signal level requirements of analogue systems is thus not easy. A simplification would be to say that the more complex digital systems require about the same minimum field–strength as analogue systems while the simplest and most robust digital systems can work with minimum signal levels some 20 dB lower than those required by analogue systems.

3. Achievable coverage for digital stations

Taking into account the need to protect the existing analogue services means, first of all, that the size of these coverage areas must be calculated. Although this has been done by most countries in Europe on an individual basis, it was decided to perform a series of calculations so that results for all European countries would be available on the same basis. At least this provided the opportunity to have a consistent view of the impact of digital television services, even in cross–border situations.

This analysis was made using a database of analogue stations which are currently operating. Of course there are other stations or even networks which have been planned and fully coordinated between neighboring administrations, but it was decided not to take these into account at present.

Using the results of the above analysis, it is then possible to calculate the maximum power which can be radiated from a new digital station in a given direction and on a given channel while still protecting analogue services against interference. In practice, this last criterion means that an increase in total interference of no more than 0.5 dB is permitted. Such an increase is generally regarded as below the threshold of visibility and a more relaxed criterion may be agreed later.

At most existing sites, it is found that there are severe restrictions on the radiated power for new digital stations on most channels. This is a direct result of the intensive use of the spectrum by analogue services and the strict interference criteria which are applied to them. Indeed, it is precisely these restrictions which prevent the introduction of new analogue services in most countries in Europe.

The advantage of digital services is that they can make use of lower wanted signal levels than can analogue services.

The result is that although the radiated power of a digital transmission may have to be kept low in order to protect existing analogue services, it may be possible, even so, to achieve a fairly substantial coverage area for the digital service from some sites, on some channels. In this context, fairly substantial means 60 to 70% of the coverage area of any existing analogue service from the same transmitter site. It must be noted, however that such values imply equivalent methods of reception. One must compare digital reception using a roof–level antenna with analogue reception using a roof–level antenna or compare digital reception on a portable receiver using a built–in or set–top antenna with analogue reception using a similar portable receiver.

It must also be noted that there will be major differences between different countries and between different stations in any given country.

The digital coverage achievable will be very dependent upon the degree of development of the analogue services. In a country with a large number of analogue programme chains and with a very extensive network of relay stations, it is to be expected that there will be less opportunity for digital stations and services. There will be fewer channels available for the digital services and for those channels which are available there will be more severe power restrictions on the digital service in order to protect the analogue services.

4. Elements of planning

4.1. Planning criteria

Some of the basic planning criteria have been reported elsewhere, for example in [1] which deals with the signal level requirements and provides preliminary information regarding protection ratios.

Further study is needed in some cases regarding the application of these criteria, especially in the case of protection of existing analogue services. This matter is discussed in more detail in *Appendix 1*. In addition, the range of C/N values under discussion for different digital systems and their variants is becoming very large and the differences between some of the C/N values are smaller than the inherent accuracy of the propagation prediction methods available. It will be necessary to restrict the interim planning studies to a representative sub–set of C/N values.

4.2. Propagation prediction methods

Propagation prediction methods using information from a terrain data bank exist in a number of countries and give significant improvements in prediction accuracy when compared with simple methods such as ITU–R Recommendation PN.370 [2]. However, it has been found that these newer methods cannot be relied upon to give accurate results when used with the terrain data from another country. It is believed that this is primarily due to the use of empirical correction factors within each of the computer programmes which improve results for the type of terrain found in a specific country. It is hardly surprising that a fairly flat country will need different empirical correction factors from those used by a mountainous country.

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

The Recommendation 370 method has recently been extended to deal, among other things, with effective transmitting antenna heights outside the range 37.5 to 1200 m and this extension has been included within the computer modules in use, even though, in a formal sense, it has not yet reached the status of a full ITU–R Recommendation.

Because of the very significant differences in propagation conditions for overland and over sea paths, a simplified coastline of Europe has been included in the propagation prediction modules.

4.3. Station information

Although a detailed database of television station information is in the process of preparation, it is still not sufficiently complete to be usable and current planning studies continue to use a database which was derived from the EBU List of VHF/UHF television stations. This list contains the television transmitters which are currently in operation in Europe. It does not include any transmitters which have been planned and co–ordinated between neighbouring countries but which have not yet been brought into operation. In some countries, transmitters in this category may be of high power and if an individual administration decides to implement any of these stations for analogue services, there could be a major impact on the planning of digital stations.

In practice, as has been noted before [3], studies are currently confined to the UHF bands because of the irregular channel plan for the VHF bands and the mixture of 7 and 8 MHz channel widths.

5. Planning methods

5.1. General

Using the station information (*Section 4.3.*) and the propagation prediction modules (*Section 4.2.*) it is possible to predict both wanted and unwanted signal levels for any location. However, the first stage is to determine the permitted radiated power in any direction for individual digital television stations on specified channels. In turn this demands a knowledge of the size of the existing analogue service areas.

A detailed examination of some of the factors involved in coverage determination is given in *Appendix 1*.

5.2. Establishment of the size of analogue coverage areas

Before any estimate can be made of the e.r.p. which a digital service (on a given channel from a given transmitting station) can use without causing excessive interference to any analogue service, it is necessary to establish the size of the analogue coverage area for each station and channel, in use or planned and fully co–ordinated.

Because a certain amount of iteration is involved, the analogue coverage areas are determined in two stages. In the first stage the service area is found. This term is used to describe the area which could be served if there were no interference. It is approximated on the basis of 36 radii, at 10 degree intervals, starting at true north. Where known, the HRP of the transmitting antenna and individual values of height above mean terrain are taken into account.

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

The nuisance field–strength from each of the interfering stations in this sub–set is calculated at each of the 36 points around the periphery of the wanted stations service area. (That is, at the service radius on each of the 36 bearings described above.) The power sum of these nuisance field–strengths is found for each of the 36 points. These power sums represent the total interference at each of the 36 points. For each of the 36 radials, it is then necessary to find the new radius at which the field–strength from the wanted station equals the sum of the nuisance fields.

Because, in general, the coverage radius thus calculated will not equal the service radius on the same bearing and thus the nuisance field–strengths will change, the process of the previous paragraph is repeated to obtain a close approximation to the required coverage radius on each of 36 bearings. (Further interations may be made if necessary).

For statistical purposes, the 36 coverage radii thus calculated may be used to calculate a coverage area in square kilometers.

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

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

5.3. Establishment of the size of digital coverage areas

This part of the overall process is substantially more complicated than any earlier part. The primary reason for this is that there are more variables, most of which have unknown values at the start of the planning process. For example, the maximum e.r.p. is unknown, the HRP is unknown and the polarization is unknown. In addition, there are several different standards of digital service which could be planned for, represented for planning purposes by their C/N values.

Clearly, it is highly desirable to divide these variants into identifiable categories:

– the maximum e.r.p. can be the largest value which does not cause unacceptable interference to existing or planned analogue services;

– the HRP may be the same as an existing analogue service on the same site *or* it may be non–directional *or* it may be entirely new;

– the polarization may be the same as that of an existing analogue service on the same site *or* it may be orthogonal to it;

– each channel in turn may be assigned to the digital service, the only channels being excluded are those in use or planned for use by an analogue service on the same site;

– a planning study may be conducted for any required standard of digital service.

Some of the above elements have a strong degree of interaction. The maximum value of e.r.p. depends on the HRP and on the polarization, for example, but can, in any case, be expressed in terms of a set of reductions below the e.r.p. of an existing analogue service.

Some care must be taken with regard to the values of interference from digital services which would be permitted by the above approach. For example, if the nuisance field from a digital transmission equals the sum of the nuisance fields from all analogue services, this is equivalent to a 3 dB increase interference. This is unlikely to be acceptable as a basis for co–ordination. It seems more realistic to allow for, say, a 0.5 dB increase in interference.

In practice, it seems necessary to adopt a two–category approach, although there is as yet no formal agreement for this. In this, the e.r.p. which a digital station might be able to use will be determined in such a way that interference to all analogue stations with more than some specified e.r.p., say 100 W, is avoided. The impact of the digital station on analogue stations of lower e.r.p. will then be determined.

This process is substantially less restrictive than assuming that the digital station must not cause interference to *any* analogue station. Even so, it will probably be necessary to determine the interference only to analogue stations with e.r.p.s down to, say, 10 W. To include all power levels would be too time consuming, especially in the subsequent analysis of the calculated results, and would not add significantly to the overall accuracy.

It will be necessary to carry out a number of experiments to determine suitable e.r.p. values to be used for the two categories. (Category 1 stations are to be protected; category 2 stations will need to have the deterioration determined, but will not necessarily be protected.)

It must be noted that this two category approach may not be acceptable in all countries. The inherent implication in the process is that the Category 2 stations would be able to remain unprotected or would be able to have their channels changed. In some countries, this may be regarded as unacceptable and then analogue stations at all power levels would need to be protected and this will place additional constraints on the radiated power of the digital stations. Of course, it is important to note that the two category process does not imply that all of the lower power analogue stations *will* suffer from interference from digital stations, it only means that restrictions would not be introduced to provide them with protection.

6. Planning studies

Taking the above considerations into account, a series of planning studies has been carried out. These are intended to illustrate the extent of the digital coverage which may be achievable, on any available channel, for a particular set of planning criteria. In this context, the C/N ratio requirement for a specific digital system is particularly important. In order to simplify the results, however, only representative values of 8, 14, 20 and 26 dB have been used for the results presented here.

Typical results are shown in *Tables 1* to *6*. Each of these Tables shows the results obtained for theoretical digital transmissions from an existing analogue transmitter site.Each Table is sub–divided to show results for different C/N ratios (8, 14, 20 and 26 dB). Within each sub–division, values of coverage area are given corresponding to the use of both horizontal and vertical polarization for the digital transmission (values for vertical polarization are shown in italics).

In deriving these values, new optimized radiation patterns for the digital station transmitting antennas were synthesized. These patterns are intended to maximize the coverage of the digital service on a given channel and polarization. Precautions are taken to ensure that the resultant radiation patterns are reasonable from the point of view of being physically realizable for each channel considered separately. However, the antenna is unlikely to be realizable for several channels taken together. It also cannot be assumed that the masts and towers in use would be able to accommodate such antennas. In this sense, the results presented represent an optimistic view of what might be achievable.

It has to be made quite clear that these exercises are intended to explore the possibilities available for digital television services. As yet, there is no attempt to synthesize a plan which would provide services in several countries or even any individual country. There is little reason to try to synthesize a plan until:

– one of the system variants has been chosen in each country;

– decisions about coverage philosophy have been reached in all countries;

– it is clear how many, if any, additional analogue stations are to be implemented in each country.

At present, it seems probable that the decisions on these three points will not be the same in all countries and, if so, this will represent a considerable complexity in the planning software and in the interpretation of the results.

It must be noted that there is also an inherent assumption in these results which may not be valid in all countries. It is assumed that analogue stations with a radiated power of 100 W or more must be protected against additional interference from digital stations. This means that any increase in interference must be limited to 0.5 dB. Analogue stations with radiated power of less than 100 W are not considered in this interference analysis. This means that if there is an increase in interference to an analogue station with a radiated power of less than 100 W, then either this interference must be accepted or a new channel for the analogue station must be found. The latter will not be at all easy.

One should not make too many generalizations on the basis of a limited sub–set of stations, but these and other studies suggest that channels can be found for some digital stations and that in a number of cases the coverage achieved could be a substantial fraction of that of the corresponding analogue station. This suggests that in many countries successful terrestrial digital stations could be introduced.

7. The digital future

One can be forgiven for asking, “why are digital services better?”. The answer must be that in the longer term, when digital services have replaced the analogue ones, the channel and power restrictions will be very much reduced and the opportunities offered by the change to digital will be enormous. Among these opportunities will be:

– improved reception quality with, in particular, no impairment caused by noise or by delayed signals (ghosts);

– good quality reception on portable receivers with a built–in or set–top antenna;

– a large increase in the number of programmes available.

Of course, terrestrial transmissions will not be the only delivery medium but they are the only way of achieving truly portable reception.

8 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		470 *721*	6174 *6320*		1036 *1376*	5542 *6305*		500 *842*	5100 *6007*	3118 *8186*
30		527 *878*	4020 *4112*		7582 *18378*	3296 *7842*		7111 *13170*		753 *1015*
40						758 *1017*			1830 *1739*	
50					1553		1262			1236 *1681*
60			1990							

14 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			4178 *4276*		617 *882*	3653 *4285*		270 *477*	3319 *4119*	1886 *5544*
30		290 *488*	2420 *2517*		5260 *13455*	1952 *5061*		4947 *9606*		425 *615*
40						425 *618*			1115	
50					914					
60			1214							

20 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			2705 *2824*			2359 *2846*			2105 *2705*	1109 *3551*
30			1385 *1421*		3559 *9920*	570 *3124*		3279 *6829*		
40										
50										
60										

26 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			1708 *1733*			1449 *1741*			1272 *1657*	636 *2146*
30			776 *772*		2318 *7038*	570 *1770*		2084 *4726*		
40										
50										
60										

Digital service C/N ratio

Table 1
Results obtained for theoretical digital television transmissions having horizontal and vertical polarization, broadcast from an existing analogue television transmitter site.

Set of results 3–JUN–94 for a digital station complementing analogue station A.
The digital station must protect all analogue stations above 100 W.
The average coverage of the analogue services on the same site is 10000 km^2.
The Table summarises the area (in square kilometers) covered by a digital service on each channel, for vertical and horizontal polarization of the digital transmission. *Values for vertical polarization are shown in italics.*
The coverage area has been suppressed for any case in which:

– a channel is in use for an analogue service from the same site;
– the coverage area is too small to be calculated reasonably accurately;
– the relevant channel is in use by other services (e.g. radioastronomy).

Digital service C/N ratio

8 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		12538 *14771*	19863 *25276*	6421 *10300*	10642 *12248*	7738 *13844*	7478 *10103*		9090 *11340*	2547 *8924*
30		8600 *11164*	1236 *4882*	8474 *9383*	6276 *10660*	1194 *2375*		5200 *10802*		2091 *3563*
40	19735 *16770*	9950 *15541*	2116 *3250*	1035 *1383*	4501 *5668*	2513 *4500*	2322 *3050*	3003 *3879*	4842 *6988*	13764 *22715*
50	1160 *2678*	4876 *5883*	18162 *11697*	2337 *3056*	3687 *5275*	11202 *14634*	12557 *17455*	17818 *25613*	14704 *14714*	
60	14256 *25244*									

14 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		9207 *10888*	13568 *17828*	4206 *6808*	7747 *8896*	5229 *9925*	4965 *6627*		6144 *786*	1548 *6066*
30		6039 *7894*	712 *3243*	5692 *6351*	4283 *7509*	725 *1529*		3483 *7810*		1307 *2342*
40	14271 *12202*	6944 *11156*	1342 *2201*	607 *830*	2986 *3978*	1622 *3010*	1475 *2026*	1889 *2617*	3197 *4814*	9835 *16897*
50	1160 *1733*	3231 *4039*	13359 *8461*	1436 *1984*	2382 *3549*	7691 *19354*	8923 *12940*	13066 *19235*	10489 *10703*	3467 *7468*
60	14256 *18949*									

20 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		6612 *7885*	9129 *12249*	2678 *4349*	5541 *6469*	3378 *6875*	3150 *4292*		4068 *5403*	905 *4049*
30		4057 *5488*	384 *2073*	3702 *4137*	2758 *5223*	406 *958*		2166 *5547*		774 *1432*
40	10101 *8680*	4675 *7877*	813 *1393*		1860 *2635*	979 *1888*	918 *1280*	1123 *1672*	2013 *3140*	6930 *12273*
50	649 *1055*	2113 *2723*	9671 *6123*	818 *1206*	1472 *2258*	5193 *7244*	6224 *9333*	9265 *14313*	7421 *7555*	2241 *5072*
60	10278 *14100*									

26 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		4677 *5650*	6059 *8202*	1679 *2728*	3831 *4580*	2084 *4753*	2016 *2653*		2592 *3564*	518 *2601*
30		2648 *3680*	*1262*	2339 *2632*	1709 *3516*	*553*		1295 *3761*		454 *836*
40	6933 *6028*	3121 *5409*	471 *813*		1086 *1711*	580 *1117*	524 *782*	622 *1021*	1214 *1915*	4720 *8775*
50		1313 *1785*	6916 *4204*		843 *1350*	3404 *4985*	4194 *6614*	6622 *10409*	5139 *5172*	1377 *3359*
60	7211 *10272*									

Table 2
Results obtained for theoretical digital television transmissions having horizontal and vertical polarization, broadcast from an existing analogue television transmitter site.

Set of results 3–JUN–94 for a digital station complementing analogue station B.
The digital station must protect all analogue stations above 100 W.
The average coverage of the analogue services on the same site is 10000 km^2.
The Table summarises the area (in square kilometers) covered by a digital service on each channel, for vertical and horizontal polarization of the digital transmission. *Values for vertical polarization are shown in italics.*
The coverage area has been suppressed for any case in which:

- a channel is in use for an analogue service from the same site;
- the coverage area is too small to be calculated reasonably accurately;
- the relevant channel is in use by other services (e.g. radioastronomy).

Digital service C/N ratio

8 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		5922 *7882*		4349 *6708*	6527 *8506*		3025 *6019*	7033 *9445*		3667 *8441*
30		2517 *6477*	1879 *4470*		7214 *11620*	10994 *20278*		1503 *3204*		
40			487 *1755*		*544*					
50	4798 *7205*	6351 *10158*	658 *904*		2325 *2960*	*1927*		*1981*		
60	1104 *2828*									

14 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		4006 *5706*		2750 *4581*	4514 *6177*		1901 *4054*	4761 *6750*		2368 *6029*
30		1565 *4462*	*2807*		4890 *8386*	7391 *14374*		*2093*		
40			*966*		*308*					
50	3077 *4998*	4244 *7302*	380 *504*		1463 *1970*	*1207*		*1246*		
60	*1800*									

20 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		2571 *3369*		1698 *3095*	2946 *4392*		1170 *2643*	3073 *4644*		1460 *4172*
30		934 *2965*	*1754*		3137 *5859*	4835 *9890*				
40										
50	1906 *3319*	2727 *5077*			882 *1246*					
60										

26 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		1596 *2608*		1019 *2010*	1869 *2951*		689 *1688*	1910 *3073*		874 *2748*
30		*1915*			1971 *4009*	3072 *6726*				
40										
50	1166 *2085*	1710 *3416*								
60										

Set of results 3–JUN–94 for a digital station complementing analogue station C.
The digital station must protect all analogue stations above 100 W.
The average coverage of the analogue services on the same site is 7000 km^2.
The Table summarises the area (in square kilometers) covered by a digital service on each channel, for vertical and horizontal polarization of the digital transmission. *Values for vertical polarization are shown in italics.*
The coverage area has been suppressed for any case in which:

– a channel is in use for an analogue service from the same site;
– the coverage area is too small to be calculated reasonably accurately;
– the relevant channel is in use by other services (e.g. radioastronomy).

Table 3
Results obtained for theoretical digital television transmissions having horizontal and vertical polarization, broadcast from an existing analogue television transmitter site.

Digital service C/N ratio

8 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		3145 *7225*	510 *971*		126 *150*	5026 *7048*	1923 *3643*	638 *1054*	5940 *890*	2707 *1172*
30	2140 *3045*		1593 *2572*	294 *498*	11948 *18269*	877 *1215*	2299 *7398*	2591 *7720*		2980 *5355*
40	5012 *3807*	7065 *9597*	2806 *3458*		20997 *22364*	14917 *21933*	1149 *2359*	546 *1002*		337 *1034*
50	371 *596*	4706 *4261*	1352 *4875*		25319 *38416*		2078 *2622*	2215 *2832*		*4866*
60										

14 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		2038 *4654*	286 *547*		*46*	3440 *5178*	1250 *2467*	364 *646*	3942 *6226*	1745
30	1240 *1818*		1028 *1755*	143 *267*	8820 *13580*	497 *737*	*5018*	1586 *5189*		1985 *3844*
40	3333 *2469*	4779 *6605*	1690 *2095*		14953 *15928*	10628 *15611*	547 *1222*	293 *594*		164 *532*
50	193 *330*	3100 *2757*	821 *3558*		18222 *27338*		1324 *1749*	1413 *1900*		*3123*
60										

20 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		1315 *2992*				2297 *3563*	728 *1571*		2482 *4204*	1084
30	675 *1027*		640 *1116*		6434 *10139*	269 *429*	*3196*	930 *3408*		1303 *2658*
40	2158 *1565*	3168 *4419*	971 *1202*		10733 *11415*	7387 *11253*	260 *590*			*270*
50		1934 *1704*	*2401*		13056 *19737*		862 *1173*	888 *1253*		
60										

26 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		805 *1862*				*2381*	426 *952*		1518 *2762*	
30	345 *562*		369 *674*		4394 *7499*	*225*		*2150*		811 *1826*
40	1367	2020 *2856*			7417 *8016*	5032 *7856*	*299*			
50			*1491*		9030 *14165*		542 *743*			
60										

Table 4
Results obtained for theoretical digital television transmissions having horizontal and vertical polarization, broadcast from an existing analogue television transmitter site.

Set of results 3–JUN–94 for a digital station complementing analogue station D.
The digital station must protect all analogue stations above 100 W.
The average coverage of the analogue services on the same site is 8500 km^2.
The Table summarises the area (in square kilometers) covered by a digital service on each channel, for vertical and horizontal polarization of the digital transmission. *Values for vertical polarization are shown in italics.*
The coverage area has been suppressed for any case in which:

– a channel is in use for an analogue service from the same site;
– the coverage area is too small to be calculated reasonably accurately;
– the relevant channel is in use by other services (e.g. radioastronomy).

Digital service C/N ratio: 8 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			3362 *10344*	15874 *21193*	2 *89*	28289 *30190*	13289 *23043*	*61*	21107 *28121*	15887 *22258*
30	6678 *8390*	539 *2454*		*2995*	2 *120*	14136 *17039*	21080 *24062*	2029 *6520*		*3755*
40	15455 *24143*	15160 *16658*	23084 *24380*	3251 *3529*	2372 *6592*		*4953*	23732 *22337*	20294 *24855*	
50	17219 *23475*	22043 *24597*		6242 *8778*	19300 *24321*		5989 *6563*	14177 *20184*	6461 *9362*	
60	12826 *22248*									

Digital service C/N ratio: 14 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			2083 *7094*	11327 *15472*	0 *18*	20395 *21727*	9226 *16552*	*17*	14971 *20112*	11202 *15951*
30	4358 *5825*	*1512*		*1879*	*28*	9748 *12112*	14898 *17266*	*4327*		*2456*
40	10787 *17289*	10616 *11931*	16536 *17549*	1949 *2176*	*4359*		*3188*	16900 *15980*	14319 *17664*	
50	12155 *16666*	15602 *17473*		3955 *5927*	13599 *17263*		3786 *4222*	9899 *14431*	4145 *6280*	
60	8835 *15793*									

Digital service C/N ratio: 20 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			*4680*	7789 *11131*	*5*	14535 *15544*	6173 *11810*		10439 *14379*	7677 *11353*
30	2832 *3869*	*881*		*1139*	*6*	6504 *8440*	10452 *12204*	*2821*		*1532*
40	7381 *12236*	7277 *8369*	11628 *12533*		*2801*		*2013*	11867 *11345*	10015 *12464*	
50	8366 *11709*	10934 *12310*		2445 *3854*	9440 *12141*		2337 *2707*	6737 *10154*	2612 *4007*	
60	5992 *11038*									

Digital service C/N ratio: 26 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			*3012*	5212 *7754*	*2*	10085 *10821*	4009 *8168*		7128 *10031*	5077 *7809*
30	1717 *2541*				*2*	4192 *5677*	7134 *8467*			
40	4897 *8472*	4843 *5722*	7986 *8707*					8171 *7834*	6822 *8593*	
50	5613 *8037*	7496 *8484*		*2406*	6394 *8368*			4439 *6973*	1587 *2532*	
60	3889 *7563*									

Set of results 3–JUN–94 for a digital station complementing analogue station E.
The digital station must protect all analogue stations above 100 W.
The average coverage of the analogue services on the same site is 6500 km^2.
The Table summarises the area (in square kilometers) covered by a digital service on each channel, for vertical and horizontal polarization of the digital transmission. *Values for vertical polarization are shown in italics.*
The coverage area has been suppressed for any case in which:

– a channel is in use for an analogue service from the same site;
– the coverage area is too small to be calculated reasonably accurately;
– the relevant channel is in use by other services (e.g. radioastronomy).

Table 5
Results obtained for theoretical digital television transmissions having horizontal and vertical polarization, broadcast from an existing analogue television transmitter site.

Digital service C/N ratio

8 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		522 *734*	3178 *5588*	2029 *2553*	1378 *1842*	303 *2297*		213 *1770*	422 *646*	3917 *7710*
30	2736 *3946*		606 *922*		7251 *15094*	*871*	1579 *1702*	942 *593*		
40	1673 *2018*			5444 *7315*		1033 *1763*		845 *1770*		4578 *5974*
50		2998 *4455*		969 *1655*	1864 *6832*	1742 *1742*				
60	929 *1690*									

14 dB

Channel	0	1	2	3	4	5	6	7	8	9
20		253 *374*	1982 *3721*	1130 *1536*	766 *1129*	*1325*		*539*		2523 *5573*
30	1629 *2517*		319 *514*		4849 *10774*	*517*		515		
40	970 *1225*			3459 *5206*		549 *987*		432		1964 *3946*
50		1792 *2893*		520 *894*	1062 *4662*	1053 *1069*				
60	*981*									

20 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			1154 *2382*		387 *665*	*685*		*539*		1502 *3813*
30	927 *1538*		139 *256*		3146 *7455*					
40	513 *685*			2000 *3459*		259 *524*				1809 *2532*
50		1036 *1770*			*3068*	573 *593*				
60										

26 dB

Channel	0	1	2	3	4	5	6	7	8	9
20			625 *1457*		172 *342*					858 *2456*
30	490 *853*				1928 *5028*					
40				1130 *2137*						1035 *1506*
50					*1915*	284 *308*				
60										

Table 6
Results obtained for theoretical digital television transmissions having horizontal and vertical polarization, broadcast from an existing analogue television transmitter site.

Set of results 3–JUN–94 for a digital station complementing analogue station F.
The digital station must protect all analogue stations above 100 W.
The average coverage of the analogue services on the same site is 10000 km^2.
The Table summarises the area (in square kilometers) covered by a digital service on each channel, for vertical and horizontal polarization of the digital transmission. *Values for vertical polarization are shown in italics.*
The coverage area has been suppressed for any case in which:

– a channel is in use for an analogue service from the same site;
– the coverage area is too small to be calculated reasonably accurately;
– the relevant channel is in use by other services (e.g. radioastronomy).

One interesting "problem" which must be faced is linked to the multiple delivery media available (cable, satellite and terrestrial). Overall, the potential number of programmes which could be delivered is very high, probably much higher than the quantity of available material. Does this mean that broadcasters will then have channels to spare and will be able to give them away to other users? Not necessarily. As spectrum capacity becomes available, it seems likely that market forces will play a more decisive role than at present in the way in which the spectrum is used. Obvious examples are:

– showing a given programme several times with differing starting times. A film could be shown many times, almost in parallel but with the starting times at, say, 15 minute intervals. Viewers would then be within 15 minutes of the start regardless of the moment at which they decided to view. Much larger differences in starting time would permit audiences with differing time schedules to see a given selection of programmes;

– multiple "shopping" channels aimed at differing audience requirements;

– a larger number of "theme" channels each with a different audience as its target;

– multiple viewpoints of the same sporting or cultural event (which does not imply that sports are non–cultural). In this case, multiple programmes within a given channel, or on separate channels, could carry the outputs of different cameras viewing the same or related events, for example different tennis games at the same event. In one sense, the viewer can then play the role of programme director by choosing his own view of the action.

It would be all too easy to regard such ideas as a "bad" use of the spectrum. However, this carries with it the idea that there is a "good" use of the spectrum. This may not be too easy to define in a way that is universally accepted. Even the currently fashionable approach of "market–value" may not provide the expected answers. If a television channel can be seen to be profitable and to be meeting the needs of a large number of viewers then it can clearly be regarded as a "good" use of the spectrum on at least two distinct bases.

The long–term future of digital television seems to be wide open with many opportunities for the development of old ideas and the introduction of new ones. There is the obstacle of a transition period during which digital and analogue will have to coexist. This transition period is potentially difficult and will certainly have to last a fairly long time. Modern television receivers are, thankfully, very reliable. While a receiver may have a nominal lifetime in many countries of "only" 7 years, in reality this is its life as the major or best receiver in a household. After that time, even if the family buys a new receiver, the old one will probably remain in use for several – perhaps many – more years. As a result it is unrealistic to think of a transition period lasting less than 10 years and many people are talking of periods in excess of 15! Even so, the prospects for the long term future make the waiting bearable.

Appendix

Impact of variation of signal level within a small area and with time

1. General

Within a small area, say 100 m by 100 m, there will be a more–or–less random variation of signal level with location. The statistics of this variation will be different for a wide–band signal, such as that from an OFDM digital television system, than for a narrow–band signal, such as that from conventional analogue television systems. For the digital signal, it is generally assumed that the standard deviation will be about 5.5 dB, while for an analogue signal the standard deviation will be about 8.5 dB. In both cases, there will be some dependence on the environment surrounding the receiving location and this is the reason that only approximate values are given.

The difference between 50% of locations (the signal level given by most prediction methods, including ITU–R Recommendation PN.370 [2], is basically for 50% of locations), and some high percentage (90 to 99%) of locations, has been taken to be 13 dB for the planning of digital television services. The lack of precision, that is the range 90 to 99% of locations, is partly caused by the fact that the locations statistics for a digital television system are not yet known. However, it must also be remembered that there is an inherent error in the predicted signal level for 50% of locations. It has thus been decided to regard the value of 13 dB as a margin between 50% of locations and some high percentage of locations, regardless of the exact value for the standard deviation of location variation for a specific wide band digital system. This margin will be used for the initial planning process and will be replaced by a more systematic approach when more practical results become available.

In the case of an analogue system, the value of 13 dB corresponds to the difference between 50 and 90% of locations. However, because of the inherent inaccuracy of predictions, it is not wise to assume that there is the exact physical meaning of 90% of locations receiving 13 dB below the 50% location value of field–strength.

Similar difficulties arise when considering the impact of interference. To a first approximation, it can be assumed that the interfering (unwanted) and wanted signals are uncorrelated and overall margins can be calculated as the root mean square of the individual margins. The complications arise because in some cases there can be expected to be correlation between wanted and unwanted signals. Much greater complications arise because the choice of a specific percentage of locations is often more of a political choice than an engineering reality. These complications are discussed in the individual sub–sections which follow. These discussions, however, are generalised. Detailed studies will also need to be carried out regarding the impact of these considerations on the coverage areas of a set of individual transmitting stations.

In addition to signal level variation with location, there is also a variation with time. In general, the value which exists at a given location for 50% of the time will be very similar to the value which exists for 90 or even 99% of the time. There *can* be exceptions, but they rarely exceed 2 or 3 dB. However, for smaller percentages of the time, there can be very large enhancements of signal level compared with the 50% time value.

These enhancements are caused by changes in the tropospheric conditions and exhibit wide variations from one type of propagation path to another and from one frequency band to another. As a generalisation, it can be said that paths which are mainly over water exhibit much larger signal level enhancements for small percentages of the time than do paths which are over land. It is also found that the enhancements are greater over warm water than over cold water, for example over the Mediterranean Sea as compared with over the North Sea. Extreme conditions can be found over and near hot seas but, fortunately, such conditions do not occur in many parts of the European area. However, it is well known that the propagation in the Eastern part of the Mediterranean is significantly different from that in the Western part of the same area.

Up until now, it has not really been possible to plan for these extreme conditions when considering analogue services. To have done so would have imposed too many constraints and the result would have been that very few services could have been implemented. As a result, it has normally been the case that the countries concerned have simply had to accept that there would be severe degradation by interference for a few percent of the time. With digital systems, which show a rapid transition between perfection and failure, this acceptance of interference may no longer be acceptable and further thought will have to be given to this matter.

2. Wanted signal level considerations

2.1 Analogue services

It has been the practice in the past, when calculating the size of the coverage area for analogue stations, to allow for the difference between 50% and, say, 90% of locations. This means that the radius of the coverage area is given by the distance at which a 50% location field–strength is 13 dB higher than the minimum value of field–strength required. For the major (or "main") stations in a country's network, the exact value of the radius for each coverage area is not too critical as it has been normal to allow for a certain degree of overlap between the coverage areas of adjacent main stations. Clearly, for coverage areas defined on the basis of a field–strength lower than 90% of locations, the overlap will be greater than for the case of exactly 90% of locations.

In addition, analogue systems have a fairly "soft" failure characteristic. This means that as the input signal falls below the "minimum" value (this value is really the lowest value which will permit reception at a specified picture quality) there will be a gradual reduction in picture quality. The picture will gradually become less satisfactory as the input signal continues to reduce in value but complete failure to receive any picture at all may not occur until the signal level is 15 to 20 dB below the nominal "minimum" value.

The combination of deliberate overlap of coverage areas and soft failure characteristic means that practical analogue reception is possible at a very high percentage of locations, even though this cannot be precisely defined.

Of course, the nature of the terrain surrounding, and near, any individual receiving location may introduce significant signal level variations from one small area to another. In particular, the combination of hills and populated valleys will create coverage failures which require the implementation of small (or "relay") stations. While these complicate the simple considerations outlined above, they do not change any of the basic assumptions.

2.2 Digital services

There are two main differences between the reception characteristics of digital and analogue signals. The more important is that digital signals have a fairly "hard" failure characteristic. In their basic forms, the transition from (near) perfection to complete failure may occur for a signal level reduction of less than 1 dB. The introduction of additional complexity can result in some softening of this characteristic but this usually only results in the transition region being increased from less than 1 dB to a few, say 3, dB. A further extension can be achieved with suitably designed systems by arranging for a receiver to switch to a different mode if the signal level drops below the minimum value for a given mode. However, for a specific mode, the failure characteristic is still "hard".

The second difference is that digital systems can take advantage of the wide band nature of their signal and compensate to some extent for the selective fading effects caused by short delay reflected signals. The result is that the standard deviation of location variation can be lower for a digital signal than for an analogue signal. It is, however, necessary not to reduce too far the margin allowed between a 50% location value and that for a high percentage of locations. This is because the basic inaccuracies of prediction systems must still be taken into account (that is, the difference between measurements and predictions for 50% of locations).

It is also necessary to consider carefully how to define the limit of the coverage area for a digital signal. This will be especially important in the transition period during which analogue and digital services will have to coexist. During this period, the radiated power of almost all digital transmitting stations will need to be limited in order to avoid interference to existing analogue services. The result is that it is very unlikely that there will be significant coverage overlaps between digital coverage areas. This, coupled with the hard failure characteristic, will result in the situation where there will be significant coverage differences between analogue and digital services even in those cases where the transmitters are co–sited.

In practical terms, this could mean (in the absence of consideration of interference) that the coverage area radius for a digital service would be 1.5 to 2 times larger if defined on the basis of 50% location than if defined on the basis of more than 90% of locations. Of course, in this coverage area "extension" (the difference between the two definitions) there would be many locations where there would be *no* reception and the percentage of such locations would increase from the inner boundary to the outer one. In this case, the simplification is adopted that reception will either be perfect or non–existent, in other words, that the transition between the two has a "cliff–edge" characteristic.

At present, it is difficult to see how to derive a completely satisfactory definition for the coverage area boundary. Choosing a definition based on a 90% location criterion will result (potentially) in a large percentage of viewers within that area being satisfied with their reception but the percentage area or percentage population of a whole country which can be claimed as "covered" may be relatively low. On the other hand, basing the definition on a 50% location criterion will permit much higher percentage area and somewhat higher percentage population values for the whole country to be claimed but with a higher percentage of viewers claimed as being covered being dissatisfied with their reception.

If the population were uniformly distributed throughout the coverage area, it would be possible to make a direct calculation of the population able to obtain more than the minimum signal level. If sufficiently detailed non–uniform population distribution information *and* propagation prediction methods capable of providing accurate values within areas of a few tens of square metres were both available, it would also be possible to provide a direct calculation of the population covered. However, none of these conditions can be met in the real world (at least, not in most countries) and it will thus be necessary to keep this problem of the definition of the coverage limit under review.

3 Interference considerations

3.1 Analogue services

In general terms, interfering (unwanted) signals vary with location in much the same way as do wanted signals and the statistics for this type of variation are the same for both wanted and unwanted signals. Because of the high protection ratios required for analogue services (in most cases), the permitted signals for the unwanted signals are low and this, in turn, means that the transmitter generating an unwanted signal will be at a considerable distance from the receiving location which requires to be protected against interference. One result of this large distance separation is that the unwanted signal level will vary significantly with time. The amount of this variation ranges from a few to tens of decibels. For a small percentage of the time the unwanted signal level will be higher than for, say, 50% of the time.

For a given combination of wanted and unwanted signals, the former being assumed to be invariant with time, the protection against interference which can be achieved is a function of time. It is thus essential to decide for what percentage of time protection will be sought. Most of the analogue television frequency planning in Europe has been carried out on the basis that wanted signals should be protected for 99% of the time, that is, interference is only permitted for 1% of the time. (There is a complication in that what is being sought in some cases is that the total time for which interference is present is only 1% and thus individual contributions at a given level must be restricted to time percentages less than 1. However, this need not be taken into account here.)

In some countries it was agreed that planning should take place on the basis of 95% time protection against interference. This results in either more programmes being available for a given size of coverage area or larger coverage areas for a given number of programmes. The difference between 95 and 99% time protection is most significant where interference paths are over–sea rather than over–land. This is because there are larger signal level differences between 1 and 5% time on the over–sea paths than those on over–land paths.

The protection ratios adopted for analogue television systems take account of the time variation of unwanted signals. In the case that an interfering signal is present for only a few percent of the time, a lower protection ratio is applied than in the case where the interference is present more–or–less continuously. To take account of this, two interference calculations need to be made, one for 50% time and the other for 1% (or 5%) time conditions. The worse of the two cases is then used to determine protection conditions.

At first sight, potential interference from a digital transmission into an analogue service would be treated in the same way as potential interference from another analogue transmission. This would mean that the radiated power from a digital transmitter towards a receiving location requiring protection would be limited to an amount which caused no more than 0.2 dB increase in interference at that location, taking account of the time and location variations discussed above and the directivity of the receiving antenna. The value of 0.2 dB does not come from any of the relevant planning conferences or agreements, but is a value commonly adopted in co–ordination negotiations.

In fact, there are no fundamental reasons why any of the considerations normally applied to the co–ordination of analogue stations should be automatically applied to that of digital stations. However care needs to be taken, not only to ensure protection of the existing analogue services but also to ensure that the procedures adopted are reasonably consistent.

If the permitted increase in interference to analogue services is raised from 0.2 dB to 0.5 dB or even 3 dB, there will be significant increases in the amount of power permitted for the digital transmission. For example, raising the permitted increase in interference from 0.2 to 0.5 dB would allow an increase in radiated power for a digital transmission of 4 dB. Raising the permitted increase from 0.5 to 3 dB would allow a digital power increase of 9dB. For the digital service this is attractive. However, the result is that the analogue viewer will receive more interference and in this context it is necessary to remember that a 3 dB increase in interference corresponds to a degradation of about one half of a picture grade, an amount which is visible.

It is not possible to approximate the effect of changing the percentage time protection requirements for analogue service in any meaningful way because of the very marked dependence on the length and nature of the propagation path. However, it is obvious that relaxing the protection requirement from 99 to 95 % of the time would permit some increase of the rdiated power for a digital station.

It thus appears that all of the approaches considered above could lead to increases in the power of digital stations and thus increases in their coverage. However, there is an inherent, hidden assumption and that is that the reference situation for the analogue station remains unchanged. This means that the analogue–to–analogue interference calculations retain their original basis, which is for 50% of locations and, say, 99% of the time.

This is not really consistent and it might be more appropriate to re–calculate the size of each analogue station's coverage area for the same set of conditions as are to be applied to interference from new digital stations. It is obvious that the size of the analogue coverage areas would increase, thus making them somewhat more difficult to protect and, in turn, increasing the restrictions for new digital stations. It is not possible, in a general case, to predict if the overall effect of a consistent reduction in analogue station protection requirements would lead to significant increases in the permitted powers of digital stations and this matter will need to be examined in detail in a number of representative cases.

3.2 Digital services

In one respect, the considerations for digital services are more simple than those for analogue services. Because of their “hard” failure characteristics, the protection ratios required by digital services are the same regardless of whether interference is present more–or–less continuously or for only a small percentage of the time. This means that when considering interference *into* digital services it is only necessary to deal with the 1 (or 5) % time case as this is invariably more critical than the 50% time case. This seems to be the only case where planning for digital services is more simple than planning for analogue ones.

Because of the hard failure characteristics of digital systems it seems to be essential to seek protection against interference for a high percentage of locations. The assumption has been made that this should be somewhere in the range 90% to 99% of locations.

It can be argued that protection of digital services against interference should be considered as more critical than, say, meeting the minimum signal level requirement at a high percentage of locations. In the latter case, there will be no effective variation with time and it will be obvious to a viewer and the receiver installer that there is no picture on some or all channels. The situation to this problem will be equally obvious: improve the receiving antenna system.

It could thus be argued that only a 50% location criterion should be imposed when defining a coverage area boundary. In most cases, hoever, it seems likely (during the transition period at least) that protection against interference will be more critical than achieving minimum signal level values (that is, protection against noise).

Where it is interference which causes a loss of picture, this will normally only occur for a relatively small percentage of time and possibly not at all locations in an area. The impact on the viewer could be particularly irritating if his normally perfect picture sometimes disappears for varying lengths of time. It seems unlikely that he will see any of the obvious signs of interference such as patterning on his screen. While the cure to this type of problem may be to install a better receiving antenna system, the time varying nature of the propagation makes it almost impossible to establish the best installation on an experimental basis.

Under such circumstances, the only solution seems to be to plan for a high degree of protection against interference, in terms of both percentage of time and percentage of locations.

4. Interim proposals

While most of the points discussed above remain to be investigated in detail, some interim proposals can be made as a basis for continued planning studies and some matters for more immediate investigation can also be identified.

Protection of analogue services should be based on a 50% location criterion. The differences between 99 and 95% time should be investigated, both for the case where the same time percentage is used for interference from analogue and digital services and for the case where the lower time percentage is used for interference from digital services only.

The permitted increase in interference to analogue services from digital transmissions should be 0.5 dB but the impact of changing this to 3 dB should also be investigated.

Protection and coverage requirements for digital services should be based on 90 to 99% of locations and 99% of time but the coverage which can be achieved in the area represented by the 50 to 90% of locations should be investigated further to provide a better estimate of the size of this area and the impact on population coverage.

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