REPORT ITU-R BO.2006

INTRODUCTION OF SATELLITE AND COMPLEMENTARY TERRESTRIAL DIGITAL SOUND BROADCASTING IN THE WARC-92 FREQUENCY ALLOCATIONS

(Questions ITU-R 93-1/10 AND ITU-R 107/10)

(1995)

NOTE 1 - This Report addresses the necessary planning elements associated with satellite and complementary terrestrial digital sound broadcasting and should be read in conjunction with the latest versions of Report ITU-R BO.955 and Report ITU-R BS. 1203.

1 Introduction

Arising from the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92), the following frequency allocations were made to the broadcasting-satellite service (sound) (BSS(S)):

- Worldwide (Regions 1, 2 and 3) except the United States America: the band 1 452-1 492 MHz is allocated for BSS(S) and complementary BS(S) on a primary basis, although some countries (mainly in Europe and Africa) have chosen to maintain this allocation on a secondary basis until I April 2007.
- For the United States and India, the band 2 310-2 360 MHz is (in a footnote) located for BSS(S) and)d complementary BS(S) on a primary basis.
- For some countries in Asia and the Russian Federation, the band 2 535-2 655 MHz (note that the bandwidth is 120 MHz), is by means of a footnote, allocated for BSS(S) and complementary BS(S) on a primary basis.

Associated with the allocations in Article 8 of the Radio Regulations (RR), there are footnotes restricting the dates of introduction and the level of service in some countries. The worldwide allocation is therefore not available in all countries as the Regulations are now phrased. In particular, the United States has an alternative allocation and (in a footnote) the band 1 452-1 492 MHz is allocated to fixed and mobile services on a primary bases.

In addition to the allocation in RR Article 8, there were several procedures for)r introduction of new sound services.

Resolution No. 527 (WARC-92) recognized that it may be possible to introduce new digital services in the terrestrial VHF broadcasting bands and opened the door to a more detailed consideration.

Resolution No. 528 (WARC-92) -eves details of the introductory procedures. It discusses the need for a planing conference, restricts the range of frequencies that may be used before the planing conference to the upper 25 MHz of the appropriate band, and details the method of calculating interference criteria (these are determined by means of Resolution No. 703 (Rev. WARC-92) procedures, and so there are as yet no formal technical procedures that can be applied).

Resolution No. 522 (WARC-92) gives details of the types of orbit that can be used and the future work that is necessary before non-GSO systems can be deployed.

Figure I shows the differences in allocations throughout the world.

2 Service requirements

2.1 Service goals

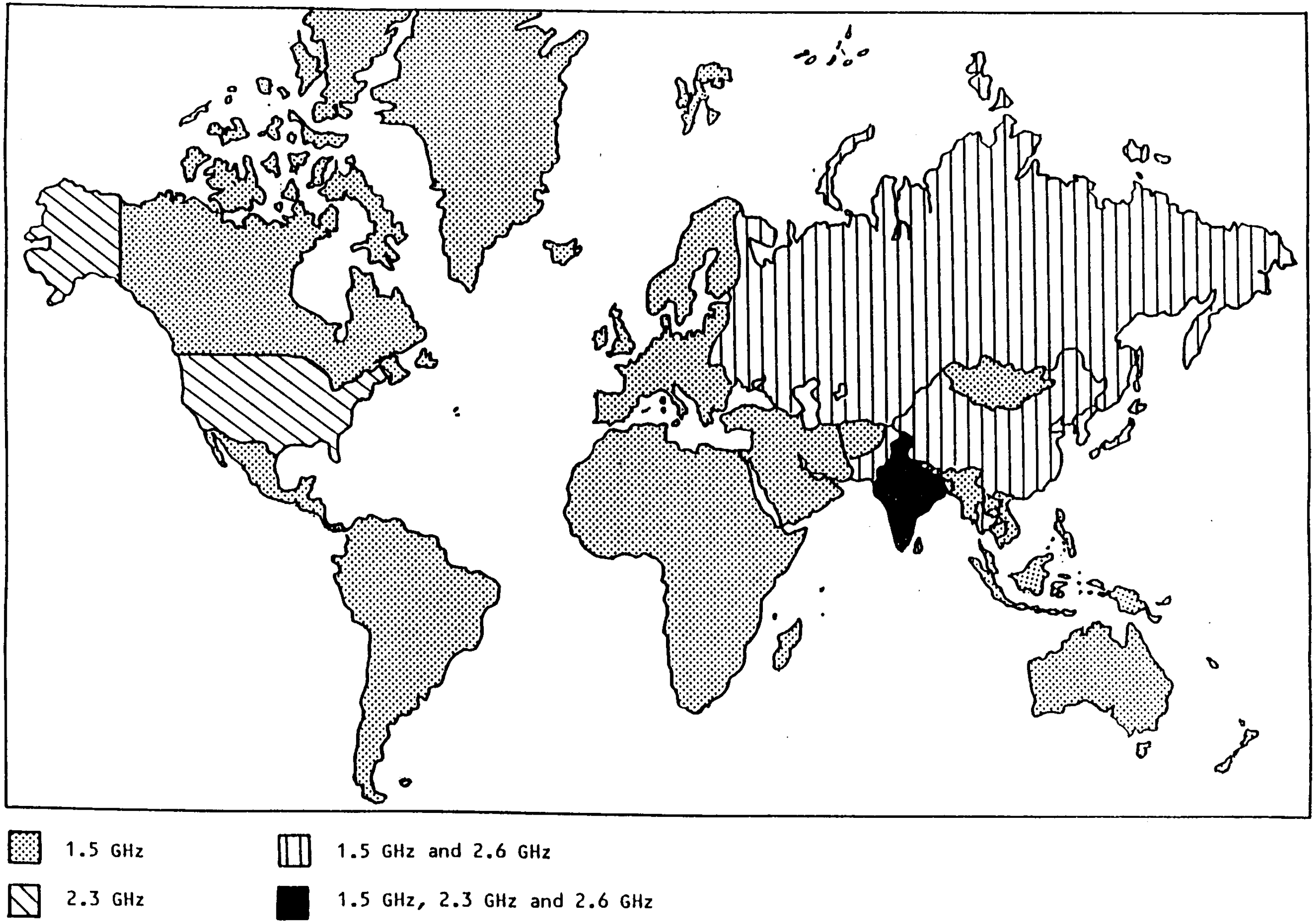
There are a number of possible goals in introducing digital sound broadcasting services:

- to replace current AM/FM broadcasting, in order to provide better quality and more reliable services and to better compete with other distribution media that can bring "CD" quality audio services to the listener;
- to provide the listener with a new service that can compete with the current AM/FM broadcasting service;
- to provide a service with conventional quality grade to large service areas for reception by very low cost receivers.

There is a recognized need for new sound broadcasting services to provide a better service to vehicular receivers (see Recommendation ITU-R BO.789). Furthermore, some services may also be directed to portable receivers for use inside buildings.

Currently, several administrations and commercial organizations have proposed sound-broadcasting satellite systems having different audio quality levels (CD, "Near-CD", FM stereophonic, FM monophonic and AM). Service to different kinds of receiver installations has been proposed (vehicular, portable and fixed), as well to a variety of environments (indoor, outdoor, rural, urban and suburban). All of these system approaches are technically feasible. One or more of them may be cost-effective and attractive to administrations depending on their state of development, the extent of their existing terrestrial systems and their broadcasting requirements.

Simplified world map of WARC-92 BSS (sound) and BS (sound) frequency allocations



There is a need to provide digital sound broadcasting services having a wide range of subjective audio quality. There may be substantial demand, particularly in developing countries and in sparsely settled countries having little terrestrial broadcasting infrastructure, for the digital equivalent of standard monophonic FM, and oven for the digital equivalent of double-sideband AM.

2.2 Service objectives

The objective of new sound broadcasting services is to improve the availability, quality and diversity of programme services to listeners. Wide area coverage-e will bring programme service to many listeners for the first tone and advanced digital techniques will allow high-quality sound equivalent to the quality available from other sound media (e.g., compact discs). Advanced digital techniques will also make possible a wide range of new programme-related and independent services with minimal impact on spectrum and power requirements. The BSS (sound) and BS (sound) is aimed at fixed, vehicular and portable reception. The technical system objectives are determined by two factors: quality and availability.

2.2.1 Quality

The service objectives for digital] sound broadcasting may play an important role in determining the type of system to be used and the overall system design and cost. Careful consideration needs to be given to the interaction between performance and economic factors. Digital sound broadcasting has been under consideration now for over 25 years, and during that time the reproduction and transmission of sound has undergone considerable development.

The expectations of the listeners have also increased considerably. Most people in urban areas now expect high-quality stereo sound, even from portable or vehicular radios. The enormous advances in the performance of domestic “hi-fi” equipment, culminating in the extensive use of compact discs, has conditioned many people to expect sound quality greater than that which even fixed FM receivers cap give. Even in remote areas, similar expectations often exist owing to the wide availability of good quality cassette recorders and compact disc players.

Much of the wide-area coverage is currently achieved by long-, medium- and short-wave ionospheric transmissions. Even though the population of those areas may prefer to receive entertainment broadcasts of the highest technical quality, it may be more economical for this type of service to accept monophonic service of medium quality provided it was reliable, and could be received on portable/vehicular receivers.

For these reasons, quality objectives can range from grade 3 on the 5-point ITU-R scale for a simple monophonic system to grade 4.5 for an advanced digital system. For the advanced digital systems, the objective is to provide a high-quality stereophonic service, comparable to compact disc quality. These distinct grades of service quality may lead to different system trade-offs.

2.2.2 Availability

Traditional methods of planing for terrestrial broadcasting have used an availability criterion which requires 50% of the locations within the coverage area to meet the quality objectives for at least 50% of the time. It can be expected that the service availability objective for all services will be increased; and, particularly for the high-quality grade service, it will need to be substantially increased from the criterion stated above.

Some possible techniques for increasing, service availability under certain conditions include time diversity, frequency diversity, and space diversity at the receiver, in addition to the use of on-channel terrestrial repeaters allowed by some modulations, to fill in shadowed areas which translates into space diversity at the transmission end.

2.3 Service concepts

2.3.1 BSS (sound) concept

The concept of satellite sound broadcasting is well described in Report ITU-R BO.955. Service areas are covered by satellite beams. The extent of the beam coverage needed on the Earth determines the size of The satellite transmit antenna. The transmission power at the satellite has to be large enough to compensate for propagation losses ,and to provide adequate fixed, portable and vehicular reception of the Earth. This concept can be used for covering sub-national, national, supra-national, and even global service areas.

2.3.1.1 Hybrid BSS (sound) concept

The satellite coverage can be improved through the use of low-power repeaters (“gap-fillers”) using the same carrier frequency to cover shadowed areas produced by large buildings, tunnels, valleys, etc. This hybrid BSS concept is a special application of the new advanced digital modulation schemes which can make constructive use of echoes and therefore are well suited to operate in a multipath environment. In such cases, active echoes deliberately introduced by co-frequency repeaters to fill the shadowed areas appear to the receiver as if they were passive echoes. This results ill a reduction of the needed satellite power to the level typically needed to cover rural areas. The retransmitted power can be very low, of the order of a few watts, depending on the size of the shadowed area to be covered.

2.3.2 BS (sound) concept

The concept of terrestrial digital sound broadcasting is well described in Report ITU-R BS. 1203. In the case of conventional AM and FM broadcasting, service areas are covered by one or more transmitters operating on different frequencies. The transmission power and the effective height of the antenna above average terrain (EHAAT) for terrestrial digital sound broadcasting stations need to be large enough to compensate for propagation losses and to provide adequate fixed, portable and vehicular reception. This concept can be used for covering local service areas with a single transmitter, or sub-national and national service areas using the single frequency network (SFN) concept described later.

2.3.2.1 Distributed emission concept for digital terrestrial sound broadcasting

Normal terrestrial broadcasting can also be augmented with the use of co-channel repeaters receiving the signal from the main transmitter and rebroadcasting it on the same frequency in the vicinity of the repeater. On-channel “gap-fillers” within the service area can be seen as a special localized case of the distributed emission concept. This requires that, as in The case of the hybrid concept, the type of modulation used allows operation in a multipath environment and makes constructive use of passive as well as active echoes.

The use of repeaters either as gap-fillers or coverage extenders to improve the terrestrial coverage allows a decrease of the required terrestrial transmitter power and, in addition, create a sharper discrimination towards a service area using The same frequency for satellite reception. The same sharper discrimination could be used to reduce the separation distance between two coverage areas using the same frequency, thus allowing greater frequency of reuse.

There exists an upper limit on co-channel repeater separation (several kilometers), and this limit is set by intersymbol interference occurring when two signals reach a receiver with a time difference which exceeds the guard interval between data symbols. Other concepts using spread spectrum signal structures, which could allow repeaters to transmit on a common channel and place fewer constraints on repeater separation, are under study.

An alternative concept utilizing frequency translating repeaters, each transmitting at a different frequency to fill shadowed areas for extended coverage, would not be constrained by the distance between repeater transmitters, but would require more channels.

2.3.2.2 Single frequency network concept (SFN)

In this concept, ideally, regularly spaced transmitters are fed synchronously by the same signal and broadcast on the same frequency. As in the previous case, there is a limit on the separation distance between these transmitters ,and this I limits it is set by the intersymbol interference produced at the receiver by the active echoes generated by these multiple transmitters.

This concept can be used to extend the reach of terrestrial broadcasting to national and even supra-national service areas.

2.3.3 Mixed satellite/terrestrial sound broadcasting service concept

The concept of a “mixed” satellite/terrestrial sound broadcasting service is based on the use of the same frequency band by both satellite and terrestrial broadcasting services. It can maximize the spectrum use by allowing these two broadcasting services to closely coordinate their service development rather than attempting sharing of the frequency band by totally unrelated services. The assumption is that with a near omnidirectional receiver antenna, the same receiver would capture the emissions of both satellite and terrestrial services. Using modem technology, the same modulation techniques need not be used for terrestrial and satellite transmissions into the same receiver. However, a common modulation technique would reduce receiver complexity and costs.

All channels not allocated to the BSS for a service area which could be used for terrestrial broadcasting in this service are subject to the usual co-channel reuse factor and adjacent channel rejection in the receivers. Certain precautions will need to be exercised in implementing such mixed satellite/terrestrial broadcasting service where the edge of coverage of a terrestrial system is situated near the edge of a satellite coverage area assigned to the same channel.

Such reuse, for terrestrial broadcasting, of the channels of adjacent satellite beams of other countries, or within the same country, maximizes the spectrum usage and provides a flexible way by which a service could evolve from strictly local terrestrial broadcasting to mixed satellite/terrestrial services when wide area national services by satellite are added. This reuse could also evolve from national (or even supra-national) services carrying national interest programming by and/or specialized services over satellite later complemented by local terrestrial services when this is more economical. This could also be attractive for the future implementation of specialized commercial services over satellite for national coverage when the receivers have reached a high level of penetration.

A study was made on the practical implication Of such additional interference from the nearby satellite beam (CCIR, 1990-1994, Doc. IOB/70). It is assumed that the geostationary satellite is on the same channel as the terrestrial service and uses the same type of modulation. It is also assumed that this interference is seen by the receiver as additive uncorrelated white Gaussian noise, therefore adding to the thermal noise level in the receiver. It is found that, using the RARC-83 copolar reference pattern for the satellite antenna, the apparent noise increase in the receiver is less than I dB for a receiver located beyond a relative angle seen from the satellite of $\varphi/\varphi_o = 1.4$ where φ_o is the half power beamwidth. The apparent noise increase becomes 3 dB at $\varphi/\varphi_o = 1.2$ and 7 dB at $\varphi/\varphi_o = 1$. Obviously, if the terrestrial DSB service is to preserve its coverage, the power of its transmitter has to be increased by the corresponding amount. In physical distances, the example shows that a 3 dB apparent increase in noise corresponds to a distance of about 500 kin from the edge of a satellite beam of 1^o. Obviously this distance can) be reduced if beam shaping producing sharper roll-off is used on the satellite.

The underlying assumption on which the above concept is based is that the same receiver can capture different programmes from the satellite and the terrestrial services. This concept of mixed satellite/terrestrial sound broadcasting leads to better and more flexible service evolution, better spectrum usage, as well as more practical and economical options for the public.

2.3.4 Band segmentation versus use of the mixed satellite/terrestrial sound broadcasting concept

During the preparation for the WARC-92 Conference, it was felt that the band to be allocated for BSS (sound) should be used by both satellite and terrestrial broadcasting in order to maximize the use of the spectrum and maximize the flexibility in operating the sound-broadcasting service. This concept was retained during the WARC-92 and resulted in the allocation of frequency bands to both services on a co-primary basis. Some thoughts are now given to the possible relevance of segmenting the band for independent use by these two services. It would appear that segmenting the bands would detract from the purpose of maximizing the potential spectrum efficiency that would otherwise have been gamed by having the band used by both services.

Two coverage scenarios were developed and are described in 8.4.1 of the “DSB Special Publication”. These scenarios illustrate the advantage of the mixed use of these bands by both satellite and terrestrial broadcast transmissions as compared to the segmentation of the band which would result in the use of each segment limited to one service. The spectrum efficiency of the mixed satellite/terrestrial coverage concept is demonstrated in these two coverage scenarios by therelatively large areas within the same region where the satellite frequency can be reused by terrestrial broadcasting. Band segmentation results in loss of spectrum efficiency since it would imply that the satellite beams frequency will not be allowed to be used in those areas where it could technically be reused. Before implementing the DSB service, the advantages of the mixed satellite/terrestrial approach should be fully considered prior to deciding on segmenting the band.

The use of the mixed concept implies however that the satellite coverage and frequencies should be taken into account when implementing terrestrial service. It also implies that the potential increase in required terrestrial power due to future satellite coverage of neighbouring service areas need to be taken into account when the terrestrial service is implemented.

3 System requirements

The system requirements for new sound broadcasting services are to improve the availability, quality and diversity of programme services to listeners.

As noted in 2.2, wide area coverage, through satellite, terrestrial and integrated satellite/terrestrial broadcasting will bring programme service to many listeners for the first time, and advanced digital techniques will also high-quality sound equivalent to the quality available from other sound media (e.g. compact discs). Advanced digital techniques will also make possible a wide range of new programme-related and independent services with initial impact on spectrum and power requirements. Digital sound broadcasting is aimed at fixed, vehicular and portable reception.

A new generation of sound broadcasting systems is needed to provide reliable wide area and high-quality service to vehicular, portable mid fixed receivers which are now becoming the major means of receiving radio services. Both satellite and terrestrial delivery means are considered feasible and desirable for this service. ,

The design and, as a consequence, the cost of a satellite sound broadcasting system, is strongly dependent on the factors affecting the propagation characteristics of the space-to-Earth path to the vehicular, portable and t-fixed receivers. The propagation path is subject to attenuation by shadowing due to buildings, trees, other foliage; and to multipath fading due to diffuse scattering from the ground and nearby obstacles. The degree of impairment to the received signal level depends of the operating frequency, the elevation angle to the satellite, mid the type of environment in which the receiver is operating: whether it is an open, rural, wooded or mountainous, suburban or dense urban environment. These impairments can also apply to BS (sound) services.

The use of diversity techniques on the vehicular receiver can significantly improve the performance of the receiver when operating in a heavily shadowed, Rayleigh fading environment. There are three primary diversity techniques:

1) frequency diversity;
2) tine diversity;
3) spatial diversity.

Some possible techniques for increasing service availability under certain conditions include time diversity, frequency diversity and spatial diversity ,at the receiver, in addition to the use of terrestrial repeaters, allowed by some modulations, to fill in shadowed areas which translates into space diversity at the transmission end. Spatial diversity may he achieved either through multiple antennas at the receiver or by transmitting the same signal from multiple transmitters.

A powerful channel coding mechanism can that be applied (convolutional code with Viterbi decoding, etc.), but it is necessary to ensure the independence between successive symbols with respect to channel fades. This is achieved by interleaving the symbols, either in tune or in frequency (the total bit rate is thereby distributed between several carries spaced sufficiently far apart in frequency). Temporal interleaving is effective however only if the receiver is mounted in a vehicle traveling above a certain speed. If the receiver is stationary, frequency interleaving must be used or, alternatively, space diversity reception.

A broad range of grades of digital sound broadcast service with various level of subjective audio quality cm be made available based on the types and status of digital audio coding technology utilized. A number of types of service are possible for digital sound broadcast (DSB). These include:

a) stereophonic CD quality audio digital broadcasting;
b) monophonic CD quality audio digital broadcasting;
c) stereophonic FM quality audio digital broadcasting;
d) monophonic FM quality audio digital broadcasting, and
e) AM quality audio digital broadcasting.

The receiver segments of DSB systems may consist of various types of receivers to be used in different parts of the world. Some technical considerations and trade-offs for digital radio receivers include:

Frequency band of operation:

- 1 452 - 1 492 MHz (L-band);
- 2 310 - 2 360 MHz (S-band);
- 2 535 - 2 655 MHz (S-bind);
- data rate (sound quality) - 16 to 256 kbit/s
- sensitivity, complexity and size of the receivers and their associated antennas;
- number of tuneable channels available on receiver, and
- modulation/transmission techniques.

Various levels of subjective audio quality may be made available resulting in a broad range of system requirements for digital sound broadcast services. Based on the type and status of digital audio coding techniques utilized, five types of service have been identified and are possible for DSB. It should be noted that these five types of service can coexist within the same beam-n pattern from the same satellite or terrestrial transmitter. The capacity of available spectrum may be expanded through frequency reuse based on cross-polarization. The power flux-density (pfd) or field strength shall be set to conform with coordination requirements. It is therefore necessary to emphasize the need for flexible planning to accommodate all service requirements and still permit digital sound broadcasting to coexist with other established radio services.

4 Regulatory provisions

The regulatory provisions are based on Resolution No. 528 (WARC-92). This, in effect has allowed ITU-R Recommendations to be accepted as Regulations, subject to the agreement of administrations under Resolution No. 703 (WARC-92). As yet there are no agreed provisions. In future, these may be developed.

Before the services are formally planned, broadcast-satellite systems are restricted to the upper 25 MHz of the appropriate band. Both satellite and terrestrial services will be limited by the need to avoid interference to established services.

After the conference that is envisaged for [1998 or before], the rules adopted by that conference will apply. The conference will need to consider both GSO (geostationary) and non-GSO systems.

4.1 Use of GSO systems

Planning techniques for satellites in the GSO are well developed and can be planned with little additional information.

However, it is clear that the main requirement is to avoid major overspill into areas outside the target service area. Limitations on satellite antennas will inevitably mean that there is some overspill, and this will be the area in which the procedures for planing and coordination are refined. The EBU studies for WARC-92 showed that it is possible to plan effective services for satellite broadcasting when other services are considered. Further work needs to be carried out to examine the effects of a shared allocation and especially with terrestrial digital sound broadcasting services.

4.2 Use of non-GSO systems

One of the main technological developments of recent times has been the possibility that the higher latitude countries could use a non-GSO to provide a service. Highly-inclined elliptical orbit (HEO) satellites which form one class of non-GEO satellite services are candidates for this application. Another class, for example, are the Low-Earth Orbit (LEO) systems.

In regulatory terms, there are problems. These satellites are not fixed. It is therefore not a trivial matter to calculate the interference to and from satellites in the same service, or to other services.

Some rigorous but efficient method of assessing the levels of interference needs to be developed if non-GSO systems are to be included in the coordination process and this might be easier for HEO systems being active only at -about ±30^o from their apogee.

In particular, there is always pressure for formal planning of a new service. Whilst planning of the GSO systems has occurred in the past, it is difficult to see how planning would be applied to a system which has as many degrees of freedom as a non-GSO system. Procedures towing equitable access may be more efficient than a formal plan. This is one area Chat needs urgent study.

4.3 Sharing between (;SO and non-GSO systems

As indicated in earlier sections, there is a need to ensure that services (up and downlinks) do not interfere with each other or with terrestrial digital sound broadcasting services. Broadcasting from GSO and non-GSO satellites is technically feasible, but the main concern is whether they can coexist.

In simple theory, any plan developed for a GSO system can be modified to include non-GSO satellites. Because of the changes in geometry, there is likely to be less interference to many areas of the globe. Some places with satellites on the radio horizon may be adversely affected. Also, the fact that the interference will vary in time needs to be considered. As a consequence careful attention needs to be paid to the regulatory provisions for non-GSO satellites.

Resolution No. 46 (WARC-92) dealt with a similar problem but for mobile-satellite services. This Resolution offers a procedural method which does not directly address the technical points. As a consequence, some additional topics may need to be included for a method which can be adopted for satellite broadcasting.

4.4 Introduction of systems prior to the [WRC 981

Before a WARC adopts a formal plan for satellite sound broadcasting, it is likely that broadcasters will want to experiment and possibly provide terrestrial digital sound broadcasting services in the band. There were many broadcasters at the Conference in Torremolinos who saw major opportunities for satellite sound broadcasting, and who had been developing proposals for services. Other broadcasters were interested in the chance of implementing services if capacity on satellites became available.

The obvious problem is that there is heavy use of the nominated bands by existing services. Only by ensuring that there is no interference to other services will the coordination procedures be effective.

Clearly there may be a major problem if agreement cannot be reached on this issue.

The decision lies with those operating in the top 25 MHz of the new band. As the users vary from country to country there may be difficulty in the negotiations. This will be exacerbated by the possible need to find different spectrum for different countries.

The interference levels at which interference is deemed unacceptably high are not yet determined. The procedures proposed for coordination are those of Resolution No. 703 (WARC-92): i.e., to use ITU-R Recommendations where appropriate. Clearly until the Radiocommunication Study Groups have studied the matter, it is not likely that there will be any relevant Recommendations. There are no Recommendations which can be readily adopted yet.

Several administrations are considering sound broadcasting services, both for terrestrial and satellite services in the same geographic area. A potentially large signal differential at the receiver may occur between the satellite service and terrestrial services. This large signal differential could also arise in the implementation of terrestrial services. This potential problem can be minimized provided the receivers offer both large dynamic range and low noise figures.

5. Sharing with non-broadcasting services

5.1 Sharing environment

WARC-92 allocated three frequency bands to the broadcasting-satellite service and the broadcasting service for implementation of digital audio broadcasting. Each of these bands is shared with other services, many on a coprimary basis as shown below:

- 1 452-1 492 MHz:
- fixed service;
- mobile service (including aeronautical telemetry).
- 2 310-2 360 MHz:
- fixed service;
- mobile service (including aeronautical telemetry);
- radiolocation service.
- 2 535-2 655 MHz:
- fixed service;
- mobile service;
- broadcasting-satellite service (community reception);
- fixed-satellite service.

5.2 Studies

Studies are needed to help in assessing the effect of interference into BSS (sound) and BS systems from signals of other services. Such studies are identified in § 5.2.1 below. In addition, information is needed to further assess the effect of interference from BSS (sound) and BS signals into other services. A list of required studies is given in § 5.2.2.

Annex 1 presents an approach to determining the interfering power-flux density limits at the edge of a BSS (sound) service area needed to protect BSS (sound) systems from terrestrial services interference. The approach follows the method specified in Report ITU-R BO.631-4, § 2.2, for protection of BSS-TV signals from terrestrial service interference. Further study is needed to determine the suitability of this approach with regard to vehicular and portable reception.

It is recommended that Annex I be brought to the attention of the Rapporteur for preparation of the Handbook on satellite sound broadcasting to portable vehicular and fixed receivers. The information contained in Annex 1 may be suitable for inclusion in a chapter of the Handbook dealing with sharing issues.

5.2.1 Interference from other services

In order to calculate power flux-density or field strength limits for each of the services listed above for protection of BSS (sound) and BS (sound) systems, a number of studies need to be carried out within Radiocommunication Working Parties 10-11S and 10B. These studies are listed below:

Detailed data must be gathered on the variety of digital sound broadcasting systems proposed for use within the three allocated frequency bands to enable calculation of required power flux-density or field strength levels. All data relevant to the determination of required power flux-density levels should be specified for each example system identified for use within each frequency band. Data should include, but not be limited to, e.i.r.p., data rate for proposed quality of service, channel bandwidth, margin assumptions (interference margin, multipath, buildings, foliage, etc.), required E_b/N_0, receive antenna gain and spreading loss.

Interference studies are needed to determine allowable levels of interference into DSB signals from the variety of signal types from the various co-primary services listed above. These studies should take into account the fact that the protection ratio will be dependent on both the RF bandwidths and power spectra of the wanted and interfering signals mid on any frequency offset between the corresponding carriers. Also the protection ratio will depend upon the partitioning between noise and interference and the partitioning of the allowable interference between the DSB and other services.

Studies should also be undertaken to ascertain sharing requirements between geostationary and nongeostationary (including low-Earth and highly elliptical orbit) spice stations providing BSS (sound) service.

Studies are needed to assess the cost/benefit of applying techniques designed to improve interservice sharing. Several techniques are available to help facilitate sharing between BSS (sound) and BS (sound) systems and other services. These include the use of diversity techniques, such as frequency, space and time diversity to reduce the effect of fading and thereby lower required margins. Use of co-channel terrestrial gap filler transmitters (hybrid systems) could further reduce the margin required to overcome shadowing. Advanced antenna technologies may contribute to improved sharing, as well. Electronically steerable phased array receive antennas for vehicular reception could allow higher gain receivers offering greater off-axis discrimination.

WARC-92 allowed for the introduction of DSB in both the broadcasting-satellite service u)d the broadcasting service in etch of the allocated frequency bands. Studies are needed to determine sharing requirements between satellite-delivered DSB, and terrestrial DSB, within the same frequency band.

Service and sharing criteria are dependent on the accuracy of the propagation model used. Close coordination with Radiocommunication Study Group 3 will be necessary in order to arrive at the most accurate model for each of the three allocated frequency bands. Particular attention should be given to propagation models for terrestrial signal propagation, especially for paths near and beyond-the physical horizon.

5.2.2 Interference to other services

Report ITU-R BO.955-2 contains information regarding the impact of BSS (sound) and BS DSB systems on other services. Some additional studies are required, however, to more fully assess the interference potential:

Identification of satellite antenna characteristics for the three frequency bands is required (e.g. practical sizes and associated gains -and roll-off characteristics).

BSS (sound) system power flux-density levels versus angle of arrival are needed to facilitate sharing with other services.

Service and sharing criteria are dependent on the accuracy of the propagation model used. Close coordination with Radiocommunication Study Group 3 will be necessary in order to arrive at the most accurate model for each of the three allocated frequency bands. Particular attention should be given to the propagation models for satellite signal propagation.

Protection criteria for aeronautical telemetry systems operating in the 1 452-1 525 MHz band in the United States of America are addressed in Doc. 10-11S114 (United States) which provides information for sharing studies between aeronautical telemetry systems and BSS (sound). A method for analyzing the interference from geostationary and non-geostationary satellite into telemetry receiving stations is described.

Numerical results, expressed as the value of satellite power flux-densities that aeronautical telemetry systems can tolerate, are obtained, based on the parameters used in United States' telemetry systems. Based on the values given in that document, a severe shirring problem would exist with respect to satellite emissions.

The document also contains the locations of many telemetry receiving stations in the United States of America, which in turn indicates the extensive use of this band for this purpose.

The development of protection criteria for aeronautical telemetry systems is under the purview of Radiocommunication Working Party 8B where the above document will be reviewed.

The results of the deliberations on this subject in Radiocommunication Working Party 8B will become a basis for further sharing studies in Radiocommunication Working Party 10-11S.

6 Other studies to be undertaken for the [1998] conference

In preparation for the [1998] conference the Radiocommunication Study Groups should consider undertaking, studies on the following subjects:

1) Regional and interregional inter-service sharing considerations. in particular:
   a) Sharing between BSS (sound) and point-to-multipoint systems.
   b) Sharing between BSS (sound) and point-to-point systems in the fixed service.
   c) Sharing with the mobile service, including aeronautical telemetry.
   d) Sharing with passive active microwave sensors.
   e) Protection of the radioastronomy service.
   f) Sharing with the space, EESS and space operation services.
   g) Sharing with ISM.
   h) Sharing between terrestrial digital sound broadcasting and point-to-multipoint systems.
   i) Geographical sharing.

The above studies should include investigation of required protection ratios to allow the necessary planning criteria to be established.

2) Sharing between digital sound broadcasting services from satellite (BSS) and terrestrial (BS). The following cases need to be considered:
   - BSS into BSS
   - BSS into BS
   - BS into BSS
   - BS into BS.
3) Planning studies related to the geostationary and non-geostationary services including possible sharing considerations between the two types of services.
4) Studies associated with planning of feeder links for the BSS (sound).
5) Studies on the joint implementation of satellite and terrestrial digital sound broadcasting services within a given band.
6) Studies relating to propagation and transmission channel characteristics.
7) Implementation strategies for terrestrial and satellite digital sound broadcasting before the [1998 WRC] to avoid a reduction in the flexibility of future spectrum assignments to these services at the WRC.

ANNEX 1

Interference protection for BSS (sound) systems

Each of the three frequency bands allocated to the BSS (sound) and the terrestrial broadcast service for DSB is also allocated to other services. Thus, in developing criteria for shared use of these frequency bands, it will be necessary to take into account relevant protection criteria for both DSB and systems in existing services; the services in question may vary by administration. Such protection criteria exists, or is in various stages of development for many of the existing services in the bands allocated to the BSS (sound). Report ITU-R BO.955-2 examines at some length the impact that BSS (sound) systems would have on various existing services. The protection of BSS (sound) from these services, however, is not addressed.

A variety of DSB systems have been studied [Docs. 10-11S/55 Annex XXII, 10-11S/88, 10-11S/93] which are designed to meet a variety of audio quality and service demands. The type of service and the desired audio quality to be achieved for each system will affect the required received signal power, the channel bandwidth, and the bit-error rate required in order to achieve the desired quality of service; these factors in turn determine the allowable level of interfering power which can be tolerated. Therefore, the development of appropriate sharing criteria for DSB systems must take into account the type of service and the level of sound quality to be achieved.

An approach to determining the interfering power-flux density limits at the edge of a BSS (sound) service area needed to protect BSS systems from terrestrial services interference is described below. The approach follows the method specified in Report ITU-R BO.631-4, § 2.2, for protection of BSS-TV signals from terrestrial service interference.

The limiting power flux-density not to be exceeded at the edge of the BSS service area is given by the formula:

$$F_s = F_{tqp} - R + D + P - M_r - M_i \qquad (1)$$

(NOTE 1 - This equation may not be valid when the satellite signal arrives near grazing incidence. In this case an additional margin must be included. It should also be noted that further study is needed to determine the appropriateness of equation (1) for vehicular and portable reception. In this case a statistical approach may be required (e.g. a correlation factor relating the relative fading of the wanted and interfering signals as a function of percentage of locations and/or time.)

where:

Fs : maximum permissible interfering power-flux density (dB (W/m^2)) within the necessary bandwidth of the broadcast satellite;

Ftqp : minimum wanted power flux-density (dB(W/m^2)) at the edge of the service area within the necessary bandwidth of the broadcast satellite (i.e. the pfd which, in the face of thermal noise only, yields an output signal quality, q, that is to be exceeded some high percentage of the time, P);

Rq : protection ratio (dB) between the wanted and interfering signals at the receiver input for barely detectable interference when the output signal quality has been degraded by the thermal noise to *q* (R_q is dependent on both the RF bandwidths and power spectra of the wanted and interfering signals s and on any frequency offset between the corresponding carriers);

D : singular discrimination (dB) against the interfering signal provided by the radiation pattern of the broadcasting satellite receiving antenna;

p : discrimination (dB) against the interfering signal due to polarization of the receiving antenna;

M_r : margin (dB) for possible ground reflection of the interfering signal;

M_i : margin (dB) for possible multiple interference entries.

The limit on interfering power flux-density given by equation (1) ensures that the output signal quality at the BSS (sound) receiver will be equal to q, even when the power flux-density of the system has faded to the minimum level, F_{tqp}. During *p%* of the time, the power flux-density of the system will be higher than F_{tqp} and the output signal quality will be higher than *q*.

Note that R_q is the overall protection margin for the BSS (sound) service and will be made up of many contributions due to inter- and intra-service sharing. It still remains to partition the overall interference allowance among these various sources.

Assuming that margins M_r *and* M_i are included in the overall interference margin used to determine R'_q, equation (1) reduces to:

$$F_s = F_{tqp} - R'q + D + P \tag{2}$$

Given sufficient information to calculate the required wanted system power-flux densities and the required interference protection ratios, equation (2) can be used to calculate power flux-density limitations, Fs, which would protect BSS (sound) systems from harmful interference from terrestrial transmitters. The power flux-density of the terrestrial system at a BSS (sound) receiver is a function of the equivalent isotropic radiated power of the terrestrial transmitter in the direction of the BSS receiver and the spreading loss, which is dependent on the path length, plus other terrain related factors. Required separation distances between terrestrial transmitters and BSS (sound) receivers can then be calculated.

The relatively high power flux-density levels required for BSS (sound) systems complicate the task of arriving at suitable sharing criteria for all services. High power flux-density levels are required, in part, to provide sufficient margin to overcome deep fades due to blockage by buildings and foliage. Diversity techniques, such as frequency, space and time diversity, can be used to reduce the effect of the fade, thereby lowering the required margin. Greater use of cochannel terrestrial gap filler transmitters (hybrid systems) could also reduce the margin required to overcome shadowing.

Another factor influencing the high power flux-density requirement is the low-gain (and therefore minimal discrimination) of the BSS (sound) receiving antenna, particularly for vehicular reception. Advanced antenna technologies, such as electronically steerable phased array antennas, could provide higher gain to reduce the required levels of power flux-density. Also means for reducing the sensitivity of BSS (sound) receivers to horizontal interference could be developed.

Finally frequency interleaving and/or spectrum avoidance in portions of the allocated bands could be used to facilitate sharing with existing services. Such techniques could, however, impact the number of programme channels available to a given service area.

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