RECOMMENDATION ITU-R SF.1005*

# SHARING BETWEEN THE FIXED SERVICE AND THE FIXED-SATELLITE SERVICE WITH BIDIRECTIONAL USAGE IN BANDS ABOVE 10 GHz CURRENTLY UNIDIRECTIONALLY ALLOCATED

(1993)

The ITU Radiocommunication Assembly,

*considering*

a) that existing sharing criteria are based on fixed-satellite systems in unidirectionally allocated frequency bands;

b) that bidirectional allocation of frequency bands to the fixed-satellite service (FSS) may be feasible in certain parts of the spectrum above 10 GHz in order to increase the overall transmission capacity of the FSS;

c) that bidirectional operation in the FSS introduces additional interference sources;

d) that the severity of the impact would depend on the extent to which such reverse-band working (RBW) is likely to be used;

e) that the impact would be greater in bands with a heavy population of fixed service receivers;

f) that bidirectional allocation of frequency bands to the FSS should not cause significant additional interference to systems in the fixed service;

g) that this can be achieved by reducing the pfd limits of space stations in reverse-band working networks relative to those currently in force for space-to-Earth transmissions;

h) that this can alternatively be achieved by reducing the criteria of maximum permissible interference to stations of the fixed service from emissions of earth stations in reverse-band working networks relative to those criteria currently in force for Earth-to-space transmissions,

*recommends*

**1.** that, to ensure the feasibility of sharing between the fixed service and the FSS with bidirectional usage in bands above 10 GHz which are at present unidirectionally allocated, the conditions stated below should apply;

**2.** that the existing sharing criteria should apply to forward-band working (FBW) satellite networks in bands shared with the fixed service;

**3.** that side lobes of satellite antennas in reverse-band working (RBW) satellite networks in the FSS should be as low as practicable and the maximum power flux-density produced at the rim of the Earth by emissions from a satellite should be lower by the following values than the limits given in Table 1 of Recommendation ITU-R SF.358 for angles of arrival within 5° above the horizontal under free-space propagation conditions (see Note 2):

– for frequency bands between 10 and 15.4 GHz: 7 dB

– for frequency bands between 15.4 and 20 GHz: 5 dB

– for frequency bands above 20 GHz: 3 dB

* Radiocommunication Study Groups 4 and 9 made editorial amendments to this Recommendation in 2000 in accordance with Resolution ITU-R 44.

**4.** that the criteria of maximum permissible interference, both long-term and short-term, from earth stations operating in RBW to stations in the fixed service should be lower by the following values than those calculated by the methods described in Recommendation ITU-R SM.1448 and Recommendation ITU-R SF.1006:

– for frequency bands between 10 and 15.4 GHz: 7 dB

– for frequency bands between 15.4 and 20 GHz: 5 dB

– for frequency bands above 20 GHz: 3 dB

**5.** that the existing sharing criteria should apply to other parameters for coordination between systems in the fixed service and networks of the FSS using reverse-band working, and that Recommendation ITU-R SF.406 will apply to transmitting stations in the fixed service shared with the FSS (Earth-to-space) using reverse-band working.

*Note 1* – In this Recommendation, FBW means operation in frequency bands of the existing allocation to the FSS and RBW means operation in those bands which might be additionally allocated to the FSS in the reverse direction by a future world radiocommunication conference.

*Note 2* – For angles of arrival more than 25° above the horizontal, the power flux-density limits in Table 1 of Recommendation ITU-R SF.358* should apply. Between 5° and 25°, the power flux-density values of this Recommendation at 5° and those of Table 1 of Recommendation ITU-R SF.358 at 25° should be linearly interpolated.

*Note 3* – The use of narrow-beam space station antennas and service areas seeing the space station at relatively high elevation angles will be likely to facilitate the implementation of reverse-band working networks in those service areas and improve sharing with the fixed stations near the Earth's rim.

*Note 4* – This Recommendation addresses a subject which may be of concern to a future world radiocommunication conference. It is not applicable to current allocations, which include the results of the World Administrative Radio Conference (Malaga-Torremolinos, 1992) (WARC-92).

*Note 5* – In applying the proposed lower values of pfd and permissible interference given in *recommends* **3** and **4**, a future world radiocommunicaton conference should also take due account of the specific band and types of fixed service systems that would be sharing with the proposed bidirectional usage by the FSS.

*Note 6* – Information relevant to the provisions of this Recommendation is given in Annex 1.

ANNEX 1

# Frequency sharing between systems of the fixed service and systems of the fixed-satellite service comprising forward band working (FBW) networks and reverse band working (RBW) networks

## 1. Bidirectional use of frequency bands shared with terrestrial services

Reverse band working (RBW) of space services in bands shared with terrestrial services would lead to a number of serious consequences which require consideration. It is the purpose of this section to expose some of the new problems which will arise where the satellite systems employ global beams or spot beams directed near to the rim of the Earth.

### 1.1 New problems for terrestrial services

In shared frequency bands, space-station transmitters interfere with terrestrial service receivers over wide areas in the downlink bands. In particular this places constraints upon terrestrial systems which would desirably be oriented towards the azimuth at which the geostationary-satellite orbit (GSO) intersects the horizon. Also, in uplink bands the Radio Regulations place limits on terrestrial power and e.i.r.p. If reversed frequency band operation were used in the space service, both of these disadvantages would be suffered by terrestrial services in all shared bands, although the effect would be reduced if additional discrimination were to be available from the satellite antenna.

Interference is also suffered in uplink bands by terrestrial receivers in the vicinity of earth stations. To limit such interference, the operation of both services is coordinated, and terrestrial services are constrained in the vicinity of earth stations. This constraint will often be minimized in geographical extent by concentrating several earth stations in one locality. If reversed frequency bands were used in the space service, it would be necessary to site the earth terminals in well-separated locations to limit interference between earth terminals. This would usually extend the area within which terrestrial services are constrained. Furthermore, within these areas the feasibility of expanding existing terrestrial systems, say by taking into use additional frequency bands not used by the space service for uplink, may be severely curtailed.

Finally, it would appear that the terrestrial system noise allocation for interference from space services would have to be divided between interference received from satellite and earth-station transmitters both in terms of interference levels and the proportion of time during which these levels may be tolerated. This could lead either to greater limitation of terrestrial services in the vicinity of earth stations or to more restrictive sharing criteria. This Annex discusses this aspect further.

### 1.2 New problems for the fixed-satellite service (FSS)

In bands shared with the fixed service, the siting of earth stations may be more difficult because interference from transmitting earth stations is added to that from stations in the fixed service. Moreover, RBW networks must observe more stringent sharing criteria towards receiving stations of the fixed service.

A new interference mode is that from a space station transmitter to an antipodal space station receiver. Such antipodal interference may be controlled by setting appropriate emission constraints towards the antipodal earth limb. The use of narrow-beam satellite antennas, together with service areas which lie sufficiently far inside the Earth's rim as seen from the satellite, will effectively contain this interference mode.

## 2. General RBW

The practicalities of introducing bidirectional working in bands shared with terrestrial radio-relay links by adding RBW satellite networks to FBW satellite networks so that satellite-to-Earth and Earth-to-satellite transmissions take place at the same frequencies are thus questionable.

It might be concluded that pfd and e.i.r.p limits of both the satellite and terrestrial fixed services would need to be tightened if the quality of each service is not to be degraded by the addition of RBW.

However, central to such thinking is an assumption of global satellite antenna beams, or spot beams pointing near to the rim of the Earth in order to provide service to earth stations with elevation angles as low as 5°. Thus a satellite antenna gain towards the rim of the Earth exceeding perhaps 18 dB relative to isotropic is implied.

The introduction of constraints on RBW to ease sharing conditions is discussed in the following section, with particular reference to RBW using spot beams to high elevation angle (> 40°) earth stations.

# 3. RBW using spot beams to high elevation angle (> 40°) earth stations

## 3.1 General

The accelerating requirement for increasing numbers of domestic or subregional satellite systems reinforces the need to review whether RBW could be introduced in a manner which would minimize constraints upon both FBW satellite networks, and terrestrial radio-relay networks.

Geometric considerations suggest that if RBW networks were to use, say, 2° spot beams primarily to serve earth stations with high elevation angles (exceeding about 40°) then many countries could be served without satellite side-lobe gains towards the rim of the Earth exceeding 8 dB relative to isotropic. The side-lobe envelope law in Recommendation ITU-R S.672 has been shown to be achievable with offset-fed satellite antennas. Compliance with Recommendation ITU-R S.672 would appear to be necessary from considerations of capacity within the FSS itself, so that the amelioration of sharing difficulties would be an additional advantage.

Figure 1 shows an example of the range of coverages that can be achieved with 2° beams, and indicates that the latitudinal extent of the terrestrial footprints depends upon longitudinal separation between satellite and earth-station location. Latitudes several degrees north of 40° N can be reached where little or no longitudinal separation applies whilst latitudes of 30° N can be covered with longitudinal separations of 30°.

Larger beamwidths than 2° can be used but the edge of the coverage footprints needs to be correspondingly further from the rim of the Earth.

## 3.2 Potential interference to space stations from stations of the fixed service

The geometry of sharing between the fixed service and the FSS is such that only transmitting stations of the fixed service at the rim of the Earth (as viewed from space stations) have the potential to produce significant levels of interference power into receiving space stations. The particular geometry of RBW using spot beams to high elevation angle earth stations is such that the high off-axis discrimination of the antenna of the receiving space station (30 dB, see Recommendation ITU-R S.672) would provide sufficient protection from interference from transmitting stations of the fixed service at the rim of the Earth without the need to impose pointing or additional e.i.r.p. restrictions.

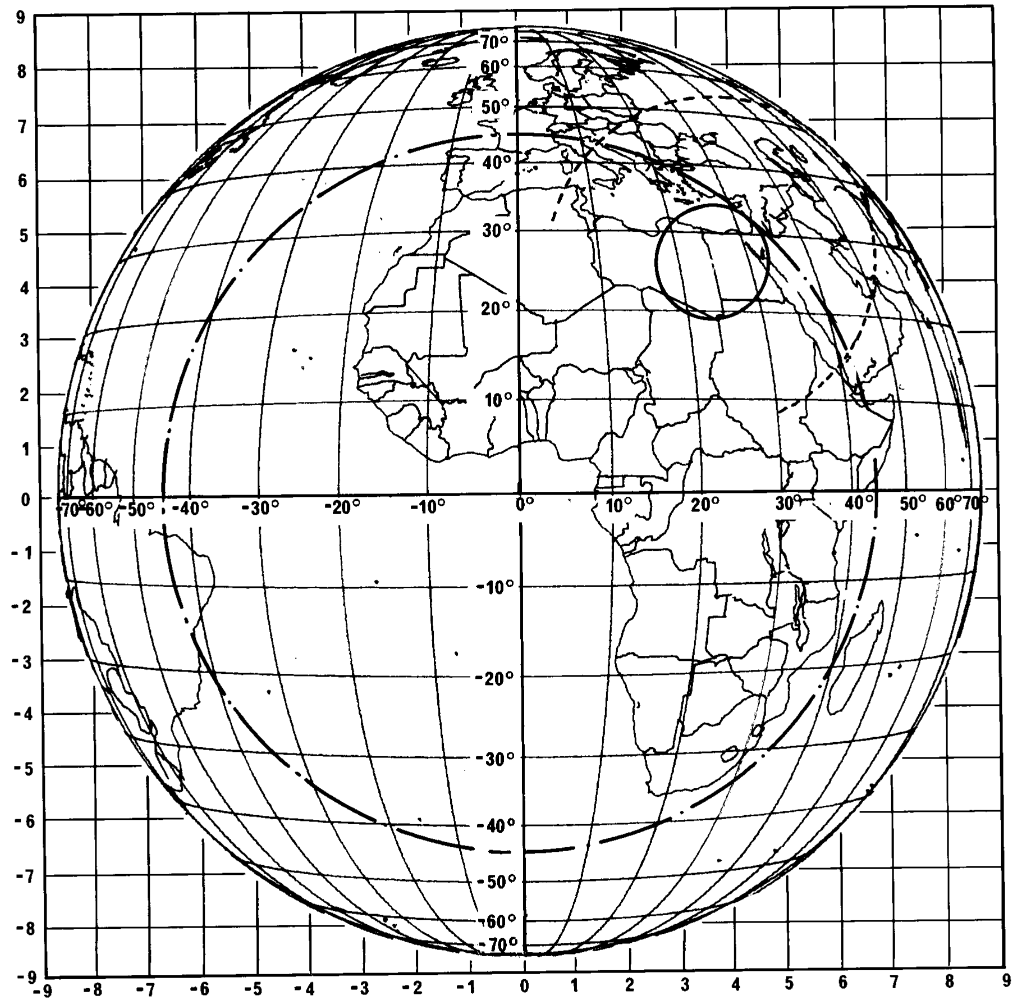
## 3.3 Potential interference into stations of the fixed service when RBW is introduced into bands used for FBW up links

The adoption of RBW in bands currently allocated to up links for FBW would introduce an additional source of interference to stations of the fixed service from the transmitting space stations. The pfd limits which can be tolerated by the receiving stations of the fixed service have been assessed by assuming that the interference from the space stations produces a noise power level in the receiver 10 dB below that of thermal noise. This assessment indicates that pfd limits below those of Recommendation ITU-R SF.358* would have to be adopted and typically a reduction of the pfd limit in the range 3-7 dB toward the rim of the Earth relative to that of Recommendation ITU-R SF.358 would have to be adopted in bands above 10 GHz.

FIGURE 1

**Permissible range for RBW with 2° beams avoiding additional sharing constraints with terrestrial services**

(View from the GSO at 0° longitude)




Coverage area of typical 2° beam

–30 dB contour for 2° beam

Limit of range: minimum earth-station elevation angle of 40°

D01

### 3.4 Potential interference to stations of the fixed service when RBW is introduced in bands used for forward band working down links

The adoption of RBW in bands currently allocated to down links for FBW would introduce a source of interference to stations of the fixed service from the transmitting earth stations in addition to that from the transmitting space stations.

The total outage and unavailability of systems in the fixed service would then be influenced by three independent mechanisms. These are the reduction of fade margin due to space station “long-term” interference, the reduction of fade margin due to earth station “long-term” interference, and the high level “short-term” interference contribution due to anomalous propagation from transmitting earth stations. A study estimated the total outage of a radio-relay system using 64-QAM digital modulation technology in an assumed bidirectionally allocated frequency band, by evaluating the contribution of each of these mechanisms. The results of the study indicate a worst-case increase of three orders of magnitude over the 10% values of *recommends* 2 and 3 of Recommendation ITU-R SF.615.

The achievement of a realizable balance between these three mechanisms may vary between different parts of the world, depending on individual circumstances. For example, in those parts of the world where extensive use is made of geostationary satellites, sharing would be difficult since it would require both the reduction of satellite e.i.r.p. limits and adoption of large separation distances between transmitting earth stations and receiving stations of the fixed service.

In other parts of the world where less extensive use is made of geostationary satellites, smaller earth station separation distances may be achievable.

## 4. RBW earth station coordination with terrestrial radio-relay stations

The usual propagation modes need to be considered when coordinating RBW earth stations and terrestrial radio-relay links, viz., clear-air coupling via propagation mode (1), and precipitation coupling via mode (2).

However, it must be borne in mind that earth-station coordination distances are determined by the short-term (0.01% time) interference experienced during anomalous propagation rather than the long-term (20% time) interference. This results in large coordination distances.

For mode (1), interference along the great-circle plane containing the earth station antenna boresight will be reduced by at least 22 dB by the increase in RBW earth-station elevation angle, from 5° to more than 40°. At other azimuths the reduction will be less, but it will be from a lower initial value of antenna gain.

For mode (2), computation is more complex but qualitatively a reduction in coupling can be inferred from the reduced common volume within the atmosphere which results from raising the RBW earth-station elevation angle from 5° to more than 40°.

## 5. RBW to lower elevation earth stations

Should network operators wish to introduce RBW with lower elevation (< 40°) earth stations (for example in higher latitudes) the geometry becomes progressively less favourable and studies on a case-by-case basis would need to be carried out. This might well prove practicable but as Fig. 1 indicates the provision of RBW to a higher latitude should not require the introduction of additional restrictions on lower latitude countries provided that the spot beam approach is employed.

## 6. Conclusion

This Annex sets out the ways in which realizable RBW can be introduced in a manner which significantly reduces the scale of the sharing difficulties with terrestrial radio-relay links. It would appear that the highly favourable geometry conferred by high elevation angle earth stations, as typified by spot beam (typically 2°) networks serving countries at latitudes of less than 40°, offers the possibility of the combination of FBW networks, RBW for some domestic and subregional networks and terrestrial radio-relay networks, to a far greater extent than would be possible in the higher latitude countries, particularly in those parts of the world which make less extensive use of the GSO. Further studies are required on systems using large beamwidths.