ANNEX B

Data and Procedures for Assessing Interactions Among Stations in the Space and Terrestrial Services

B.1 GENERAL

Chapter 8 of this Manual contains criteria and procedures applicable to spectrum sharing among stations in the space radiocommunication services and between stations in the space and terrestrial radiocommunication services. This Annex supplements Chapter 8 with supporting data and verification procedures appropriately cross-referenced to the various sections of Chapter 8.

B.1.1 Limitations on Power and Direction of Maximum Radiation of Stations in the Fixed Service in the Band 8025-8400 MHz

Power and antenna pointing limitations are specified in Section 8.2.34. A description is also provided therein of two computerized procedures for checking proposed new stations or systems for compliance with the specified limits during the FAS and SPS review processes.

The following table will assist in ensuring that the main antenna beam of a fixed or mobile station does not point at the geostationary orbit. This table is appropriate for use by federal agencies in the earlier planning stages of systems in the fixed and mobile services, within the limitations imposed by the following basic assumptions:

(a) an e.i.r.p. of +55 dBW, and therefore, a required separation angle of 1.5° from the geostationary orbit;

(b) an angle of elevation of the antenna main beam between -1° and +4°; and,

(c) atmospheric refraction in the range of -2° to 0°.

For an assignment to a station with an antenna elevation angle between -1° and +4° with an e.i.r.p. of less than +55 dBW, the azimuthal sectors to be avoided will be smaller, but are contained within the sectors indicated in the table. This table cannot be used where the elevation angle is not between -1° and +4°. Calculation of the azimuthal sectors to be avoided for elevation angles not between -1° and +4° should be accomplished using ITU-R Report 393 (1990).

Ranges of Azimuths to be Avoided (Northern Hemisphere)

Latitude of Terrestrial Station (N)	From	To	From	To
0	88.50	91.50	268.50	271.50
1	88.60	91.73	268.27	271.40
2	88.70	91.95	268.05	271.30
3	88.80	92.18	267.82	271.20
4	88.90	92.41	267.59	271.10
5	88.99	92.63	267.37	271.01
6	89.09	92.86	267.14	270.91
7	89.19	93.09	266.91	270.81
8	89.29	93.33	266.67	270.71
9	89.38	93.56	266.44	270.62
10	89.48	93.80	266.20	270.52
11	89.58	94.04	265.96	270.42
12	89.68	94.28	265.72	270.32
13	89.78	94.52	265.48	270.22
14	89.88	94.76	265.24	270.12
15	89.97	95.01	264.99	270.03
16	90.07	95.26	264.74	269.93
17	90.17	95.52	264.48	269.83
18	90.27	95.77	264.23	269.73
19	90.38	96.03	263.97	269.62
20	90.48	96.30	263.70	269.52
21	90.58	96.57	263.43	269.42

Latitude of Terrestrial Station (N)	From	To	From	To
22	90.68	96.84	263.16	269.32
23	90.79	97.12	262.88	269.21
24	90.89	97.40	262.60	269.11
25	91.00	97.69	262.31	269.00
26	91.11	97.98	262.02	268.89
27	91.22	98.28	261.72	268.78
28	91.33	98.58	261.42	268.67
29	91.44	98.89	261.11	268.56
30	91.56	99.21	260.79	268.44
31	91.67	99.54	260.46	268.33
32	91.79	99.87	260.13	268.21
33	91.91	100.21	269.79	268.09
34	92.03	100.56	259.44	267.97
35	92.16	100.92	259.08	267.84
36	92.28	101.29	258.71	267.72
37	92.41	101.67	258.33	267.59
38	92.54	102.06	257.94	267.46
39	92.68	102.46	257.54	267.32
40	92.82	102.88	257.12	267.18
41	92.96	103.31	256.69	267.04
42	93.11	103.75	256.25	266.89
43	93.26	104.21	255.79	266.74
44	93.41	104.69	255.31	266.59
45	93.57	105.19	254.81	266.43
46	93.74	105.70	254.30	266.26
47	93.91	106.24	253.76	266.09
48	94.08	106.80	253.20	265.92
49	94.26	107.38	252.62	265.74
50	94.45	107.99	252.01	265.55
51	94.65	108.63	251.37	265.35
52	94.85	109.30	250.70	265.15
53	95.06	110.00	250.00	264.94
54	95.29	110.74	249.26	264.71
55	95.52	111.53	248.47	264.48
56	95.76	112.35	247.65	264.24
57	96.02	113.23	246.77	263.98
58	96.29	114.17	245.83	263.71
59	96.57	115.17	244.83	263.43
60	96.87	116.23	243.77	263.13
61	97.19	117.38	242.62	262.81
62	97.52	118.61	214.39	262.48
63	97.88	119.95	240.05	262.12
64	98.27	121.40	238.60	261.73
65	98.68	122.99	237.01	261.32
66	99.13	124.73	235.27	260.87
67	99.60	126.66	233.34	260.40
68	100.13	128.82	231.18	259.87
69	100.69	131.25	228.75	259.31
70	101.31	134.02	225.98	258.69
71	102.00	137.23	222.77	258.00
72	102.75	141.03	218.97	257.25
73	103.60	145.68	214.32	256.40
74	104.55	151.67	208.33	255.45
75	105.62	160.34	199.66	254.38

Ranges of Azimuths to be Avoided (Southern Hemisphere)

Latitude of Terrestrial Station (S)	From	To	From	To
0	88.50	91.50	268.50	271.50
1	88.27	91.40	268.70	271.73
2	88.05	91.30	268.70	271.95
3	87.82	91.20	268.80	272.18
4	87.59	91.10	268.90	272.41
5	87.37	91.01	268.99	272.63
6	87.14	90.91	269.09	272.86
7	86.91	90.81	269.19	273.09
8	86.67	90.71	269.29	273.33
9	86.44	90.62	269.38	273.56
10	86.20	90.52	269.48	273.80
11	85.96	90.42	269.58	274.04
12	85.72	90.32	269.68	274.28
13	85.48	90.22	269.78	274.52
14	85.24	90.12	269.88	274.76
15	84.99	90.03	269.97	275.01
16	84.74	89.93	270.07	275.26
17	84.48	89.83	270.17	275.52
18	84.23	89.73	270.27	275.77
19	83.97	89.62	270.38	276.03
20	83.70	89.52	270.48	276.30
21	83.43	89.42	270.58	276.57
22	83.16	89.32	270.68	276.84
23	82.88	89.21	270.79	277.12
24	82.60	89.11	270.89	277.40
25	82.31	89.00	271.00	277.69
26	82.02	88.89	271.11	277.98
27	81.72	88.78	271.22	278.28
28	81.42	88.67	271.33	278.58
29	81.11	88.56	271.44	278.89
30	80.79	88.44	271.56	279.21
31	80.46	88.33	271.67	279.54
32	80.13	88.21	271.79	279.87
33	79.79	88.09	271.91	280.21
34	79.44	87.97	272.03	280.56
35	79.08	87.84	272.16	280.92
36	78.71	87.72	272.28	281.29
37	78.33	87.59	272.41	281.67
38	77.94	87.46	272.54	282.06
39	77.54	87.32	272.68	282.46
40	77.12	87.18	272.82	282.88
41	76.69	87.04	272.96	283.31
42	76.25	86.89	273.11	283.75
43	75.79	86.74	273.26	284.21
44	75.31	86.59	273.41	284.69
45	74.81	86.43	273.57	285.19
46	74.30	86.26	273.74	285.70
47	73.76	86.09	273.91	286.24
48	73.20	85.92	274.08	286.80
49	72.62	85.74	274.26	287.38
50	72.01	85.55	274.45	287.99
51	71.37	85.35	274.65	288.63
52	70.70	85.15	274.85	289.30
53	70.00	84.94	275.06	290.00

Latitude of Terrestrial Station (S)	From	To	From	To
54	69.26	84.71	275.29	290.74
55	68.47	84.48	275.52	291.53
56	67.65	84.24	275.76	292.35
57	66.77	83.98	276.02	293.23
58	65.83	83.71	276.29	294.17
59	64.83	83.43	276.57	295.17
60	63.77	83.13	276.87	296.23
61	62.62	82.81	277.19	297.38
62	61.39	82.48	277.52	298.61
63	60.05	82.12	277.88	299.95
64	58.60	81.73	278.27	301.40
65	57.01	81.32	278.68	302.99
66	55.27	80.87	279.13	304.73
67	53.34	80.40	279.60	306.66
68	51.18	79.87	280.13	308.82
69	48.75	79.31	280.69	311.25
70	45.98	78.69	281.31	314.02
71	42.77	78.00	282.00	317.23
72	38.97	77.25	282.75	321.03
73	34.32	76.40	283.60	325.68
74	28.33	75.45	284.55	331.67
75	19.66	74.38	285.62	340.34

B.1.2 Earth Station Antenna Elevation Angle and EIRP Toward the Horizon

For transmitting earth stations in the bands 7900-7975 and 8025-8400 MHz, Section 8.2.35 places an upper limit on the equivalent isotropically radiated power (EIRP) toward the horizon and a minimum antenna elevation angle above the horizontal plane.

Earth stations should be evaluated for compliance with those provisions before or at the time of the systems review under Chapter 10. An algorithm to perform this evaluation is presented below together with an illustrative example.

Algorithm

Frequency Check: Determine whether the system under consideration includes a transmitting earth station operating in either the 7900-7975 or 8025-8400 MHz band. If it does not, terminate the check. Does the transmitting earth station operate in either of the above bands?

YES _ NO _

Antenna Elevation Angle: Check for compliance with minimum antenna elevation angle requirements. Use the planned minimum operating elevation angle of the antenna as provided in the systems review data. The requirements for the various services are as follows:

Space Research (Deep Space) $\leq$ 10°

Space Research (Near Earth) $\leq$ 5°

Other Earth Stations $\leq$ 3°

If the appropriate limitation is not met, the constraints of Section 8.2.35 are violated. Does the station meet the criteria for the applicable service?

YES _ NO _

EIRP Limitations: These limitations are a function of the horizon elevation angle. As an upper bound on the EIRP limitation, determine the maximum EIRP in a 409 kHz band (antenna mainbeam gain in dB above isotropic + maximum power density in dBW/Hz + 36 dB [conversion from 1 Hz to 4 kHz]). If this value is below 40 dBW/4 kHz, then the system meets the EIRP criteria, if not, perform the more detailed examination explained below.

Compute the EIRP/4 kHz (P_h) radiated toward the horizon for each intended operating azimuth using the

following data:

Note: All data elements are required under Chapter 10 by reference to Appendixes 3 and 4 to the ITU Radio Regulations.

- Φ Planned operating azimuth angles;
- $\cdot \theta_2$ Elevation angle of the horizon measured from the horizontal plane for the Φ azimuth;
- $\cdot \theta_1$ Operating elevation angle of the antenna above the horizontal plane for the Φ azimuth;
- $\cdot$ G Antenna pattern information; and
- $\cdot$ P Maximum power density in dBW/Hz averaged over the worst 409 kHz band.

Computation:

$P_h = P + 36 + G^{\Phi}(\theta_1 - \theta_2)$dBW/4 kHz

Where $G^{\Phi}(\theta_1 - \theta_2)$ is the gain of the antenna

$\theta_1 - \theta_2$ degrees off axis, determined for each azimuth Φ.

Check P_h (EIRP/4 kHz) for compliance with the following limits:

Horizon	P_h limits
$\theta_2 > 5°$	No restriction
$0° < \theta_2 \leq 5°$	$< 40 + 3\theta_2$ dBW/4 kHz
$\theta_2 \leq 0°$	< 40 dBW/4 kHz

If P_h exceeds these limits, the constraints of Section 8.2.35 are violated. Does the station meet the above EIRP limits?

YES _ NO _

A station to be in compliance with Section 8.2.35 must conform to the criteria under the three headings above for all azimuths.

Illustrative Example

Data Submitted:
Station: Earth Station in the Fixed-Satellite Service
Frequency: 8.23 GHz.
Power Density: P = -6 dBW/Hz.
Mainbeam Azimuth: $\Phi = 103°$
Mainbeam Elevation Angle: $\theta_1 = 8°$ for $\Phi = 103°$
Horizon Elevation Angle: $\theta_2 = 3°$ for $\Phi = 103°$ (extracted from geographical data provided for horizon around earth station)
Mainbeam Antenna Gain: 51 dB

Antenna Gain: $G^{\Phi}(\theta_1 - \theta_2) = 14.5$ dB
This gain is at the natural horizon at an azimuth of 103° and is taken from a point on the graphical antenna pattern 5° from the center of the mainbeam ($\theta_1 - \theta_2 = 5°$).
Frequency Check: The submitted transmitting frequency is in one of the specified bands.
Operating Elevation Angle: The minimum operating elevation angle of 8° does meet the criteria for the fixed-satellite service.
EIRP Limitations: The maximum EIRP is 81 dBW/4 kHz (51 + 36 - 6 dBW/4 kHz). As this exceeds the value of 40 dBW/4 kHz, a detailed examination must be made.
Computation of EIRP toward the horizon:
Ph = -6 + 36 + 14.5 dBW/4 kHz
= 44.5 dBW/4 kHz
The criterion for a horizon elevation of 3° is 49 dBW/4 kHz (40 + 3.3°). The computed EIRP toward the

horizon is less than the criterion and therefore complies with the constraint.

As the data in this example meet the criteria in each of the headings, the station complies with Section 8.2.35.

B.1.3 POWER FLUX DENSITY LIMITS

Section 8.2.36 specifies constraints on the power flux density (PFD) from space stations in certain bands. The constraints are of three forms: a) PFD limits at the Earth's surface in dBW/m^2/4 kHz (or in some bands /1 MHz or /1.5 MHz); b) power spectral density at the receiver input of a troposcatter system in dBW/4 kHz; and c) PFD limits in dBW/m^2/4 kHz at the geostationary orbit from space stations using non-geostationary orbits.

The latter constraint is applicable only to the space-to-Earth operations in the earth exploration-satellite service in the band 8025-8400 MHz. Compliance with this provision of Section 8.2.36 will be examined on a case-by-case basis and will not be further considered in the Annex.

The constraint on the power spectral density from a space station at the receiver input of a troposcatter system applies in the bands 1670-1700, 1700-1710, and 2200-2300 MHz. In view of the very small number of troposcatter systems within the US&P in these bands, examination of proposed systems for compliance with this provision will be considered on a case-by-case basis.

Limitations on the PFD at the Earth's surface from a space station are imposed in most of the downlink bands between 1670 MHz and 22 GHz which are shared with the terrestrial services. Evaluation of space stations for compliance with this provision should be accomplished before or at the time of the systems review under Chapter 10. An algorithm to perform this evaluation is presented below together with an illustrative example.

Algorithm

This algorithm checks compliance with the PFD limits at the Earth's surface from a space station in the geostationary orbit.

Frequency Band/Service Check: Determine whether the proposed system is for one of the combinations of frequency band and radio service given in Table 1. If it is not, terminate the check. Determine whether the satellite is in the geostationary orbit. If it is not, a case-by-case review is necessary. Is the space station in a geostationary orbit and in a frequency band and service combination given in Table 1?

YES _ NO _

Power Flux Density Limits: The PFD of the station at the Earth's surface must be computed and compared with established criteria. When earth coverage antennas are used in the satellite, the antenna gain across the visible portion of the Earth's surface is assumed to be constant. When spot beam antennas are used, a worst case is assumed (full gain) unless a complete description of the pattern, side lobes, and exact pointing direction is provided. In that case a detailed examination is necessary.

The most stringent PFD limitation on satellites with earth coverage antennas is imposed for low angles of arrival at the Earth's surface. Thus the computed PFD is compared with the limits imposed at low angles of arrival (see Table 1).

It is recognized that the limitations are referenced to different bandwidths, i.e., 4 kHz, 1 MHz, and 1.5 MHz. Thus it is necessary to select the appropriate bandwidth from Table 1 for the particular band and service under consideration.

In computing the PFD, it is assumed that:

(a) atmospheric losses are negligible;

(b) the geostationary orbit is 35,700 km; and,

(c) the Earth's radius is constant, i.e., the Earth is smooth.

To compute the power flux density PE at the Earth's surface, the following data are used:

P_D Maximum power spectral density in dBW/Hz averaged over the reference bandwidth (4 kHz, 1 MHz, or 1.5 MHz).

B_R Reference bandwidth in Hz.

G Mainbeam antenna gain in dB.

The computation to determine the power flux density is:

$$P_E = P_D + 10\log B_R + G \quad 163 dBW/m^2/B_R$$

Once this value is determined, it is checked against the appropriate criteria given in Table 1.
Is the computed PFD less than (more negative) than the applicable value given in Table 1?

YES _ NO _

A station to be in compliance with Section 8.2.36 must conform to the criteria specified in Table 1.

Illustrative Example

Data Submitted:

Frequency Band: 7300-7750 MHz
Service: Fixed-Satellite
Orbit: Geostationary
Power Density: -46 dBW/Hz
Antenna Gain: 17 dB

Table: Power Flux Density Limits at the Earth's Surface from Space Stations in Bands Shared with the Fixed and Mobile Services

Frequency Band (MHz)	Space Radiocommunication Service	Limit
1670-1690	Meteorological-Satellite	-154 dBw/m^2/4 kHz
1690-1700	Meteorological & Earth Exploration-Satellite (for countries mentioned in ITU RR 5.382)	
1700-1710	Space Research	
2200-2300	Space Research	
7300-7750	Fixed-Satellite	
7450-7550	Meteorological-Satellite	-152 dBW/m^2/4 kHz
8025-8400	Fixed-Satellite	
8025-8400	Earth Exploration-Satellite	-150 dBW/m^2/4 kHz
8400-8500	Space Research	
21200-22000	Earth Exploration-Satellite	
1690-1700	Meteorological & Earth Exploration-Satellite	-133 dBW/m^2/4 kHz

Frequency Band/Service Check: The space station described above is in the geostationary orbit and operates in a frequency band and radiocommunication service given in Table 1.

Power Flux Density Limits: The reference bandwidth for the band under consideration is 4 kHz. Using this value and the above data, the computed power flux-density is -156 dBW/m^2/4 kHz
(-46 + 36 + 17 -163 dBW/m^2/4 kHz). This value is less than (more negative) the limit of -152 dBW/m^2/4 kHz specified in Table 1, and, therefore, the station complies with the provisions in Section 8.2.36.

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