RECOMMENDATION ITU-R SA.1278*

FEASIBILITY OF SHARING BETWEEN THE EARTH EXPLORATION-SATELLITE SERVICE (SPACE-TO-EARTH) AND THE FIXED, INTER-SATELLITE, AND MOBILE SERVICES IN THE BAND 25.5-27.0 GHz

(Question ITU-R 220/7)

(1997)

The ITU Radiocommunication Assembly,

considering

a) that the fixed, inter-satellite (ISS) and mobile services are allocated on a primary basis in the 25.5-27.0 GHz band;

b) that World Radiocommunication Conference (Geneva, 1997) (WRC-97) agenda item 1.9.4.2 addresses consideration of an allocation to the Earth Exploration-Satellite service (EESS) near 26 GHz;

c) that Recommendation ITU-R SA.1024 indicates the requirement for wideband EESS downlinks above 25 GHz to transmit future high resolution sensor data;

d) that required separation distances** between receiving EESS earth stations and transmitting fixed stations are relatively small (typically 10-20 km) because atmospheric effects, vegetation loss, and space loss increase significantly compared to lower frequencies;

e) that currently no plans are known for mobile service use of this band;

f) that this band is used by some countries for high-density fixed applications,

noting

a) that due to the small number of expected EESS earth stations to be deployed worldwide (10-40 stations), coordination between fixed and land mobile systems and the EESS stations would not put undue constraints on either of the services,

recommends

1 that sharing between transmitting EESS satellites and receiving data relay satellites (DRS) operating in the ISS near 26 GHz is feasible given the following constraints:

– EESS satellites in sun-synchronous orbit or in an orbit that is proximate to the orbits of the DRS user satellites shall not produce a power-flux-density (pfd) greater than –155 dB(W/m^2) in 1 MHz at any location on the geostationary orbit (GSO) for more than 0.1% of the time (see Note 1);

– EESS satellites in orbits other than that mentioned above shall not produce a pfd greater than –155 dB(W/m^2) in 1 MHz at any location on the GSO for more than 1% of the time;

2 that, when designing EESS systems, the probability of receiving brief periods of interference from DRS user satellites in the ISS should be taken into account. This interference should exist for less than 0.1% of the time;

3 that EESS systems be designed to operate within the currently applicable pfd limits in the band:

Limit (dB(W/m^2)) in 1 MHz bandwidth for angle of arrival, φ, above the horizontal plane		
0° - 5°	5° - 25°	25° - 90°
–115	–115 + 0.5(φ–5)	–105

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4, 8 and 9.

** Separation distance refers to the distance that could be achieved in coordination.

4 that separation distances required between EESS receiving earth stations and the fixed and mobile transmitting stations may be derived using the methodology outlined in Annex 1 and the interference criterion for space-to-Earth EESS links contained in Recommendation ITU-R SA.1026 (separation distance refers to the distance that could be achieved in coordination);

5 that suitable measures related to the deployment of EESS earth stations may need to be identified in order not to constrain the use of the band 25.5-27.0 GHz by the FS.

NOTE 1 – Proximate orbits are defined as two circular orbits whose difference in altitude is smaller than 500 m and difference in orbital plane angle is smaller than 1.5°.

ANNEX 1

Separation distances between EESS earth stations and FS stations around 26 GHz

The following material provides an estimation of separation distances for various types of FS system applications and e.i.r.p. density levels.

System parameters for point-to-point radio-relay as well as point-to-multipoint (P-MP) systems have been received from FS representatives. Table 1 summarizes the applicable technical data.

TABLE 1

FS characteristics used in sharing studies around 26 GHz

	Point-to-point – Radio-relay		P-MP Central station	P-MP Out station
Modulation	QPSK	OQPSK		
Capacity (Mbit/s)	2 × 2/4 × 2	2 × 2/ 4 × 2/16 × 2		
Antenna gain (dBi)	35-40 (dish)	35-40 (dish)	6 (omni) 14-17 (sector)	25-30 (planar) 30-35 (dish)
Output power (dBW) – typical value – range	 –10 –25/0	 –10 –25/0	–10	–10
e.i.r.p. (dBW)	25 to 30	25 to 30	–4 to 7	15 to 25
Receiver IF bandwidth (MHz)	2.5/5.0	2.5/5.0/20	14/28/56/112	14/28/56/112
Noise figure (dB)	10	10		
Maximum C/N (dB) for BER = 1×10^{-6}	21 (23)	18		
e.i.r.p. density (dB(W/MHz))	21/23	21/17	–10.5	7.5

QPSK: Quadraphase shift keying.

OQPSK: Offset quaternary phase shift keying.

Adequate protection criteria for the EESS can be found in Recommendation ITU-R SA.1027. The received interference power density shall not exceed –145 dB(W/MHz) for 1% of the time.

In addition to the above parameters, a worst case e.i.r.p. density of 36 dB(W/MHz) for radio-relay systems has been evaluated. For the P-MP systems, it was assumed that the required antenna gain is basically a function of the transmitted data rate.

Typical e.i.r.p. density values would result from a combination of lowest data rate with lowest antenna gain and vice versa. As a worst case, a combination of highest antenna gain and 56 MHz bandwidth was assumed for the calculation of the required separation distance. For central stations, it was assumed that in general no off-pointing would be feasible (10 dBi was used in two favourable cases), whereas for out stations limited off-pointing may be feasible. Mean antenna heights around 20 m have been assumed.

Attention is drawn to the difference between coordination distance and separation distance. Coordination distance is merely the distance from a receiving earth station where the potential of interference has to be studied if a transmitting earth station is closer than this boundary. This does not mean that interference is actually caused if the distance between the two stations is less than the coordination distance. It is simply a trigger for closer investigation of the potential interference situation.

The separation distance in turn is the boundary distance below which in all likelihood harmful interference will be caused to the receiving earth station unless additional blockage of the signal path, for example by buildings, trees or hills, takes place. The following assessment gives an idea of the distances to be expected.

The free space loss is given by $L_s \cong 20 \log (42\, df)$ and is the basic transmission loss by spreading of the signal in space. In addition to this basic transmission loss, further attenuation will occur due to atmospheric effects, path obstacles and diffraction due to the Earth's curvature. The total signal attenuation, L_t, is then given by the sum of the free space loss, L_s, the atmospheric loss, L_a, the diffraction losses, L_d and L_o and the vegetation, L_v.

$$L_t = L_s + L_a + L_d + L_o + L_v$$

The atmospheric absorption loss can be estimated by means of several equations listed in Appendix S7 of the Radio Regulations as well as Recommendation ITU-R P.676. The attenuation rate per kilometre is composed of attenuation due to water vapour, attenuation due to oxygen and attenuation due to all other effects.

Recommendation ITU-R P.526-2 (Geneva, 1992) proposes an estimation of the diffraction losses due to curvature of the Earth based on the equations:

$$L_d = -\left(F(X) + G(Y_1) + G(Y_2)\right)$$

$$F(X) = 11 + 10 \log X - 17.6\, X$$

$$G(Y) \cong 20 \log\left(Y + 0.1^3\right) \qquad \text{for } 10\,K < Y < 2$$

$$G(Y) \cong 17.6\left(Y - 1.1\right)^{1/2} - 5 \log\left(Y - 1.1\right) - 8 \qquad \text{for } 10 \quad Y > 2$$

$$X = 2.2\, \beta\, f^{1/3}\, a_e^{-2/3}\, d$$

$$Y = 9.6 \times 10^{-3}\, \beta\, f^{2/3}\, a_e^{-1/3}\, h$$

where:

d: path length (km)

h: antenna height (m)

f: frequency (MHz)

a_e: equivalent Earth's radius ($\cong$ 8 500 km)

β: polarization parameter ($\cong$ 1)

K: surface admittance factor (<0,01).

The signal attenuation is primarily a function of the distance (km) and to a smaller extent dependant on the antenna heights of the transmitting and receiving terminals. Of major significance are path obstacles and attenuation due to vegetation. EESS stations are typically installed in a valley or an area protected by hills or vegetation. Hills can be considered as single rounded obstacles for which diffraction models exist. The attenuation L_o due to obstacles is composed of three components as given by Recommendation ITU-R P.526-2 (Geneva, 1992).

$$L_o = J(\nu) + T(\rho) + Q(\chi)$$

$$J(\nu) = 6.9 + 20 \log\left(\sqrt{(v - 0.1)^2 + 1} + v - 0.1\right)$$

$$v = 2 \sin\left(\frac{\theta}{2}\right)\sqrt{\frac{2\left(d_a + R\frac{\theta}{2}\right)\left(d_b + R\frac{\theta}{2}\right)}{\lambda d}}$$

$$T(\rho) = 7.2\,\rho - 2\rho^2 + 3.6\,\rho^3 - 0.8\rho^4$$

$$\rho^2 = \frac{R(d_a + d_b)}{d_a\, d_b \left(\pi\frac{R}{\lambda}\right)^{1/3}}$$

$$Q(\chi) = 12.5\chi \qquad \text{for } 0 \le \chi \le 4$$

$$\chi = \left(\pi\frac{R}{\lambda}\right)^{1/3}\theta$$

where:

- θ: angle between both paths tangential to obstacle
- d: distance between EESS and FS stations
- d_a: distance between EESS station and top of hill (obstacle)
- d_b: distance between FS station and top of hill (obstacle)
- R: effective radius of terrain curvature
- λ: wavelength.

Vegetation attenuation guidelines for woodland can be found in Recommendation ITU-R P.833. As this Recommendation covers only frequencies up to 10 GHz, the attenuation rate has been extrapolated for 26 GHz, for which 1.7 dB per kilometre were derived.

The separation distance is naturally also a function of the antenna azimuth and will decrease with the offset to the pointing direction. Antenna gain values between –10 and +15 dBi have to be taken into account. Off pointing of FS antennas will also have a significant effect on the separation distance.

Table 2 summarizes the separation distances based on a combination of various assumptions. It can be seen that even the worst case with maximum antenna gains, free space loss and atmospheric losses only, the separation distance is very moderate. It is, of course, extremely unlikely to encounter a combination of all adverse effects so that a number of typical cases have been listed in addition. In reality, EESS stations will normally be found in areas which offer protection through hills and vegetation. In such a case, the separation distances will reduce to values around 10 to 20 km. Taking also into account some off-pointing between the maximum angle of radiation of the FS station and the maximum gain of the receiving EESS station, separation distances around 10 km are likely to be sufficient.

Coordination through geographical and/or frequency separation is largely ineffective in the 25.5-27.0 GHz shared band allocation for the purpose of placing an EESS earth station within a high-density FS deployment area, because the spacings between densely deployed adjacent FS stations are smaller than the required separation distances by an order of magnitude or more. Therefore, a single EESS earth station placed within a potential high-density FS deployment area would create an excessive exclusion zone ranging from several city blocks to an entire service area.

Conclusions

This assessment shows that the separation distances are significantly shorter around 26 GHz as compared to lower frequencies, e.g. the 2 GHz or 8 GHz bands. Typical values taking average situations result in separation distances around 10 km. The coordination problem will be minimized if there is a limited number of EESS earth stations and if interference mitigation techniques such as terrain shielding are applied. However, studies have indicated that small and low-cost EESS stations are in the design stage. Such stations would be unpredictable in terms of number and deployment patterns and coordination with such stations would be difficult and not feasible for high-density fixed applications. Suitable measures (such as antenna size) that could be undertaken by the EESS in order not to constrain the use of the band by administrations deploying FS systems need to be identified.

It can be concluded that a limited number of EESS stations can share with FS point-to-point as well as P-MP systems.

TABLE 2

Separation distances for various parameter combinations

Combination of effects	Separation distance (km)			
	Point-to-point 21 dB(W/MHz)	Point-to-point 36 dB(W/MHz)	P-MP Central station	P-MP Out station
Worst case: Maximum FS system e.i.r.p. spectral density Maximum EESS antenna gain (15 dBi) No FS station off-pointing Flat terrain, no vegetation	34	39	23	30
Mean parameters plus FS station off-pointing: Maximum FS system e.i.r.p. spectral density Mean EESS antenna gain (3 dBi) FS station off-pointing (40/40/10/20 dB) Flat terrain, 50% vegetation	2	7	2	4
Mean parameters plus low EESS station gain: Maximum FS system e.i.r.p. spectral density Low EESS antenna gain (–10 dBi) Mean FS station off-pointing (20/20/0/10 dB) Flat terrain, 50% vegetation	4	11	1.3	3
Mean parameters plus hill in-between: Maximum FS system e.i.r.p. spectral density Mean EESS antenna gain (3 dBi) Mean FS station off-pointing (20/20/0/10 dB) Hill of 50 m, 50% vegetation	0.1	0.9	0.1	0.1
Mean parameters plus forest in-between: Maximum FS system e.i.r.p. spectral density Mean EESS antenna gain (3 dBi) Mean FS station off-pointing (20/20/0/10 dB) Flat terrain, forest between both stations	7	12	4	6
Mean parameters (typical case): Maximum FS system e.i.r.p. spectral density Mean EESS antenna gain (3 dBi) Mean FS station off-pointing (20/20/0/10 dB) Hill of 20 m for P-P system, no hill for P-MP, 50% vegetation	0.9	7	4	8
Favourable case in flat terrain: Maximum FS system e.i.r.p. spectral density Low EESS antenna gain (–10 dBi) FS station off-pointing (40/40/10/20 dB) Flat terrain, forest between stations	0,5	2	0,5	1,0