

RECOMMENDATION ITU-R S.1557

Operational requirements and characteristics of fixed-satellite service systems operating in the 50/40 GHz bands for use in sharing studies between the fixed-satellite service and the fixed service*

(Question ITU-R 250-1/4)

(2002)

The ITU Radiocommunication Assembly,

considering

- a) that the band 37.5-42.5 GHz is allocated to the fixed service and the fixed-satellite service (FSS) (space-to-Earth) on a co-primary basis;
- b) that some FSS systems plan to provide data rates ranging from synchronous transfer mode 1 (STM-1) or higher, up to 10 STM-4;
- c) that most FSS systems propose using small earth station antennas, less than 1 m in diameter for the user link, to provide end-to-end link availability of at least 99.7%;
- d) that FSS systems may need to use larger earth terminal antennas, of up to 3 m in diameter, for gateway applications involving individually-coordinated earth stations at geographically dispersed hubs or fibre access points (FAPs) and that these applications will require the end-to-end link availability of at least 99.9%;
- e) that the feasibility of using larger antennas having a diameter greater than 2.4 m ($D/\lambda \gg 300$), given the effects of main reflector distortion, surface roughness, radome attenuation and auto tracking facilities capable of minimizing pointing loss in this band, remains to be determined;
- f) that some proposed FSS systems operating in this band use on-board processing for small earth terminal users, and use a transparent transponder for gateway or hub/FAP applications;
- g) that the propagation impairments are very severe in this frequency range;
- h) that most FSS systems plan to provide a clear-air bit error ratio (BER) of the order of 1×10^{-7} to 1×10^{-10} ;
- j) that current planned FSS systems use quadrature phase shift keying (QPSK) modulation, and future FSS systems may use higher order modulation schemes such as 8-PSK or quadrature amplitude modulation, 16-QAM,

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 7, 8 and 9 and Joint Working Party 4-9S.

recommends

- 1 that FSS system design and sharing studies in the band 37.5-42.5 GHz should take into account the operational requirements in Annexes 1 and 2;
- 2 that FSS characteristics in Annexes 3 through 6 which contain technical information on some FSS systems operating in the 37.5-42.5 GHz band, should be taken into consideration when conducting sharing studies between the 50/40 GHz FSS service and co-frequency, co-primary services;
- 3 that administrations planning modifications to these systems or proposing future satellite networks in the 50/40 GHz bands should submit FSS network technical characteristics to ITU-R to update the Annexes.

ANNEX 1

Required downlink parameters of FSS systems operating in the 37.5-42.5 GHz band

1 Introduction

This Annex presents data on the required downlink power flux-density (pfd) in the 37.5-42.5 GHz band to allow FSS systems operating in this band to operate with various earth terminal antenna sizes. The study is based on the proposed FSS operating in the 50/40 GHz bands.

Based on the ITU filing, a considerable number of FSS systems, planned to operate within the bands 37.5-42.5 GHz and 47.2-50.2 GHz, have been received. These systems plan to provide data rates ranging from video-conferencing quality through very high speed transmission of STM-1 (155 Mbit/s) or higher, up to 10 STM-1, to earth terminal antennas ranging in size from 1 m to 3 m. Most FSS systems propose using small earth terminals, less than 1 m in diameter, to provide 99.7% link availability, and the systems using bigger earth terminal antenna sizes, from 1.5-3 m for gateway-to-gateway or hub-to-hub applications, will require higher link availability. Because the propagation impairments are very severe in the 40/50 GHz bands, most proposed systems will provide service at higher minimum elevation angles than FSS systems operating in frequency bands below 30 GHz. The typical minimum operational elevation angle at 40/50 GHz is 20°; however, some systems, like the GSO SV plan to provide service at a 15° minimum elevation angle. Technical characteristics of several proposed FSS systems planning to operate in these bands have been included in Recommendation ITU-R S.1328.

The purpose of this Annex is to provide additional technical characteristics of the FSS systems operating in the 40/50 GHz bands for use in future sharing studies in ITU-R.

2 Required earth terminal antenna size vs. downlink pfd

This section contains computations of the downlink pfd levels that are required to allow the FSS satellite networks operating in the 40/50 GHz band to operate with various earth terminal antenna sizes and desired link availabilities.

The pfd at the Earth's surface can be shown as:

$$pfd = S - G_{rxE/S} + 21.45 + 20 \log(f) + 10 \log\left(\frac{1}{BW = sps}\right)$$

where:

pfd : power flux-density (dB(W/(m² · MHz))

S : receive signal strength (dBW)

BW : transmit bandwidth (necessary bandwidth) (MHz)

sps : symbol rate (Msymbols)

f : frequency (GHz)

$G_{rxE/S}$: on-axis gain of receiving earth station (dBi).

The received $E_b/(N_0 + I_0)$ at the receiver can be computed as:

$$\frac{E_b}{(N_0 + I_0)_\downarrow} = \frac{S}{N_0 + I_0} - 10 \log(bps)$$

and

$$\left(\frac{S}{N_0 + I_0}\right) = S - (N_0 + I_0) = S - G_{rxE/S} + (20.4 + 20 \log(D) + 20 \log(f) + 10 \log(\eta)) - (N_0 + I_0)$$

and

$$(N_0 + I_0) = 10 \log \left(10^{\left(\frac{N_0}{10}\right)} + 10^{\left(\frac{I_0}{10}\right)} \right)$$

where:

$N_0 = -228.6 + 10 \log(T)$ (dB(W/Hz)), thermal noise power density

T : earth station receiver noise temperature + noise temperature increases due to rain (K)

I_0 : self interference + interference from other FSS systems operating in the same band (dB(W/Hz))

D : earth station antenna diameter (m)

f : frequency (GHz)

η : earth station antenna efficiency

bps : bit rate.

It is important to note that the FSS downlink must satisfy the pfd limits at all slant ranges and elevation angles, while the E_b/N_0 of interest to a designer is the minimum E_b/N_0 over all slant ranges, elevation angles, and positions within a beam. Also the calculated pfd at the Earth's surface is based on the free-space propagation conditions. The received downlink E_b/N_0 at the FSS receiver, can be shown as:

$$\left(\frac{E_b}{N_0 + I_0} \right)_{\downarrow} = pfd + 10 \log \left(\frac{sps}{bps} \right) + 20 \log(D) + 10 \log(\eta) - (N_0 + I_0) - 61.05 - L_{atm/scin} - L_p - EOC - M_{fade} - M_{system}$$

where:

$L_{atm/scin}$: atmospheric loss and scintillation loss. In this band, the atmospheric and scintillation loss are about 1.2 dB

L_p : depending on antenna size (dB)

EOC : edge of coverage, typically 3.5 dB

M_{fade} : required rain fade margin to achieve its link availability (dB)

M_{system} : system margin (2 dB is allocated to system margin).

From the above expressions the receive earth terminal antenna size in metres can be shown as:

$$D = 10^{\left(\frac{1}{20} \left(\left(\frac{E_b}{N_0 + I_0} \right)_{\downarrow} - pfd - 10 \log \left(\frac{sps}{bps} \right) - 10 \log(\eta) + (N_0 + I_0) + 61.05 + L_{atm/scin} + L_p + EOC + M_{fade} + M_{system} \right) \right)}$$

2.1 Downlink $E_b/(N_0 + I_0)$

The required receive $E_b/(N_0 + I_0)$ depends on the modulation (QPSK, 8-PSK, 16-QAM, etc.), BER, coding and implementation loss. Most of the proposed systems in these bands plan to use QPSK modulation and to provide a BER of the order of 1×10^{-7} to 1×10^{-9} . The required $E_b/(N_0 + I_0)$, including the implementation loss, is in the range from 7 dB to 9 dB depending on the coding. If the higher modulations such as 8-PSK, 16-QAM, etc. are used, the required $E_b/(N_0 + I_0)$ is significantly higher. In this study, both QPSK and 8-PSK modulations are used.

The required downlink $E_b/(N_0 + I_0)$ depends on whether the satellite payload functions as an on-board processor (OBP) or a transparent transponder (bent-pipe (BP)). In the case of an OBP, the downlink $E_b/(N_0 + I_0)$ is the same as the required $E_b/(N_0 + I_0)$ to achieve its BER. When the satellite payload functions as a transparent transponder, the downlink $E_b/(N_0 + I_0)$ can be computed as:

$$\left(\frac{E_b}{N_0 + I_0} \right)_{\downarrow} = -10 \log \left(10^{\left((-0.1) \frac{E_b}{N_0 + I_0} \right)_{required}} - 10^{\left((-0.1) \frac{E_b}{N_0 + I_0} \right)_{\uparrow}} \right)$$

In this study, the downlink $E_b/(N_0 + I_0)$ is assumed to be equal to uplink $E_b/(N_0 + I_0)$. Therefore the downlink $E_b/(N_0 + I_0)$ is 3 dB higher than the required receive $E_b/(N_0 + I_0)$.

2.2 Thermal noise density, N_0 and interference noise density, I_0

Thermal noise density, N_0 , can be shown as:

$$N_0 = -228.6 + 10 \log(T_{rx} + T_{rain}) \quad \text{dB(W/Hz)}$$

where:

T_{rx} : earth station receive system noise temperature (K). Typical ground antenna system temperature is 800 K (antenna noise temperature = 70 K, Receiver noise figure = 4.5 dB, filter/diplexer = 0.7 dB and cable loss = 0.3 dB)

T_{rain} can be computed as:

$$T_{rain} = 280 (1 - 10^{-0.1 (\text{rain fade margin})})$$

For example, if the rain fade margin is 18 dB, the noise temperature increase due to rain is 275 K.

Interference noise density, I_0 : Calculated interference noise density should include intra- and inter-system noise density. In this study, 1.5 dB is allocated to the intra-system interference. Calculated inter-system interference from other FSS systems operating in the same frequency band depends on the earth station antenna roll-off and the downlink pfd from other FSS systems. In this study, all FSS systems are assumed to operate at the same pfd and the geostationary-satellite orbit (GSO) is assumed to be populated at 4° intervals. For example, if all GSO FSS systems operate at a downlink pfd of $-105 \text{ dB (W/(m}^2 \cdot \text{MHz))}$, the received interference noise density of 1 m earth terminal operating in the 40 GHz band is -203.44 dB(W/Hz) .

2.3 Required rain fade margin

As mentioned above, most proposed systems plan to provide 99.7% link availability to the very small aperture terminal (VSAT) users and provide higher link availability to gateway-to-gateway or hub-to-hub users. The required rain fade margin is shown in Fig. 1. In the calculation, 99.7% link availability and a 25° elevation angle are assumed. Figure 2 shows the link availability of FSS systems operating in the 40 GHz band with an 18 dB rain fade margin.

Figure 2 shows that the 18 dB rain fade margin will not achieve the 99.7% link availability for most locations around world. In addition, the systems that plan to provide service at elevation angles less than 25° must use mitigation techniques, such as variable data rates, site diversity, frequency diversity, heavy coding, etc. to achieve the desired link availability.

FIGURE 1

Required rain fade margin
(Frequency band = 40 GHz; elevation angle = 25°; link availability = 99.7%)

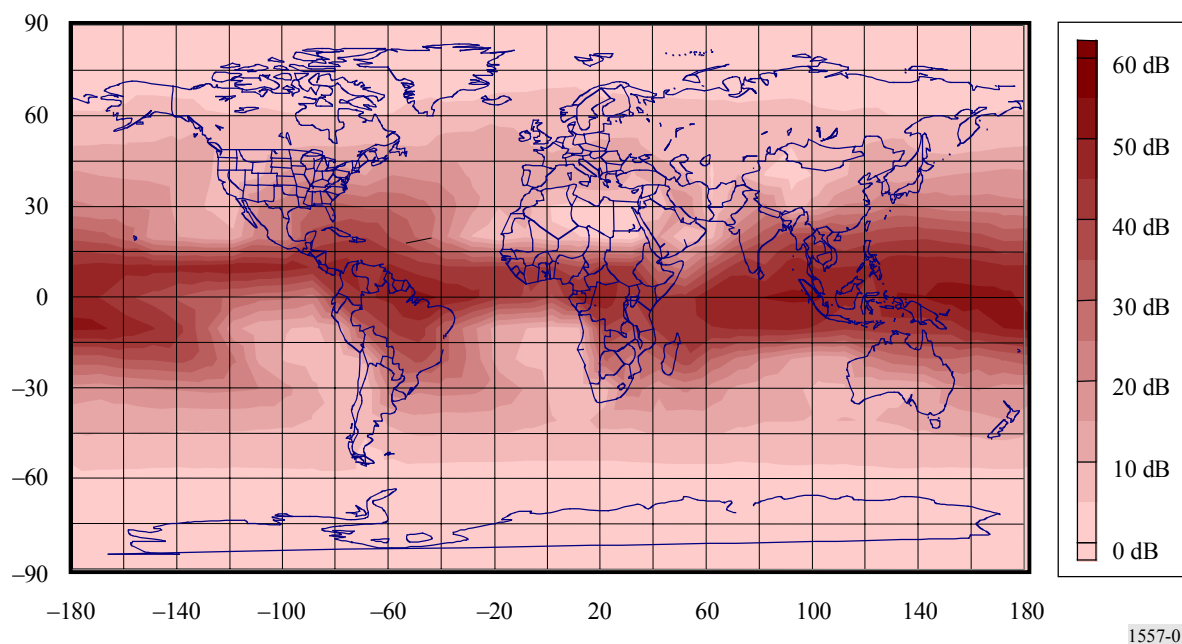
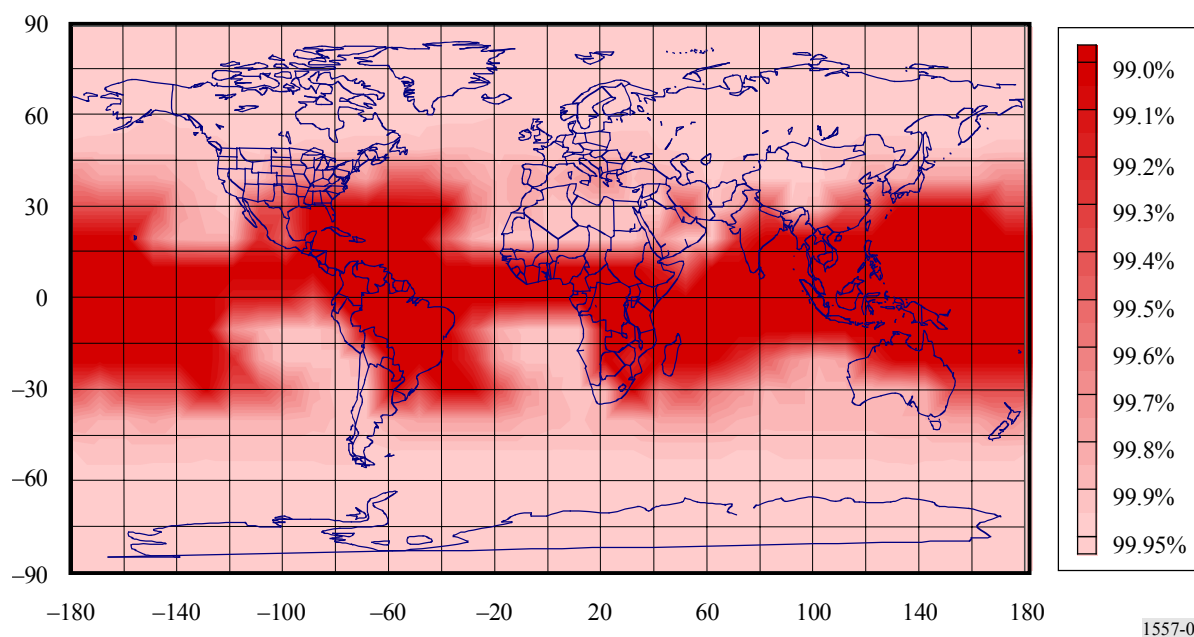


FIGURE 2

Link availability
(Frequency band = 40 GHz; elevation angle = 25°; rain fade margin = 18 dB)



2.4 Pointing loss

The off-axis antenna pointing loss (dB) for an idea uniformly-illuminated circular aperture can be derived from physical optics:

$$Loss = 10 \log \left(\frac{2J_1(x)}{x} \right)^2$$

where:

$$x = \frac{\pi f D}{c} \sin(\varphi)$$

and

f : frequency

D : antenna diameter

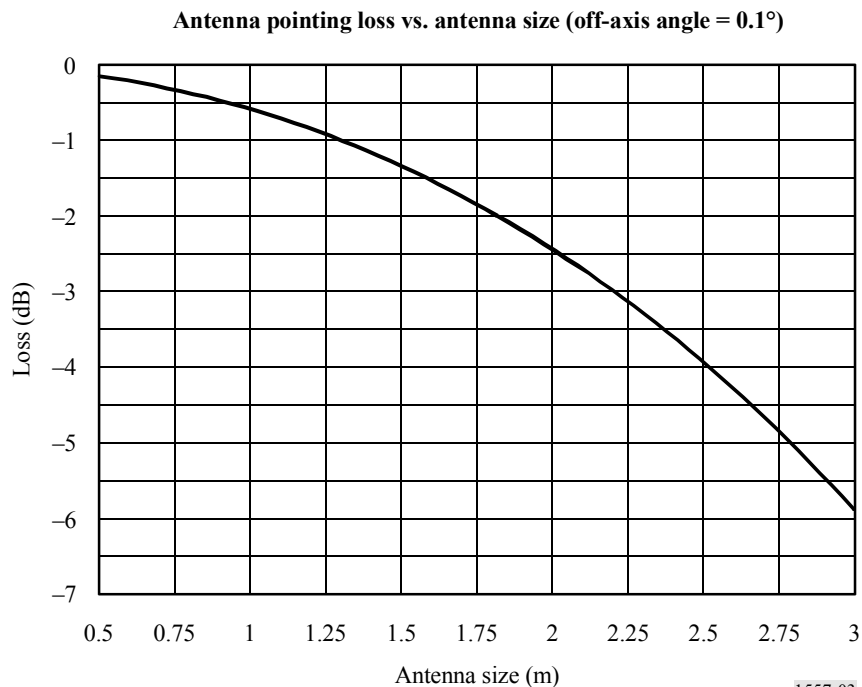
c : speed of light

φ : off-axis angle

$J_1(x)$: first order of Bessell function.

For an off-axis angle of 0.1° the pointing loss versus earth terminal antenna size is shown in Fig. 3. In this study, 0.7 dB is allocated to earth terminal antenna pointing loss.

FIGURE 3



2.5 Results

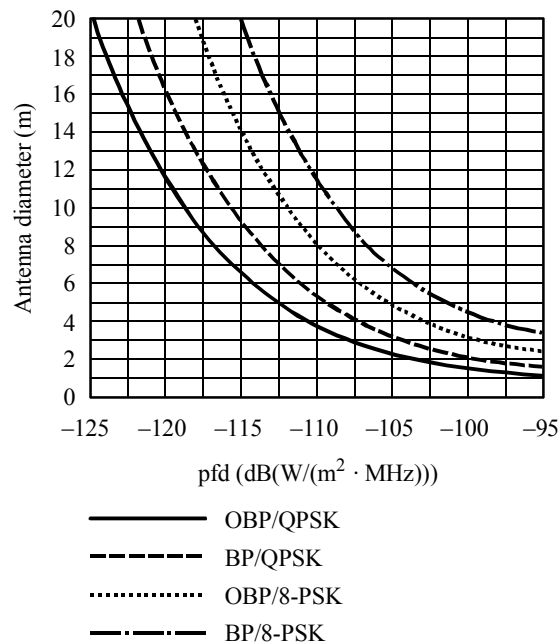
Figure 4 shows the required earth terminal antenna size versus the downlink pfd level. The calculation is based on the following assumptions:

- Rain fade margin = 18 dB
- Earth terminal receive noise temperature = 800 K
- Pointing loss = 0.7 dB
- Atmospheric and scintillation loss = 1.2 dB
- Degradation due to self-interference = 1.5 dB
- EOC = 3.5 dB
- Antenna efficiency = 70%
- Frequency = 40 GHz
- System margin = 2 dB

- Required E_b/N_0 :
 - OBP:
 - QPSK = 7.0 dB
 - 8-PSK = 10.5 dB
 - BP (transparent transponder):
 - QPSK = 10.0 dB
 - 8-PSK = 13.5 dB.

FIGURE 4

Earth terminal antenna size vs. downlink
pfd levels



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3 Discussion of results

Most proposed FSS systems operating in the 40/50 GHz bands use OBP for VSAT users, and use a transparent transponder or BP for gateway-to-gateway or hub-to-hub users. The typical antenna diameter of VSAT users is in a range from 0.5 m to 1 m, and the antenna diameter of gateway-to-gateway or hub-to-hub users is in a range from 1 m to 3 m. Most proposed FSS systems in the 40/50 GHz do not plan to use earth terminal antennas bigger than 3 m because the complexity of an auto track antenna capable of minimizing pointing loss in these frequency bands is very high.

Figure 4 shows that for a QPSK system a downlink pfd level of $-95 \text{ dB(W/(m}^2 \cdot \text{MHz))}$ will allow the use of a 1 m user terminal VSAT operating in this band. The 3 m gateway-to-gateway antenna size may close the link with a pfd level of $-105 \text{ dB(W/(m}^2 \cdot \text{MHz))}$. If the smaller antenna size is used, the pfd must be greater than $-95 \text{ dB(W/(m}^2 \cdot \text{MHz))}$ for VSAT and $-105 \text{ dB(W/(m}^2 \cdot \text{MHz))}$ for gateway users. However, required downlink pfd levels can be different depending on the rain region. Furthermore, if higher modulations, such as 8-PSK, 16-QAM are used, the required downlink pfd levels will be significantly increased.