



Recommendation ITU-R P.682-3
(02/2012)

**Propagation data required for the design
of Earth-space aeronautical mobile
telecommunication systems**

P Series
Radiowave propagation



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Foreword

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P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

Electronic Publication
Geneva, 2012

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RECOMMENDATION ITU-R P.682-3

**Propagation data required for the design of Earth-space
aeronautical mobile telecommunication systems**

(Question ITU-R 207/3)

(1990-1992-2007-2012)

Scope

This Recommendation describes propagation effects of particular importance to aeronautical mobile-satellite systems. Relevant ionospheric and tropospheric propagation impairments are identified, and reference made to ITU-R Recommendations that provide guidance on these effects. Models are provided to predict the propagation effects caused by signal multipath and scattering from the Earth's surface.

The ITU Radiocommunication Assembly,

considering

- a) that for the proper planning of Earth-space aeronautical mobile systems it is necessary to have appropriate propagation data and prediction methods;
- b) that the methods of Recommendation ITU-R P.618 are recommended for the planning of Earth-space telecommunication systems;
- c) that further development of prediction methods for specific application to aeronautical mobile-satellite systems is required to give adequate accuracy for all operational conditions;
- d) that, however, methods are available which yield sufficient accuracy for many applications,

recommends

- 1** that the methods contained in Annex 1 be adopted for current use in the planning of Earth-space aeronautical mobile telecommunication systems, in addition to the methods recommended in Recommendation ITU-R P.618.

Annex 1**1 Introduction**

Propagation effects in the aeronautical mobile-satellite service differ from those in the fixed-satellite service and other mobile-satellite services because:

- small antennas are used on aircraft, and the aircraft body may affect the performance of the antenna;
- high aircraft speeds cause large Doppler spreads;
- aircraft terminals must accommodate a large dynamic range in transmission and reception;
- aircraft safety considerations require a high integrity of communications, making even short-term propagation impairments very important, and communications reliability must be maintained in spite of banking manoeuvres and three-dimensional operations.

This Annex discusses data and models specifically required to characterize the path impairments, which include:

- tropospheric effects, including gaseous attenuation, cloud and rain attenuation, fog attenuation, refraction and scintillation;
- ionospheric effects such as scintillation;
- surface reflection (multipath) effects;
- environmental effects (aircraft motion, sea state, land surface type).

Aeronautical mobile-satellite systems may operate on a worldwide basis, including propagation paths at low elevation angles. Several measurements of multipath parameters over land and sea have been conducted. In some cases, laboratory simulations are used to compare measured data and verify model parameters. The received signal is considered in terms of its possible components: a direct wave subject to atmospheric effects, and a reflected wave, which generally contains mostly a diffuse component.

There is current interest in using frequencies near 1.5 GHz for aeronautical mobile-satellite systems. As most experiments have been conducted in this band, data in this Recommendation are mainly applicable to these frequencies. As aeronautical systems mature, it is anticipated that other frequencies may be used.

2 Tropospheric effects

For the aeronautical services, the altitude of the mobile antenna is an important parameter. Estimates of tropospheric attenuation may be made with the methods in Recommendation ITU-R P.618.

The received signal may be affected both by large-scale refraction and by scintillations induced by atmospheric turbulence. These effects will diminish for aircraft at high altitudes.

3 Ionospheric effects

Ionospheric effects on slant paths are discussed in Recommendation ITU-R P.531. These phenomena are important for many paths at frequencies below about 10 GHz, particularly within $\pm 15^\circ$ of the geomagnetic equator, and to a lesser extent, within the auroral zones and polar caps. Ionospheric effects peak near the solar sunspot maximum.

Impairments caused by the ionosphere will not diminish for the typical altitudes used by aircraft. A summary description of ionospheric effects of particular interest to mobile-satellite systems is available in Recommendation ITU-R P.680. For most communication signals, the most severe impairment will probably be ionospheric scintillation. Table 1 of Recommendation ITU-R P.680 provides estimates of maximum expected ionospheric effects at frequencies up to 10 GHz for paths at a 30° elevation angle.

4 Fading due to surface reflection and scattering

4.1 General

Multipath fading due to surface reflections for aeronautical mobile-satellite systems differs from fading for other mobile-satellite systems because the speeds and altitudes of aircraft are much greater than those of other mobile platforms.

4.2 Fading due to sea-surface reflections

Characteristics of fading for aeronautical systems can be analysed with procedures similar to those for maritime systems described in Recommendation ITU-R P.680, taking careful account of Earth sphericity, which becomes significant with increasing antenna altitude above the reflecting surface.

4.2.1 Dependence on antenna height and antenna gain

The following simple method, based on a theoretical model, provides approximate estimates of multipath power or fading depth suitable for engineering applications.

The procedure is as follows:

Applicable range:

Frequency: 1-2 GHz

Elevation angle: $\theta_i \geq 3^\circ$ and $G(1.5\theta_i) \geq -10$ dB

where $G(\theta)$ is the main-lobe antenna pattern given by:

$$G(\theta) = -4 \times 10^{-4} (10^{G_m/10} - 1) \theta^2 \quad \text{dB} \quad (1)$$

where:

G_m : value of the maximum antenna gain (dB)

θ : angle measured from boresight (degrees).

Polarization: circular and horizontal polarizations; vertical polarization for $\theta_i \geq 8^\circ$

Sea condition: wave height of 1-3 m (incoherent component fully developed).

Step 1: Calculate the grazing angles of the specular reflection point, θ_{sp} , and the horizon, θ_{hr} , by:

$$\theta_{sp} = 2 \gamma_{sp} + \theta_i \quad \text{degrees} \quad (2a)$$

$$\theta_{hr} = \cos^{-1} [R_e / (R_e + H_a)] \quad \text{degrees} \quad (2b)$$

where:

$$\gamma_{sp} = 7.2 \times 10^{-3} H_a / \tan \theta_i$$

R_e : radius of the Earth = 6 371 km

H_a : antenna height (km)

Step 2: Find the relative antenna gain G in the direction midway between the specular point and the horizon. The relative antenna gain is approximated by equation (1) where $\theta = \theta_i + (\theta_{sp} + \theta_{hr})/2$ (degrees).

Step 3: Calculate the Fresnel reflection coefficient of the sea:

$$R_H = \frac{\sin \theta_i - \sqrt{\eta - \cos^2 \theta_i}}{\sin \theta_i + \sqrt{\eta - \cos^2 \theta_i}} \quad \text{(horizontal polarization)} \quad (3a)$$

$$R_V = \frac{\sin \theta_i - \sqrt{(\eta - \cos^2 \theta_i) / \eta^2}}{\sin \theta_i + \sqrt{(\eta - \cos^2 \theta_i) / \eta^2}} \quad \text{(vertical polarization)} \quad (3b)$$

$$R_C = \frac{R_H + R_V}{2} \quad \text{(circular polarization)} \quad (3c)$$

$$\eta = \epsilon_r(f) - j60 \lambda \sigma(f)$$

where:

$\epsilon_r(f)$: relative permittivity of the surface at frequency f (from Recommendation ITU-R P.527)

$\sigma(f)$: conductivity (S/m) of the surface at frequency f (from Recommendation ITU-R P.527)

λ : free space wavelength (m).

Step 4: Calculate the correction factor C_θ (dB):

$$C_\theta = \begin{cases} 0 & \text{for } \theta_{sp} \geq 7^\circ \\ \theta_{sp} - 7) / 2 & \text{for } \theta_{sp} < 7^\circ \end{cases} \quad (4)$$

Step 5: Calculate the divergence factor D (dB) due to the Earth's curvature:

$$D = -10 \log \left[1 + \frac{2 \sin \gamma_{sp}}{\cos \theta_{sp} \sin (\gamma_{sp} + \theta_i)} \right] \quad (5)$$

Step 6: The mean incoherent power of sea reflected waves, relative to the direct wave, P_r , is given by:

$$P_r = G + R + C_\theta + D \quad \text{dB} \quad (6)$$

where:

$$R = 20 \log |R_i|$$

with $R_i = R_H, R_V$ or R_C from equations (3).

Step 7: Assuming the Nakagami-Rice distribution, fading depth is estimated from:

$$A + 10 \log \left(1 + 10^{P_r/10} \right) \quad (7)$$

where A is the amplitude (dB) read from the ordinate of Fig. 1 of Recommendation ITU-R P.680.

Figure 1 below shows the mean multipath power of the incoherent component obtained by the above method as a function of the elevation angle for different gains. By comparing with the case of maritime mobile-satellite systems (Fig. 2 of Recommendation ITU-R P.680), it can be seen that the reflected wave power P_r for aeronautical mobile-satellite systems is reduced by 1 to 3 dB at low elevation angles.