ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R P.2041
(09/2013)

Prediction of path attenuation on links between an airborne platform and Space and between an airborne platform and the surface of the Earth

P Series

Radiowave propagation

ITU

International Telecommunication Union

Foreword

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

RECOMMENDATION ITU-R P.2041

Prediction of path attenuation on links between an airborne platform and Space and between an airborne platform and the surface of the Earth

(2013)

Scope

This Recommendation predicts the various propagation effects needed in planning airborne systems operating in either the airborne-to-space or airborne-to-Earth direction.

The ITU Radiocommunication Assembly,

considering

a)   that, in the design of airborne systems, there is a need for an accurate knowledge of the system performance due to radiowave propagation between an airborne platform and a satellite, and between an airborne platform and the surface of the Earth;

b)   that the airborne platform may be located at any altitude between the surface of the Earth and the top of the stratosphere;

c)   that the systems may operate beyond line of sight;

d)   that the frequency bands used may be in the range from 30 MHz to 50 GHz or higher,

noting

a)   that the ITU-R has established and tested prediction methods that predict the long-term average impairments due to atmospheric effects (e.g. gas attenuation, rain attenuation, cloud attenuation, and the attenuation due to scintillation) between a terminal located on the surface of the Earth and space;

b)   that these ITU-R Earth-space propagation prediction methods can be scaled to predict the performance of airborne links between an airborne platform and a satellite and between an airborne platform and the surface of the Earth,

recommends

that the following prediction methods should be used to predict the long-term average impairments (e.g. attenuation and scintillation fading) due to atmospheric effects between an airborne platform and a satellite and between an airborne platform and the surface of the Earth.
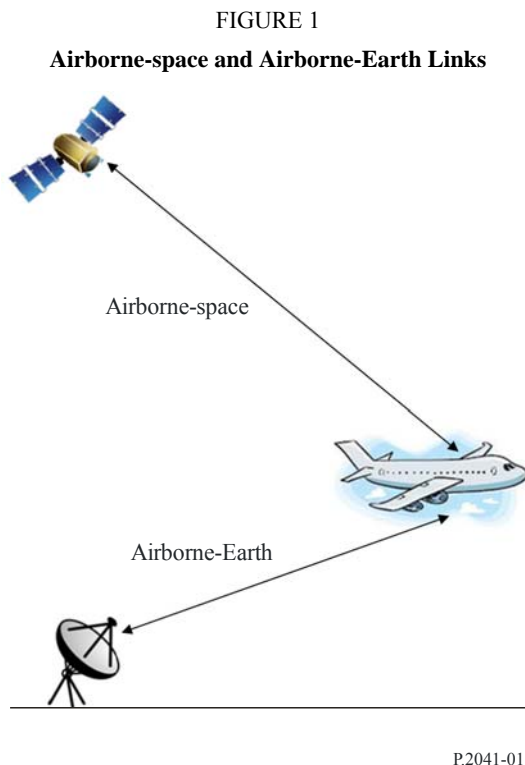
1   Relation to other ITU-R Recommendations

Other P-series Recommendations address propagation from airborne platforms: Recommendation ITU-R P.528 – Propagation curves for aeronautical mobile and radionavigation services using the VHF, UHF, and SHF bands; and Recommendation ITU-R P.682 – Propagation data required for the design of Earth-space aeronautical mobile telecommunication systems.

–   Recommendation ITU-R P.528 predicts the basic transmission losses for frequencies between 125 MHz and 15.5 GHz between two antennas at various heights and distances. While the model is predominantly intended to treat the effects of multipath, diffraction, and troposcatter, it also includes simple gaseous and rain attenuation models that are applicable to generic continental temperate locations. As a result, the model is not applicable to higher frequencies and different climates where the gaseous, rain, and cloud attenuation dominate.

–   Recommendation ITU-R P.682 addresses the tropospheric effects, ionospheric effects, fading due to surface reflections and scattering between an airborne platform and space for frequencies near 1.5 GHz.
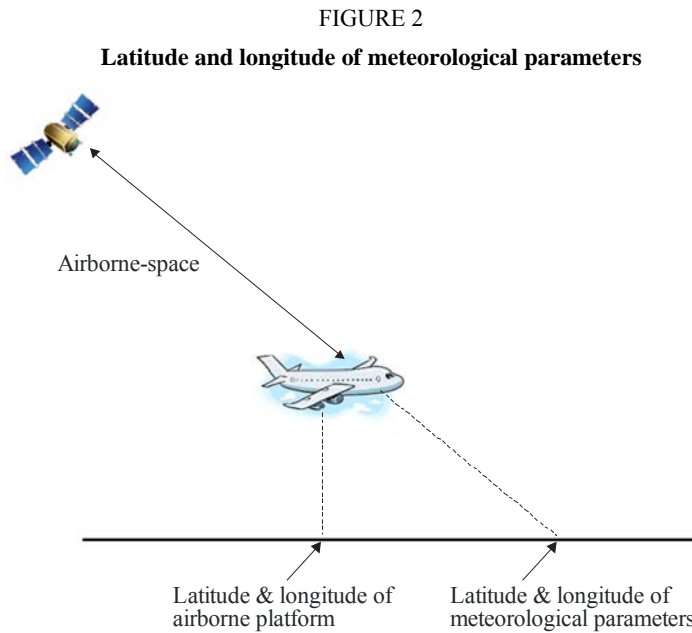
The airborne-space and airborne-Earth links are shown in Fig. 1.

FIGURE 1

Airborne-space and Airborne-Earth Links

Airborne-space

Airborne-Earth

P.2041-01

While the following prediction methods are considered to be approximately correct, they have not been tested and validated with measured data.

2   A note on the use of the digital meteorological maps

There are various maps of meteorological parameters that are functions of latitude and longitude at the surface of the Earth. For a path between an airborne platform and space, the various meteorological parameters should be determined at the point where the path between space and the airborne platform would intercept the Earth rather than the latitude and longitude of the airborne platform. This distinction, shown in Fig. 2, is important since some meteorological parameters are defined at the surface of the Earth (e.g. surface temperature, and the wet term of the radio refractivity).

FIGURE 2

Latitude and longitude of meteorological parameters

Airborne-space

Latitude & longitude of
airborne platform

Latitude & longitude of
meteorological parameters

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3 A note on consistent notation

Recommendations ITU-R P.836 and ITU-R P.618 use the variable p for exceedance probability, and Recommendation ITU-R P.676 uses the variable P for exceedance probability. The variable p will be used in the following discussion.

4 Applicability of the prediction methods

These predictions methods are applicable to links between an airborne platform and space and between an airborne platform and the surface of Earth, where:

–   frequency $\leq$ 55 GHz;

–   elevation angle (φ) from the local horizontal plane $\geq$ 5°.

Depending on the frequency and elevation angle, multipath fading may need to be considered (see Recommendation ITU-R P.528); and depending on the location, time of day, and solar activity, the ionospheric scintillation may need to be considered for frequencies below about 6 GHz (see Recommendation ITU-R P.531).

5 Attenuation between an airborne platform and space

5.1 Total attenuation prediction method

If the airborne platform is below the rain height.

Similar as in Recommendation ITU-R P.618, the total attenuation between an airborne platform and space, $A_T^{AS}(p)$, is computed by:

$$A_T^{AS}(p) = A_G^{AS}(p) + \sqrt{\left(A_R^{AS}(p) + A_C^{AS}(p)\right)^2 + \left(A_S^{AS}(p)\right)^2} \tag{1}$$

where:

$A_R^{AS}(p)$:   attenuation due to rain for a fixed probability (dB)

$A_C^{AS}(p)$:   attenuation due to clouds for a fixed probability (dB)

$A_G^{AS}(p)$:   gaseous attenuation due to water vapour and oxygen for a fixed probability (dB)

$A_S^{AS}(p)$:   fading due to tropospheric scintillation for a fixed probability (dB)

and

$$A_C^{AS}(p) = A_C^{AS}(1\%) \quad \text{for } p < 1.0\% \tag{2a}$$

$$A_G^{AS}(p) = A_G^{AS}(1\%) \quad \text{for } p < 1.0\% \tag{2b}$$

If the airborne platform is above the rain height.

The total attenuation between an airborne platform and space, $A_T^{AS}(p)$, is computed by:

$$A_T^{AS}(p) = A_G^{AS}(p) + A_C^{AS}(p) \tag{3}$$

where:

$A_C^{AS}(p)$:   attenuation due to clouds for a fixed probability (dB)

$A_G^{AS}(p)$:   gaseous attenuation due to water vapour and oxygen for a fixed probability (dB)

and

$$p \geq 0.1\%.$$

For Earth-space paths, the gaseous attenuation, cloud attenuation, rain attenuation, and scintillation fading are estimated using the various associated digital meteorological maps, usually on a 1.125° × 1.125° grid. The following paragraphs describe the method of adjusting the prediction methods that apply to Earth-space paths for paths between an airborne platform and space.

5.2   Gaseous attenuation

The gaseous attenuation for an Earth-space path is predicted by Recommendation ITU-R P.676:

$$A_G(p) = \frac{A_o + A_w(p)}{\sin\varphi} \tag{4}$$

For a path between an airborne platform and space, the corresponding gaseous attenuation is:

$$A_G^{AS}(p) = \frac{A_o^{AS} + A_w^{AS}(p)}{\sin\varphi} \tag{5}$$

A_o^{AS} is predicted as follows:

$$A_o^{AS} = A_o e^{-altitude/h_o} \tag{6}$$

where *altitude* is the altitude above the surface of the Earth, and h_o is obtained from Recommendation ITU-R P.676 using the frequency of interest and r_p at the surface of the Earth.

$A_w^{AS}(p)$ is predicted from Recommendation ITU-R P.676, where $V_t(p)$ is obtained from Annex 2 of Recommendation ITU-R P.836, and *alt* is the altitude of the airborne platform above mean sea level specified in Annex 2, § 1 e) of Recommendation ITU-R P.836.

5.3 Cloud attenuation

It is difficult to predict cloud attenuation from an airborne platform to space since different cloud types are at different altitudes with different vertical extents. However, a conservative approach is to assume the cloud base is at the rain height specified in Recommendation ITU-R P.839 and the cloud top is at 6 km. Compute the cloud attenuation per Recommendation ITU-R P.840 as follows: use 100% of the total columnar content of cloud liquid water for altitudes below the rain height, 0% of the total columnar content of cloud liquid water for altitudes above the cloud top, with a linear transition of total columnar content of cloud liquid water between the cloud base and the cloud top.

5.4 Rain attenuation

Rain attenuation is predicted from Recommendation ITU-R P.618 which computes the slant-path length, L_S, from h_S, the height of the Earth station above mean sea level. For a path between an airborne platform and space, h_S is replaced by the altitude of the airborne platform above mean sea level with the constraint that if h_S is greater than or equal to h_R, then the rain attenuation is 0 dB.

5.5 Fading due to tropospheric scintillation

Fading due to tropospheric scintillation is predicted from Recommendation ITU-R P.618. If the airborne platform is at an altitude below the rain height specified in Recommendation ITU-R P.839, tropospheric scintillation is calculated assuming the airborne platform is located at the surface of the Earth. If the airborne platform is at an altitude above the rain height specified in Recommendation ITU-R P.839, tropospheric scintillation is ignored.

6 Attenuation between an airborne platform and the surface of the Earth

6.1 Total attenuation prediction method

Similar as in Recommendation ITU-R P.618, the total attenuation between an airborne platform and the surface of the Earth, $A_T^{AE}(p)$, is computed by:

$$A_T^{AE}(p) = A_G^{AE}(p) + \sqrt{\left(A_R^{AE}(p) + A_C^{AE}(p)\right)^2 + \left(A_S^{AE}(p)\right)^2} \tag{7}$$

where:

$A_R^{AE}(p)$:   attenuation due to rain for a fixed probability (dB)

$A_C^{AE}(p)$:   attenuation due to clouds for a fixed probability (dB)

$A_G^{AE}(p)$:   gaseous attenuation due to water vapour and oxygen for a fixed probability (dB)

$A_S^{AE}(p)$:   fading due to tropospheric scintillation for a fixed probability (dB)

and

$$A_C^{AE}(p) = A_C^{AE}(1\%) \quad \text{for } p < 1.0\% \tag{8a}$$

$$A_G^{AE}(p) = A_G^{AE}(1\%) \quad \text{for } p < 1.0\% \tag{8b}$$

6.2 Gaseous attenuation

$A_G^{AE}(p)$ is predicted as follows:

$$A_G^{AE}(p) = A_G(p) - A_G^{AS}(p) \tag{9}$$

where:

$A_G(p)$:   gaseous attenuation between the surface of the Earth and space along the same path

$A_G^{AS}(p)$:   calculated per equation (5).

6.3   Cloud attenuation

It is difficult to predict cloud attenuation from an airborne platform to the surface of the Earth since different cloud types are at different altitudes with different vertical extents. However, a conservative approach is to include cloud attenuation predicted by Recommendation ITU-R P.840 for all altitudes.

6.4   Rain attenuation

$A_R^{AE}(p)$ is predicted as follows:

$$A_R^{AE}(p) = A_R(p) - A_R^{AS}(p) \qquad (10)$$

where $A_R(p)$ is the rain attenuation between the surface of the Earth and space.

6.5   Fading due to tropospheric scintillation

Fading due to tropospheric scintillation is predicted from Recommendation ITU-R P.618. Tropospheric scintillation is included for all altitudes.

7   Applicability to specific airborne missions

The prediction methods described in this Recommendation correspond to the long-term average availability at a specific altitude and elevation angle. These prediction methods can also be used to predict the worst-case or average link availability for any applicable altitude and elevation angle profile. The time duration of an impairment (e.g. rain attenuation) will be dependent on the dynamics of the airborne platform.

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