

RECOMMENDATION ITU-R F.1333-1

**ESTIMATION OF THE ACTUAL ELEVATION ANGLE FROM A STATION
IN THE FIXED SERVICE TOWARDS A SPACE STATION TAKING
INTO ACCOUNT ATMOSPHERIC REFRACTION**

(Question ITU-R 163/9)

(1997-1999)

The ITU Radiocommunication Assembly,

considering

- a) that in some frequency sharing studies between the fixed service and space radiocommunication services, including fixed-satellite, broadcasting-satellite and space science services, it is necessary to estimate various factors related to propagation such as slant path attenuation by atmospheric gases and attenuation due to Fresnel zone blockage;
- b) that the above attenuation is a function of the actual elevation angle as seen from a station in the fixed service towards a space station (geostationary or non-geostationary);
- c) that it is necessary to establish a simplified calculation method to estimate the actual elevation angle towards a space station taking into account atmospheric refraction where the elevation angle of a space station is known only in free-space propagation conditions in vacuum;
- d) that it is generally appropriate to estimate the actual elevation angle of a space station under the condition of the mean annual global reference atmosphere given in Recommendation ITU-R P.835,

recommends

- 1 that the method for estimating the actual elevation angle as seen from a station in the fixed service towards a space station (geostationary or non-geostationary) under the condition of the mean annual global reference atmosphere in Recommendation ITU-R P.835 as described in Annex 1 should be used where the elevation angle towards a space station is known only in free-space propagation conditions in vacuum (see Notes 1 and 2);
- 2 that for an atmospheric refractivity model other than the mean annual global reference atmosphere as given in Recommendation ITU-R P.835, a different numerical formula should be derived corresponding to the specific atmospheric refractivity model (see Note 3).

NOTE 1 – This Recommendation can be used, for example, for estimation of slant path attenuation by atmospheric gases and Fresnel zone blockage attenuation required in Recommendation ITU-R F.1249.

NOTE 2 – Annex 1 to Recommendation ITU-R F.1108 gives an example method for calculating the elevation angle towards a non-geostationary space station in free-space propagation conditions, and Annex 2 to Recommendation ITU-R F.1249 gives a method for calculating the elevation angle towards a geostationary space station in free-space propagation conditions.

NOTE 3 – Annex 2 to Recommendation ITU-R SF.765 (and also Annex 2 to Recommendation ITU-R F.1249) gives an example of the numerical formulae for refraction corrections corresponding to the exponential model of $N_0 = 400$ and $\Delta N = -68$ (for maximum refraction correction) and the exponential model of $N_0 = 250$ and $\Delta N = -30$ (for minimum refraction correction), where N_0 is the sea-level radio refractivity and ΔN is the gradient (difference between sea level and 1 km altitude), which are used for determination of the separation angle between the fixed service antenna main beam direction and the direction towards the geostationary-satellite orbit (GSO) (or a specific orbital location in the GSO).

Actual elevation angle where the elevation angle of a space station is known only in free-space propagation conditions

1 Introduction

In some cases of sharing studies, the elevation angle of a space station (geostationary or non-geostationary), as seen from a fixed service station, is known only in free-space propagation conditions in vacuum. In such cases, it is necessary to estimate the actual elevation angle taking account of atmospheric refraction. This annex gives a calculation method for such a need.

2 Visibility of space station

Under a quasi-exponential model of atmosphere for refraction, such as in Recommendation ITU-R P.835, the radio beam emitted from a fixed service station (h (km) altitude above sea level and θ (degrees) elevation angle) is bent towards the Earth due to the effect of atmospheric refraction. This refraction correction, τ (degrees), can be evaluated by the following integral:

$$\tau = - \int_h^{\infty} \frac{n'(x)}{n(x) \cdot \tan \varphi} dx \quad (1)$$

where φ is determined as follows on the basis of Snell's law in polar coordinates:

$$\cos \varphi = \frac{c}{(r + x) \cdot n(x)} \quad (2)$$

$$c = (r + h) \cdot n(h) \cdot \cos \theta \quad (3)$$

where:

r : Earth's radius (6 370 km).

The function $n(x)$ is the atmospheric refractive index at altitude x (km), and can be calculated by using the formula for the radio refractive index in Recommendation ITU-R P.453 based on the mean annual global reference atmosphere in Recommendation ITU-R P.835. In addition, $n'(x)$ is the derivative of $n(x)$.

The values of $\tau(h, \theta)$ (degree) have been evaluated under the condition of the mean annual global reference atmosphere and it was found that the following numerical formula gives a good approximation:

$$\tau(h, \theta) = 1 / [1.283 + 0.7491 \theta + 0.01986 \theta^2 + h(0.3114 + 0.07020 \theta)] \quad (4)$$

The above formula has been derived as an approximation for $0 \leq h \leq 3$ km and $\theta_m \leq \theta \leq 90^\circ$, where θ_m is the angle at which the radio beam is just intercepted by the surface of the Earth and is given by:

$$\theta_m = - \arccos \left(\frac{r}{r + h} \frac{n(0)}{n(h)} \right) \quad (5)$$

or, approximately, $\theta_m = -0.875 \sqrt{h}$ degrees.