

RECOMMENDATION ITU-R PN.453-4

THE RADIO REFRACTIVE INDEX: ITS FORMULA AND REFRACTIVITY DATA

(Question ITU-R 201/3)

(1970-1986-1990-1992-1994)

The ITU Radiocommunication Assembly,

considering

- a) the necessity of utilizing a single formula for calculation of the index of refraction of the atmosphere;
- b) the need for reference data on refractivity and refractivity gradients all over the world,

recommends

- 1. that the atmospheric radio refractive index, n , be computed by means of the formula given in Annex 1;
- 2. that refractivity data given on world charts in Annex 1 should be used, except if more reliable local data are available.

ANNEX 1

1. The formula for the radio refractive index

The atmospheric radio refractive index, n , can be computed by the following formula:

$$n = 1 + N \times 10^{-6} \quad (1)$$

where:

N : radio refractivity expressed by:

$$N = \frac{77.6}{T} \left(P + 4810 \frac{e}{T} \right) \quad (2)$$

P : atmospheric pressure (hPa)*

e : water vapour pressure (hPa)*

T : absolute temperature (K).

This expression may be used for all radio frequencies; for frequencies up to 100 GHz, the error is less than 0.5%.

For ready reference, the relationship between water vapour pressure e and relative humidity is given by:

$$e = \frac{H e_s}{100} \quad (3)$$

with:

$$e_s = a \exp \left(\frac{b t}{t + c} \right) \quad (4)$$

where:

H : relative humidity (%)

t : Celsius temperature (°C)

* It should be noted that the World Meteorological Organization (WMO) has recommended the adoption of hPa, which is numerically identical to mb, as the unit of atmospheric pressure.

e_s : saturation vapour pressure (hPa) at the temperature t (°C) and the coefficients a , b , c , are:

for water:

$$a = 6.1121$$

$$b = 17.502$$

$$c = 240.97$$

(valid between -20° to $+50^\circ$,
with an accuracy of $\pm 0.20\%$)

for ice:

$$a = 6.1115$$

$$b = 22.452$$

$$c = 272.55$$

(valid between -50° and 0° ,
with an accuracy of $\pm 0.20\%$)

Vapour pressure e is obtained from the water vapour density ρ using the equation:

$$e = \frac{\rho T}{216.7} \quad \text{hPa} \quad (5)$$

where ρ is given in g/m^3 . Representative values of ρ are given in Recommendation ITU-R PN.836.

2. Surface radio refractivity

World charts of monthly mean values of N_0 , extrapolated to sea level for reference purposes, are presented in Figs. 1 and 2 for February and August respectively. In accordance with Recommendation ITU-R PN.369, the value of refractivity at the Earth's surface may be computed by means of the formula:

$$N_s = N_0 \exp(-h_s / h_0) \quad (6)$$

where:

h_s : height of the Earth's surface above sea level (km), and

h_0 : constant usually taken equal to 7.35 km.

It is to be noted, however, that the contours of Figs. 1 and 2 were derived using a value of $h_0 = 9.5$ km.

3. Vertical refractivity gradients

The vertical gradient of radio refractivity in the lowest layer of the atmosphere is an important parameter for the estimation of path clearance and propagation effects such as ducting, surface reflection and multipath on terrestrial line-of-sight links.

Figures 3 to 6 present isopleths of monthly mean decrease (i.e. lapse) in radio refractivity over a 1 km layer from the surface. The change in radio refractivity, ΔN , was calculated from:

$$\Delta N = N_s - N_1 \quad (7)$$

where N_1 is the radio refractivity at a height of 1 km above the surface of the Earth. The ΔN values were not reduced to a reference surface.

Refractivity gradient statistics for the lowest 100 m from the surface of the Earth are used to estimate the probability of occurrence of ducting and multipath conditions. Where more reliable local data are not available, the charts in Figs. 7 to 10 give such statistics for the world.

FIGURE 1

