



Report ITU-R RA.2189
(10/2010)

**Sharing between the radio astronomy
service and active services in the frequency
range 275-3 000 GHz**

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***Note:** This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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1 Introduction

Certain characteristics of the frequency range 275-3 000 GHz combine to reduce the likelihood of interference between the radio astronomy service and active services in this range. The purpose of this Report is to present a basic introduction to those characteristics and how they affect potential sharing scenarios. Based on the analysis in this Report, there is little chance for interference to radio telescopes from co-frequency terrestrial, airborne, or satellite transmitters, particularly at frequencies above 1 000 GHz. The results of this study are applicable to current and future discussions relating to extending No. 5.565 of the Radio Regulations to frequencies in the 275-3 000 GHz range, and studies related to the advancement of technology at frequencies above 275 GHz¹.

¹ In this Report, “THz frequencies” refers to the range 275-3 000 GHz.

2 Atmospheric absorption

In the range 275-3 000 GHz, propagation through the Earth's atmosphere is strongly affected by absorption due to atmospheric molecules. The molecular species most responsible for the absorption are oxygen (O₂) and water vapour (H₂O). Non-resonant absorption creates a general continuum of absorption that steadily increases with frequency, while exceedingly large values of attenuation are found at specific frequencies corresponding to natural resonances of the molecules. At sea level, the general continuum of absorption is approximately 5 dB/km at 275 GHz, 300 dB/km at 1 000 GHz, and 4 000 dB/km at 3 000 GHz. At specific molecular resonances in this range, the attenuation can be as large as 550 000 dB/km.

Attenuation will decrease with altitude due to lower concentrations of oxygen and water vapour. Figure 1 shows attenuation in dB/km at 4 different altitudes: sea level, 300 m, 1 000 m, and 3 000 m. The curve assumes the 1976 Standard Atmosphere model^{2,3}, with the addition of a column of 2 cm total precipitable water vapour with a scale height of 2 km, at a sea-level relative humidity of 50%. The atmospheric parameters were used in the *am* atmospheric transmission model to compute the absorption curves^{4,5}. Based on the assumed atmospheric characteristics, the following inputs were used in the *am* model:

TABLE 1
Assumed atmospheric properties for calculating absorption
over a horizontal path of 1 km in length

Altitude (m)	Temperature (K)	Pressure (mbar)	Column density of dry air (cm ⁻²)	Column density of water vapour (cm ⁻²)
0	288.15	1013.25	$2.55 \times 1\,024$	$3.34 \times 1\,022$
300	286.20	977.73	$2.47 \times 1\,024$	$2.87 \times 1\,022$
1 000	281.65	898.75	$2.31 \times 1\,024$	$2.03 \times 1\,022$
3 000	268.65	701.09	$1.89 \times 1\,024$	$7.45 \times 1\,021$

² U.S. Standard Atmosphere [1976] U.S. Government Printing Office, Washington DC, http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19770009539_1977009539.pdf.

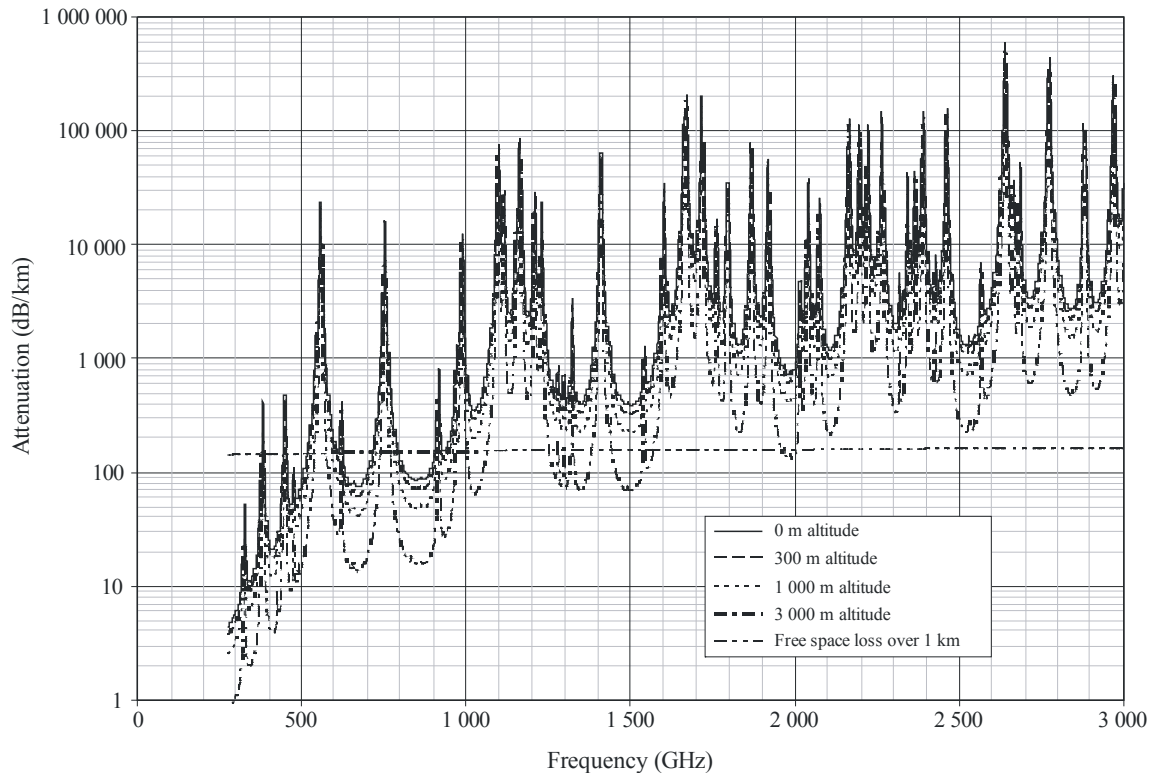
³ Standard atmosphere calculator available at <http://www.luizmonteiro.com/StdAtm.aspx>.

⁴ Paine, Scott, "The *am* Atmospheric Model", Submillimeter Array Technical Memo #152 (Revision 3); available at <http://www.cfa.harvard.edu/~spaine/am/>.

⁵ Recommendation ITU-R P.676 accurately calculates atmospheric attenuation up to a maximum frequency of 1 000 GHz. The *am* model is more rigorous for frequencies above 1 000 GHz. For a consistency check, the data in Fig. 1 and those in Fig. 5 of Recommendation ITU-R P.676 agree well in the region of overlapping frequency coverage. Figure 1 of this Report is based on *am* for the entire range.

FIGURE 1

Atmospheric attenuation computed over horizontal paths of 1 km at four different altitudes, assuming the atmospheric properties of Table 1.
For reference, free-space loss over 1 km is also plotted



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Because atmospheric absorption is a strong factor for terrestrial systems at THz frequencies, calculation of path loss between a transmitter and receiver must include this factor. The signal level at the receiver is:

$$P_R = P_T + G_T + G_R - PL - A \quad (1)$$

where:

- P_R : the power at the output port of the receive antenna
- P_T : the power at the input port of the transmit antenna
- G_T : the gain of the transmit antenna in the direction of the receive antenna
- G_R : the gain of the receive antenna in the direction of the transmit antenna
- PL : the “traditional” path loss between transmit and receive antennas due to geometric spreading and terrain blockage
- A : the additional loss factor due to atmospheric absorption.

All terms are expressed in logarithmic units.

Due to extreme atmospheric absorption, typically the only possible interference scenarios involve a transmitter and victim receiver that are line-of-sight to one another, and therefore the PL factor is free-space loss:

$$PL(\text{dB}) = 20 \log D_{\text{km}} + 20 \log f_{\text{GHz}} + 92.44 \quad (2)$$