2-IV B3

PHASE DELAY AND ATTENUATION IN THE 50 TO 70 GHz BAND FOR ATMOSPHERIC PATH MODELS AT VARIOUS ALTITUDES*

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The complex transfer function τ of a clear atmosphere is dominated throughout the 40 to 80 GHz band by many (>43) molecular resonance lines of oxygen. The structure of τ depends critically on the altitude h.

We present results of a computer analysis of attenuation and excess phase profiles due to O_2 for horizontal (α, ϕ) and zenith (A,T) paths through the U.S. Std. Atm. 62. Known molecular constants, the Lorentzian line shape, and a semi-empirical model of line width were used. The constants of the width model, as determined by Carter et al.[1] from fits of extensive attenuation measurements taken a various altitudes, form the basis for our results.

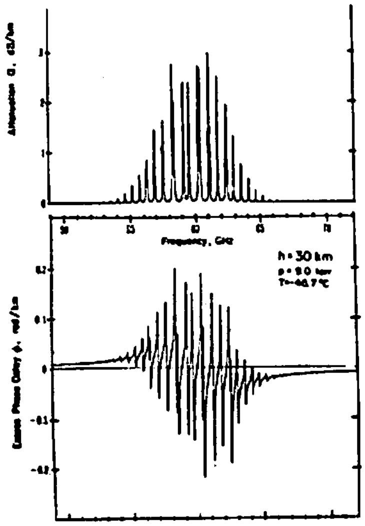

Fig. 1 - Well-resolved atmospheric oxygen spectrum for a horizontal path model at h = 30 km.

HORIZONTAL (homogeneous) PATHS

The attenuation per unit distance is given by[2]

$$\alpha = [(4\pi f/c)\ 10 \log e] n''(f),\ \mathrm{dB/km}, \quad (1)$$

the excess phase per unit distance is

$$\phi = (2\pi f/c) \Delta n'(f),\ \mathrm{rad/km}; \quad (2)$$

where f-frequency, c-speed of light. n''(f) (extinction spectrum) and $\Delta n'$ (f) (dispersion of refractive index) were evaluated as the sum of the first 43 O_2^{16} lines. Fig. 1 shows at h = 30 km the individual lines fairly well isolated, while at h = 0km all lines have merged to one broad line (Fig. 2). Fig. 2 shows differences in α and ϕ that result from discrepancies in the width parameter (same for all lines) obtained from fits of field[1] (666 MHz) and of Artman's Laboratory[3] (968 MHz) data.

We are presently conducting an

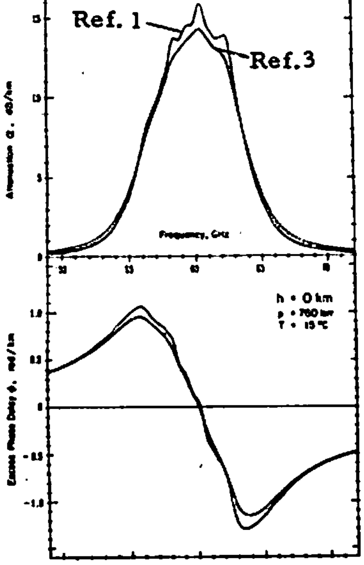

Fig. 2 - Atmospheric transmission response at sea level (U. S. Std. Atm. 62)

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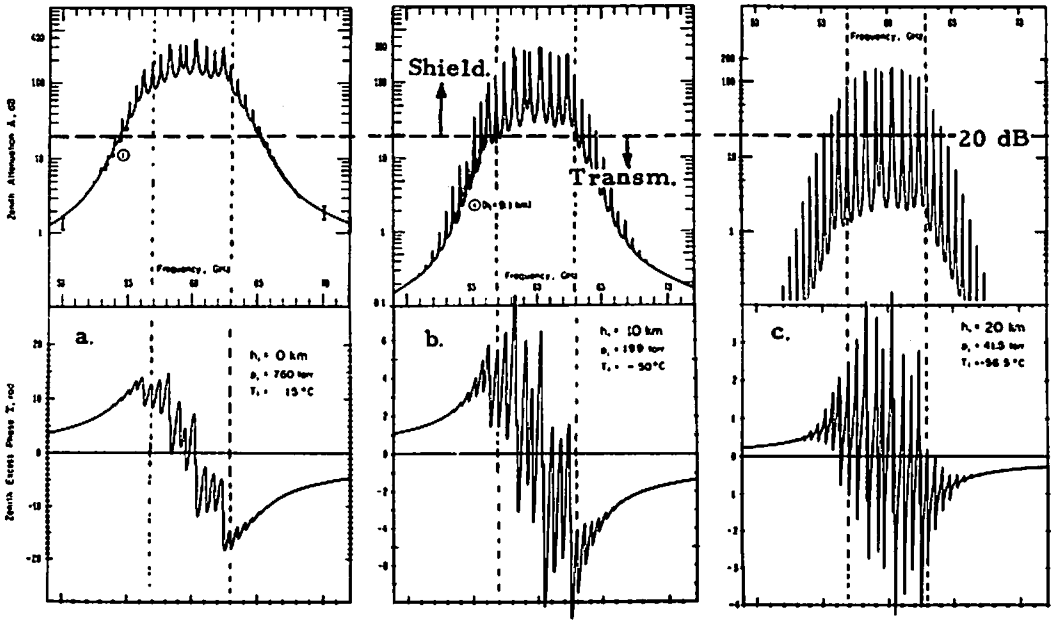

Fig. 3 - Total attenuation and excess phase delay due to atmospheric oxygen for zenith paths from different initial altitudes, h_i to outer space.

extensive experimental program to establish reliable values for α and ϕ over the full meteorological range of p and T using a pressure-scanning ($\Delta n'$ and n'') spectrometer.

ZENITH PATHS

The zenith attenuation if given by:

$$A = \int_{h_i}^{\infty} [\alpha(h)\, d\, h] \text{, in dB;}$$

and the integrated excess phase is:

$$T = \int_{h_i}^{\infty} [\phi(h)\, d\, h] \text{, in rad.}$$

The integration was performed numerically using Simpson's rule and dividing the U.S. Std. Atm. 62 into 151 layers ($\Delta p \leq 10$ torr) from the initial altitude, $h_i = 0$ up to 80km. The calculation is quite involved requiring, e.g., for Fig. 3a about 3.9×10^7 individual computations for 1000 frequency steps. Three examples are given in Fig. 3.

More complete results and a detailed discussion are being published.[4]

APPLICATIONS

The spectrum between 57 and 63 GHz offers one feature not found at any lower frequency: High attenuation and phase delay rates related to the fairly stable (compared to H_2O density fluctuations) dry part of the atmosphere. This effords shielding of satellite-satellite links against ground interferences and restricted-range (secure) communication systems.

However, the shielding properties break down as a jammer gains altitude. If we arbitrarily assume a medium loss of 20 dB to separate shielding (+dB) from transmission (-dB), we find from $h_i = 0$km, $\geq +85$ dB, from $h_i = 10$km, $\geq +10$ dB. At $h_i = 15$ km 8 propagation channels (bandwidths 0.3 to 0.5 GHz) open up (≤ -12 dB). Transmission increases to $\leq -18/-19.5$ dB for $h_i = 20/25$ km. T in the pass band of these 8 channels varies roughly between ∓ 5 to ∓ 3 radians (see Fig. 3).[4] Differential phase measurements between two points are also of interest to gain absolute integrated dry term refractivity for correction of e.m. distance measurements.

REFERENCES

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2. Liebe, IEEE Trans. AP-17, 621, 1969.
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4. Liebe-Welch, Tele. Res. Rept., OT-ITS, 1971 (and IEEE-Trans. AP).