ATMOSPHERIC ABSORPTION

By Tom Irvine
Email: tomirvine@aol.com

May 29, 2009

Atmospheric absorption originates from two effects:

1. Thermal conduction and viscosity of the air.
2. Relaxation losses of oxygen and nitrogen molecules in the air.

Both effects cause attenuation of the sound wave. Sound energy is converted into heat in both cases.

The attenuation is larger at high frequencies than at low frequencies.

The attenuation also depends on the humidity in the air. The relationship between the absorption coefficient and the relative humidity is complicated. But greater attenuation tends to occurs in drier air over lower and middle audio frequencies.

The following equations are taken from Reference 1.

Variables

α	=	Absorption coefficient
f	=	Frequency (Hz)
$f_{r,N}$	=	Relaxation frequency of nitrogen (Hz)
$f_{r,O}$	=	Relaxation frequency of oxygen (Hz)
h	=	Molar concentration of water vapor in the atmosphere (percent)
p_a	=	Atmosphere pressure (Pa)
p_r	=	101,325 Pa
p_{sat}	=	Saturation vapor pressure (Pa)
r_h	=	Relative humidity (percent)
T	=	Temperature (Kelvin)

T_{20} = 293.15 K

The absorption coefficient is

$$\alpha = 8.686 f^2 \sqrt{\tau_r} \left[(1.84e-11)\, \rho_r^{-1} + \tau_r^{-3} (b_1 + b_2) \right] \quad \text{dB/meters} \tag{1}$$

where

$$\tau_r = T / T_{20} \tag{2}$$

$$\hat{p}_r = p_a / p_r \tag{3}$$

$$b_1 = 0.1068 \exp(-3352/T) \;/\; (f_{r,N} + f^2 / f_{r,N}) \tag{4}$$

$$b_2 = 0.01275 \exp(-2239.1/T) \;/\; (f_{r,O} + f^2 / f_{r,O}) \tag{5}$$

$$f_{r,N} = \hat{p}_r \sqrt{\tau_r} \left\{ 9 + 280 h \exp(-4.17\, (\tau_r^{-1/3} - 1)) \right\} \tag{6}$$

$$f_{r,O} = \hat{p}_r \left\{ 24 + 40400 h\, (0.02 + h) / (0.391 + h) \right\} \tag{7}$$

$$h = r_h \frac{p_{sat}}{\hat{p}_r} \tag{8}$$

$$p_{sat} = 10^{C_{sat}} \tag{9}$$

$$C_{sat} = -6.8346\, (T_{01}/T)^{1.261} + 4.6151 \tag{10}$$

T_{01} = 273.16 K, the triple-point temperature of water (11)

Consider Wallops, VA as an example. Note that the Wallops average annual humidity = 71%. The average monthly humidity levels vary from 50% to 76%.

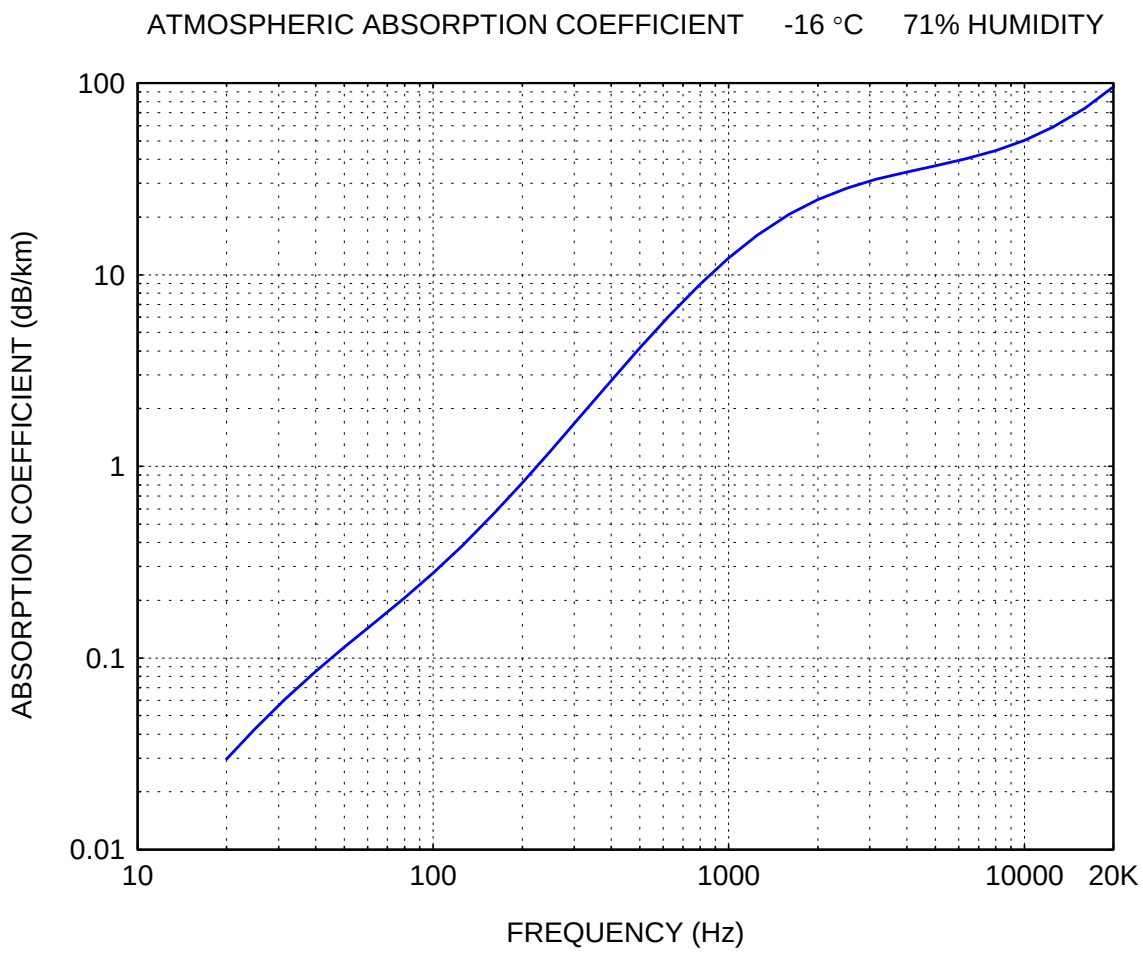
ATMOSPHERIC ABSORPTION COEFFICIENT -16 °C 71% HUMIDITY
ABSORPTION COEFFICIENT (dB/km)
100
10
1
0.1
0.01
10
100
1000
10000
20K
FREQUENCY (Hz)

Figure 1.

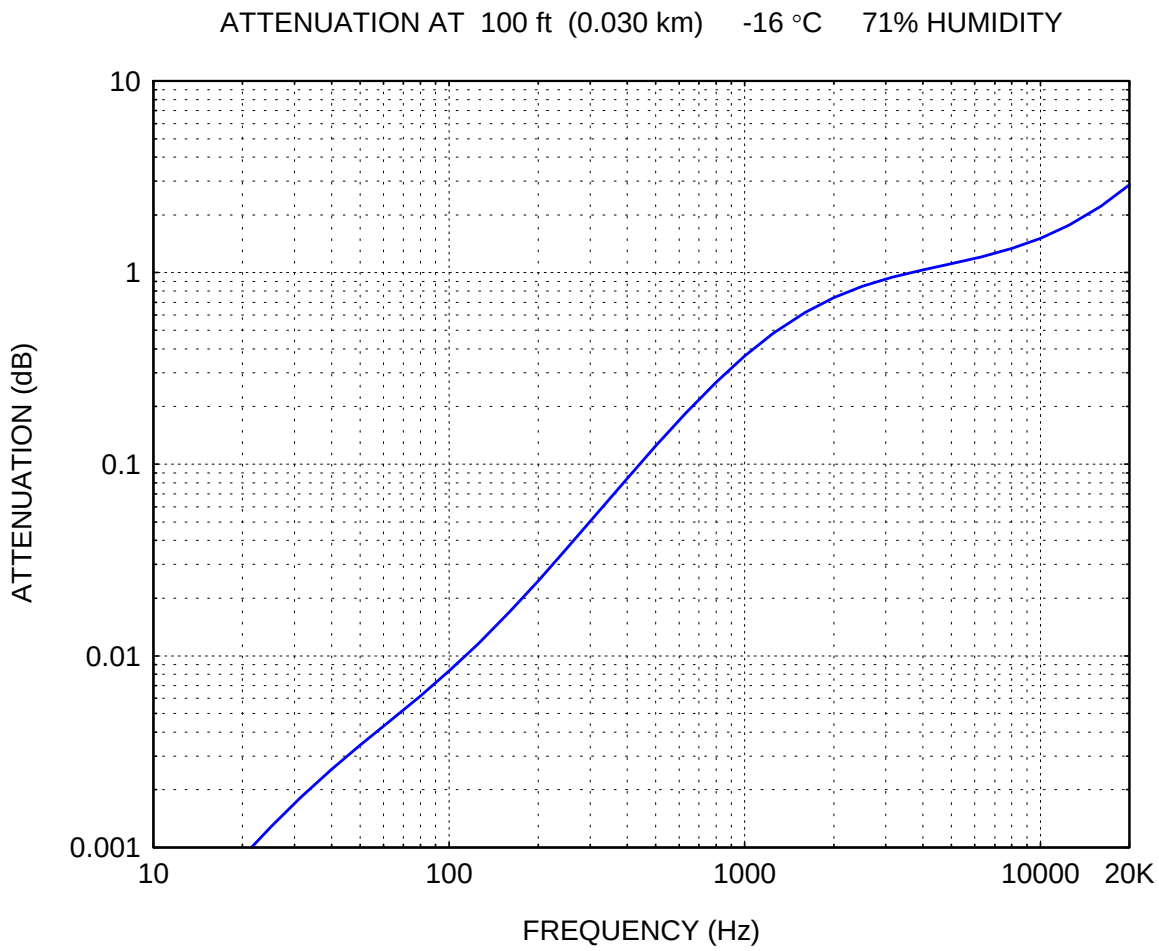

Figure 2.

References

1. E. M. Salomons, Computational Atmospheric Acoustics, Kluwer Academic Publishers, 2001.
2. http://www.climate-zone.com/climate/unitestates/virginia/wallops-island/