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Atmospheric Transmission Calculations for Optical Frequencies

Kamran Shaik

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91109

Abstract

A quantitative study of the transmission loss through the entire atmosphere for optical frequencies likely to be used for an earth-space communication link using existing databases on scattering and absorption characteristics of the atmospheric constituents is presented.

1.0 Introduction

Laser communication technology can potentially provide (i) an enormous data bandwidth for significantly improved channel performance, (ii) an advantage in weight, size, and power consumption over conventional systems in use today, and (iii) non-interacting multiple access link geometries that are amenable to extensive frequency reuse, and secure systems with low probability of interception and jamming. For these reasons, the development of an optical communication systems for deployment in space is being actively pursued at the Jet Propulsion Laboratory (JPL).

Development of robust line-of-sight earth-space optical communication depends on an accurate description of the expected propagation loss through the atmosphere. In the absence of thick clouds, which can completely close down a communication link, the transmission loss is primarily due to absorption and scattering by molecules, aerosols, fog, haze, and other particulate matter in the atmosphere. The present work attempts to quantify these adverse atmospheric effects on light propagation to provide reasonable estimates of link budgets for optical communications.

2.0 Transmission Calculations

2.1 Transmission Codes

The High Resolution Transmittance (HITRAN) computer code, developed at the Air Force Geophysics Laboratory (AFGL), is one of the most complete compilations of molecular absorption data [1]. The compilation gives various line parameters for almost 350,000 lines over a spectral region from ultra-violet to millimeter waves with a resolution of 10^{-5} nm^{-1}. This code can be used to make a detailed study of laser frequencies which are likely to be used for communication purposes and ensure that the carrier frequency does not fall on a strong absorption line. However, the computer codes LOWTRAN (Low Resolution Transmission) and FASCOD (Fast Atmospheric Signature Code), also developed by AFGL, are better suited for the analysis at hand [2-3]. Both LOWTRAN and FASCOD include the ability to compute transmission loss due to thin cirrus clouds, aerosols, and haze. Also, these computer codes can account for changes in transmission loss due to station altitude and the zenith angle of the signal beam. The resolution of these codes (20 cm^{-1}) is lower than the HITRAN database, but it does not represent a problem as it compares well with the obtainable laser line widths.

2.2 Results

The data and the results of the investigation are shown in a compact graphic form in figs.1-5. The parameters relevant to the calculation are labeled on the graph. Fig.1 shows a plot of transmission values over a large range of optical frequencies at sea level for clear skies.

Fig.2 shows a transmission vs. altitude plot for Nd:YAG and doubled Nd:YAG wavelengths (1.064 μm and 0.532 μm respectively), which are likely to be used for an earth-space optical communication link. For example, it is seen that the transmittance improves by about 10% as the ground station altitude is changed from 1 Km to 4 Km. Fig.3 shows the effect of altitude over a range of optical frequencies.

Fig.4 depicts the effect of meteorological visibility on transmittance for 0.532 and 1.064 μm wavelength. For reference, a visibility of 17.0 Km represents clear weather and a visibility of 23.5 Km is defined to be standard clear.

With increasing zenith angle the signal beam has to travel a longer distance in the atmosphere. This results in a decreasing transmittance with the zenith angle, as shown in Fig.5.

3.0 Conclusion

A preliminary site-independent study using generalized atmospheric models to quantify transmittance at optical frequencies for an earth-space path have been completed. The work also quantifies the effect of altitude, which will be helpful in the process of site selection for a ground station. Once a site for the ground station has been selected, a more accurate atmospheric profile for the chosen area can be developed and used to obtain still better estimates of the link loss due to the atmosphere.

4.0 Acknowledgement

The author wishes to thank Kelly Cowles and Garret Okamoto for their help, especially in the acquisition and installation of the necessary computer codes.

5.0 References

1. L.S. Rothman *et al.*, 'AFGL Atmospheric Absorption Line Parameters Calculation: 1982 Edition,' Appl. Opt., vol.22, pp.2247-2256, 1983.

2. F.X. Kneizys *et al.*, 'Users Guide to LOWTRAN7,' Report no. AFGL-TR-88-0177, AFGL, 1988.

3. S.A. Clough *et al.*, 'Atmospheric Radiance and Transmittance: FASCOD2,' Sixth conf. on Atmospheric Radiation, Williamsburg, Va., pp.141-144, 13-16 May, 1986.

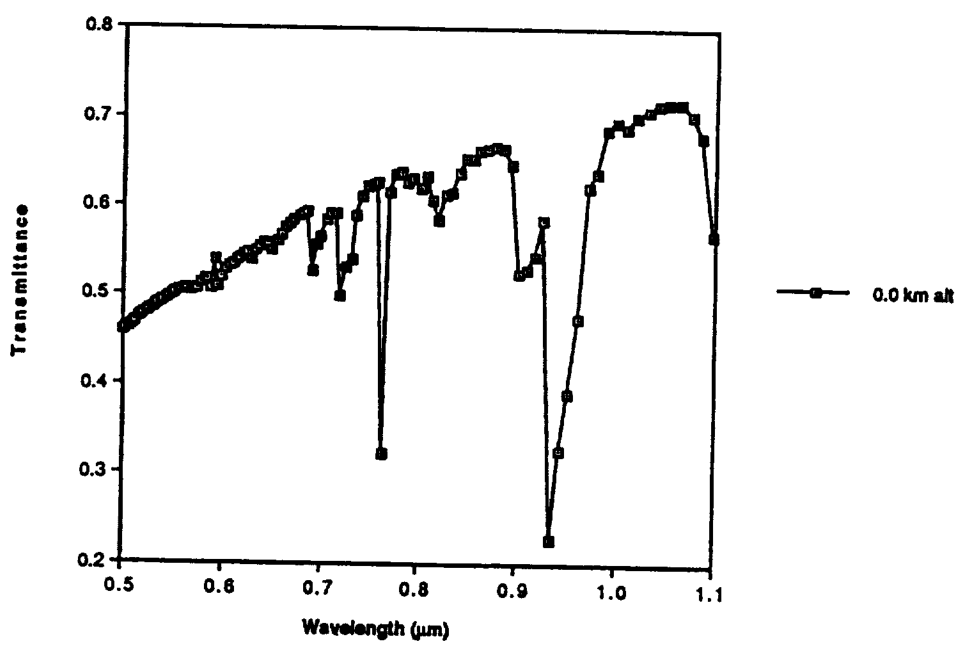

Fig. 1. Transmittance vs. Wavelength with
(i) 1976 U. S. Standard Atmosphere
(ii) Cirrus Attenuation, NOAA Model
(iii) Zenith Angle = 0 degrees
(iv) Visibility = 17.0km

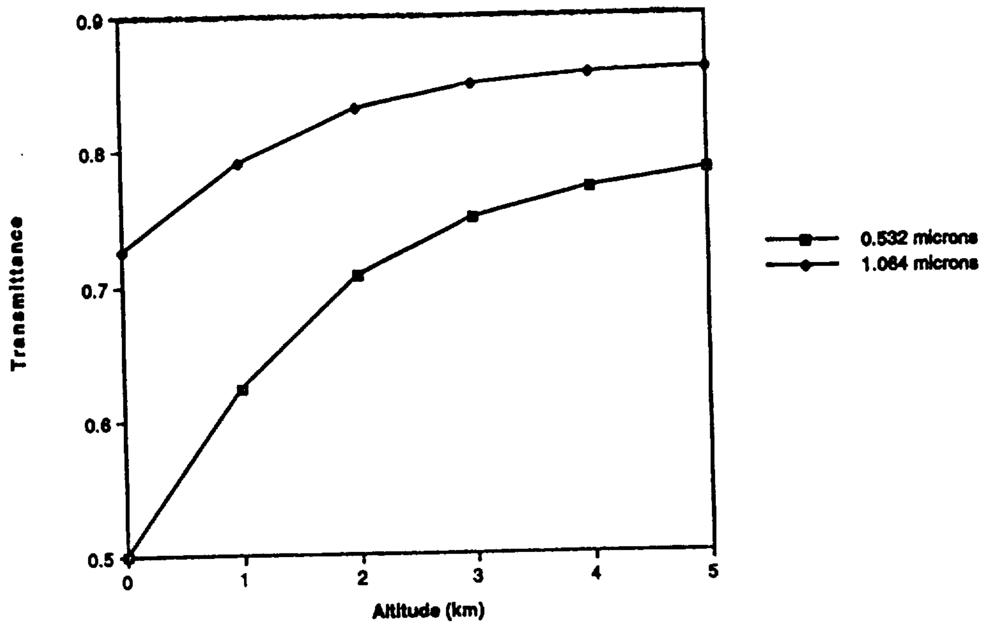

Fig. 2. Transmittance vs. Altitude with
(i) Midlatitude Winter Atmosphere
(ii) Cirrus Attenuation, NOAA Model
(iii) Zenith Angle = 0 degrees
(iv) Visibility = 17.0km

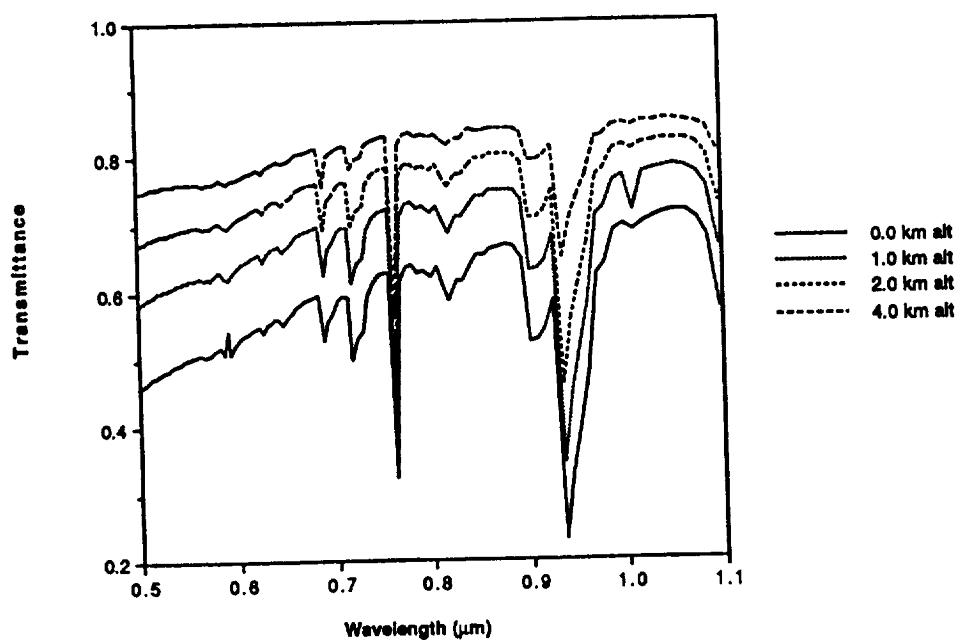

Fig. 3. Transmittance vs. Wavelength with
(i) 1976 U. S. Standard Atmosphere
(ii) Cirrus Attenuation, NOAA Model
(iii) Zenith Angle = 0 degrees
(iv) Visibility = 17.0km

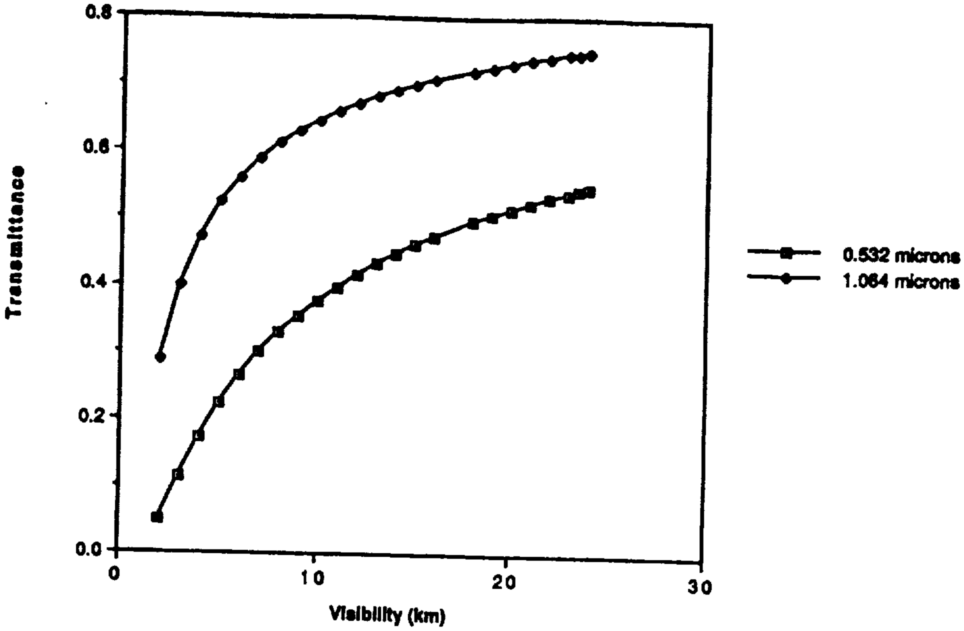

Fig. 4. Transmittance vs. Visibility with
(i) 1976 U. S. Standard Atmosphere
(ii) Cirrus Attenuation, NOAA Model
(iii) Zenith Angle = 0 degrees
(iv) Altitude = 0.0km

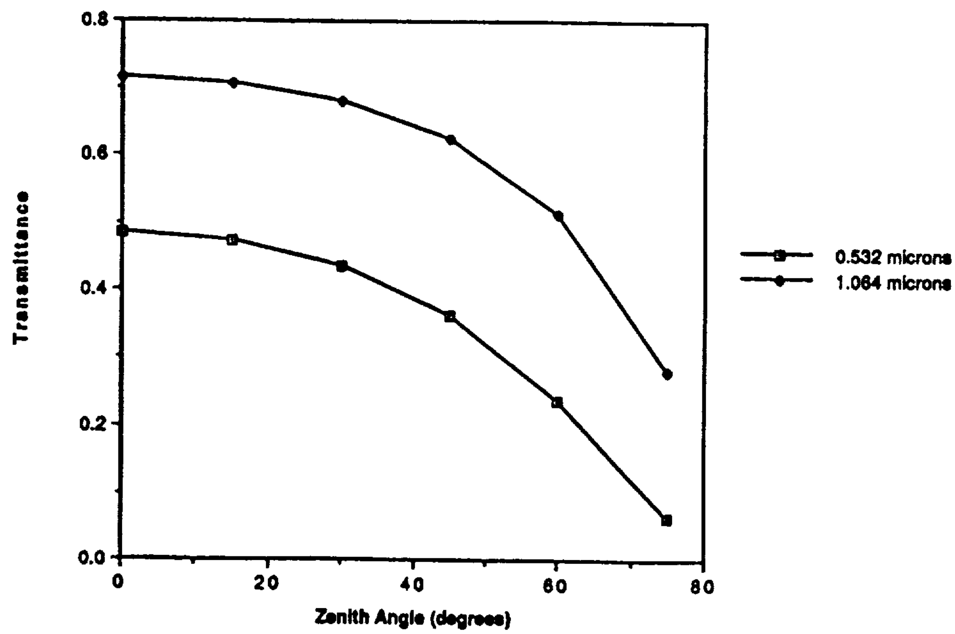

Fig. 5. Transmittance vs. Zenith Angle with
(i) 1976 U. S. Standard Atmosphere
(ii) Cirrus Attenuation, NOAA Model
(iii) Visibility = 17.0km
(iv) Altitude = 0.0km