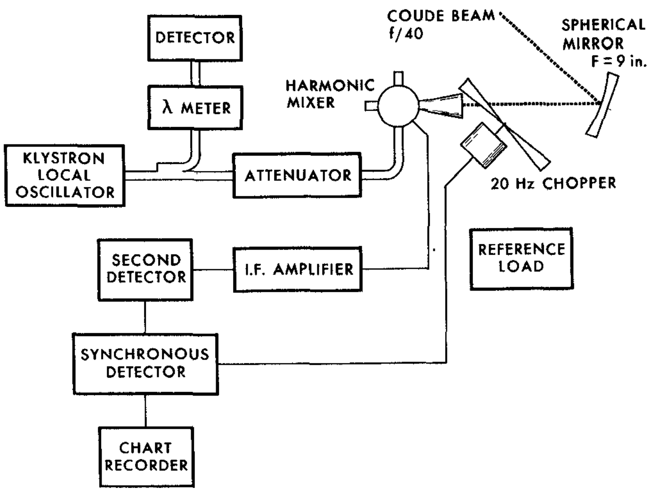

Fig. 1. Block diagram of millimeter radiometer.

Measurement of Atmospheric Attenuation at 1.3 and 0.87 mm with an Harmonic Mixing Radiometer

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***Abstract*—The atmospheric attenuation at 1.3 and 0.87 mm was measured above Mount Hamilton, California in the period December 5 to December 9, 1973. The measured value of the zenith attenuation varied from 1 to 5 dB at 1.3 mm over this five-day period, and was 2.5 dB at 0.87 mm on December 9, 1973. The total beamwidth of the 120″ Lick Observatory telescope used in the Coudé configuration was measured to be 3′ at 1.3 mm.**

I. EXPERIMENTAL ARRANGEMENT

The detector for this experiment was a second-harmonic mixing radiometer using a Schottky barrier diode made by G. T. Wrixon of Bell Telephone Laboratories. The local oscillator frequency was 115 GHz and the signal was accepted in two sidebands 300 MHz wide centered 1200 MHz on either side of 230 GHz. A parametric amplifier with a noise temperature of 150 K was used as the IF amplifier. The total system noise temperature was measured to be 37 000 K. An off-axis spherical mirror with a 9-in focal length was used to focus the $f/40$ Coudé beam into the $f/3$ microwave horn. A block diagram of the apparatus is shown in Fig. 1.

The system was calibrated by measuring the temperature difference between an absorber (Eccosorb AN-72) at liquid nitrogen temperature and another at ambient temperature.

II. OBSERVATIONS AND RESULTS

In order to measure the attenuation of the atmosphere and the losses in the telescope, the sky brightness temperature was measured as a function of zenith distance z. The total temperature seen by the receiver is

$$T_{\text{total}} = T_{\text{atmos}}[1 - \exp(-\tau_0 \sec z)][\exp(-\tau_{\text{tel}})] + T_{\text{tel}}[1 - \exp(-\tau_{\text{tel}})]$$

where τ_0 is the optical depth of the atmosphere at zenith and $\exp(+\tau_{\text{tel}})$ is the attenuation of the telescope. For simplicity, we assume that $T_{\text{atmos}} = T_{\text{tel}} = 280$ K and thus

$$T_{\text{total}} = 280\{1 - \exp[-(\tau_{\text{tel}} + \tau_0 \sec z)]\}.$$

Fig. 2 shows the total optical depth at 1.3 mm as a function of sec z for five zenith scans on four days. The slope of each set of data

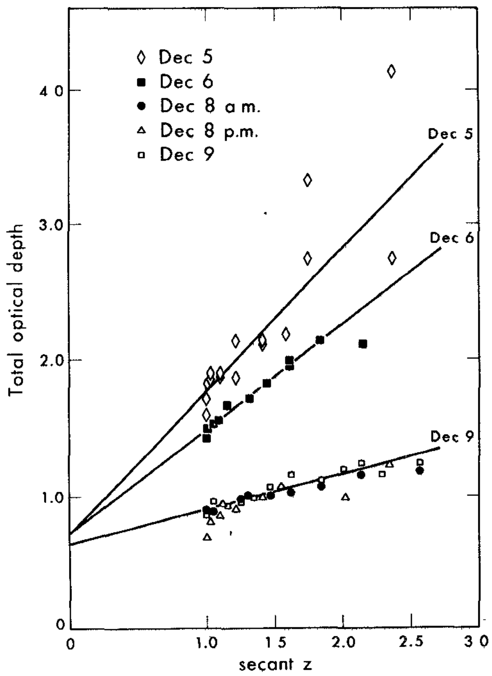

Fig. 2. Zenith scans of atmosphere at 1.3-mm wavelength.

gives τ_0, the optical depth of the atmosphere at zenith. The extrapolated intercept at sec z = 0 yields the effective optical depth of the telescope, $\tau_{\text{tel}} = 0.65$, implying a transmission of 52 percent. We verified this value of τ_{tel} independently by carrying the entire apparatus outdoors and measuring the sky brightness temperature at zenith without the telescope. The difference between this temperature and those measured 1 h earlier and 1 h later indoors using the telescope gives $0.35 \leq \tau_{\text{tel}} \leq 0.8$. In Table I the various τ_0 are given together with the total ground level absolute humidity at the time of the observations. It appears that ground level absolute humidity is a poor indicator of atmospheric attenuation.

The beam solid angle of the system at 1.3 mm was determined from the observed temperature of Venus, using the formula

$$\Omega_B = \Omega_♀ \frac{T_♀}{T_{\text{ON}} - T_{\text{OFF}}} (1 - (T_{\text{OFF}}/280))$$

where $T_♀ = 283$ K [1], $T_{\text{ON}} - T_{\text{OFF}}$ is the signal from Venus, measured to be 2.4 ± 0.1 K, and T_{OFF} is the sky temperature just off the source, measured to be 196 K. This yields an effective beamwidth of 3.2 ± 0.1′ using 32″ as the diameter of Venus.

On the last day of observations we measured the sky brightness at 0.87 mm (345 GHz) by inserting a 310-GHz high-pass filter ahead of the mixer and using the third harmonic of the local oscillator. At this frequency the system noise temperature was 280 000 K. The

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TABLE I

Date	Absolute Humidity (torr)	τ_o optical depths	τ_o dB
5 Dec.	5.0	1.04	4.5
6 Dec	6.3	.78	3.4
8 Dec. (a.m.)	5.9	.22	1.0
8 Dec. (p.m.)	2.2	.24	1.0
9 Dec.	1.8	.25	1.1

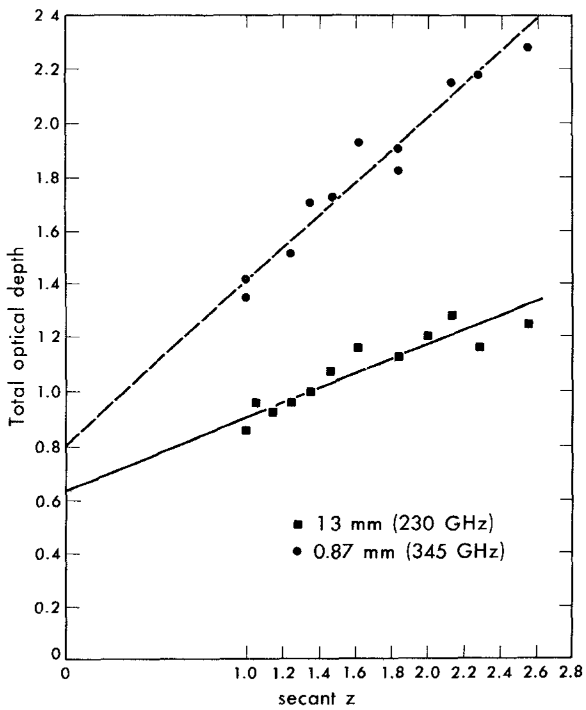

Fig. 3. Zenith scans of atmosphere at wavelengths of 1.3 and 0.87 mm.

results of a zenith scan at 0.87 mm are given in Fig. 3 along with a zenith scan at 1.3 mm taken 1 h earlier. From the slopes of the curves we conclude that the zenith attenuation at 0.87 mm (2.4 dB) is approximately 1.3 times greater than that at 1.3 mm (1.1 dB).

The attenuation in this wavelength region is due primarily to water vapor absorption lines at 2.25 mm (183.3 GHz), 0.926 mm (323.8 GHz), and 0.795 mm (377.4 GHz) [2]. The present measurements confirm the expectation of Ulaby and Straiton that their predicted attenuation between the lines (230 GHz) is too low compared to the attenuation near line center (345 GHz).

REFERENCES

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[2] F. T. Ulaby and A. W. Straiton, "Atmospheric absorption of radio waves between 150 and 350 GHz," *IEEE Trans. Antennas Propagat.* (*Special Issue on Millimeter Wave Antennas and Propagation*), vol. AP-18, pp. 479–485, July 1970.