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WATER VAPOR ATTENUATION MEASUREMENT BY RADIOMETERS AT 18 GHz

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1. Introduction

In the frequency bands above 10 GHz, water vapor attenuation is a significant problem on Earth-to-space propagation paths, as well as rain attenuation. Many studies on water vapor attenuation have been made at various frequencies,[1][2] and water vapor attenuation coefficients are summarized in the report of the International Radio Consultative Committee (C.C.I.R.).[3]

For the estimation of the water vapor attenuation on slant paths, the relationship between the water vapor attenuation and the surface water vapor density, or the relationship between the water vapor attenuation and the total water vapor along the slant path is necessary, as well as the water vapor attenuation coefficient. The correlation between the water vapor attenuation and the surface water vapor density has been studied.[2] However, correlation between the water vapor attenuation and the total water vapor along slant paths has not yet been reported.

This paper presents experimental results on the relationships mentioned above and on the water vapor attenuation coefficient obtained from 18 GHz attenuation measurement data by two radiometers and meteorological data for a period of one year.

2. Theory

Under conditions in which the water vapor attenuation is caused by absorption only, water vapor attenuation L is given by

$$L=-10\cdot\log(1-T_{sky}/T_m) \qquad \text{(dB)} \qquad (1)$$

where T_m is the mean temperature of the atmosphere averaged over the slant path, and T_{sky} is the sky noise temperature due to water vapor. In this paper, the value of 280°K is used as T_m.

3. Sky noise temperature measurement

Sky noise temperature was measured by two radiometers at Kawasaki near Tokyo, from March 1975 to February 1976. Measurement was made for two different antenna elevation angles, 20 and 55 degrees, at the same time to investigate the elevation angle dependence of attenuations. Measured data were recorded on magnetic tape every 30 seconds. Calibrations for two radiometers were made at hourly intervals.

Water vapor attenuation measurement error is caused by errors in measurements of ambient temperature, attenuator temperature for the calibrations and the mean atmospheric temperature. Maximum error is within 0.08 dB for this measurement system.

Meteorological data at the surface and radiosonde data were taken at Yokohama weather station about 10 km from two radiometers and at Tateno weather station about 67 km from two radiometers, respectively.

4. Noise temperature estimation from ground and due to oxygen

Noise temperature from the ground and due to oxygen, included in measured noise temperature, is also a cause of error in water vapor attenuation measurement. Noise temperature from the ground and due to oxygen was estimated by the following method. Measured noise temperature depends on surface water vapor density $\rho_w(0)$ (gr/m^3), as shown in Fig.1. Therefore, the value of regression equation at $\rho_w(0)=0$ can be taken as the average noise temperature from the ground and due to oxygen. The average noise temperatures obtained by this method are listed in Table 1. In the water vapor attenuation estimation, noise temperatures listed in Table 1 are used as noise temperatures from the ground and due to oxygen.

Table 1 Estimated noise temperature values from ground and due to oxygen

	20° elev.	55° elev.
clear weather	24.1 °K	18.2 °K
no rainy weather	24.3 °K	18.8 °K

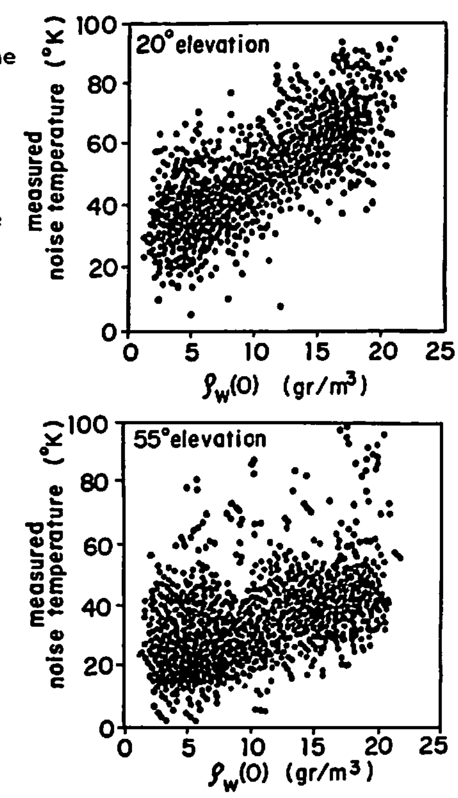

Fig.1 Scattergrams of measured noise temperature and surface water vapor density $\rho_w(0)$ (gr/m^3)

5. Relationship between water vapor attenuation and total water vapor along a vertical path

It is expected that water vapor attenuation is correlated with the total water vapor along the vertical path, which is defined as

$$I_w=\int_0^\infty \rho_w(h)\,dh \quad (km \cdot gr/m^3) \qquad (2)$$

h: height above sea level (km)

For investigation on the relationship between water vapor attenuation and total water vapor, radiosonde data are needed. However, radiosonde data were not available near the radiometers. Radiosonde data were taken at Tateno weather station about 67 km from the radiometers. If correlation is close between surface water vapor densities at Tateno and Yokohama weather stations, the correlation is probably close between water vapor densities above the two weather stations. Then, the correlation is also probably close between the total water vapor along vertical paths near the two weather stations. Surface water vapor densities scattergrams for two weather stations are shown in Fig.2. Close correlation is seen from Fig.2. Therefore, the water vapor density data at Tateno weather station were used to investigate the relationship between water vapor attenuation and total water vapor along a vertical path.

Scattergrams of water vapor attenuation and total water vapor along a vertical path, I_w (km gr/m^3) are shown in Fig. 3 for no rainy weather condition. Radiosonde data were taken only twice a day (at 9 a.m. and 9 p.m.). Therefore, the amount of data is small. Regression equations are expressed as

$$L=\alpha I_w+\beta \quad (dB) \qquad (3)$$

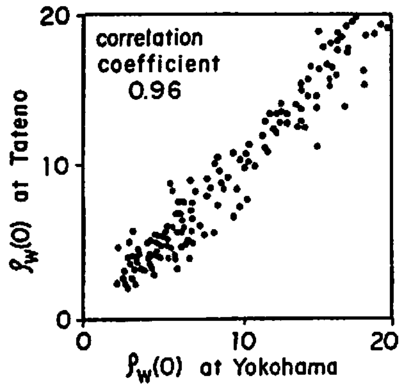

Fig.2 Correlation between surface water vapor densities $\rho_w(0)$ at Yokohama and Tateno weather stations.

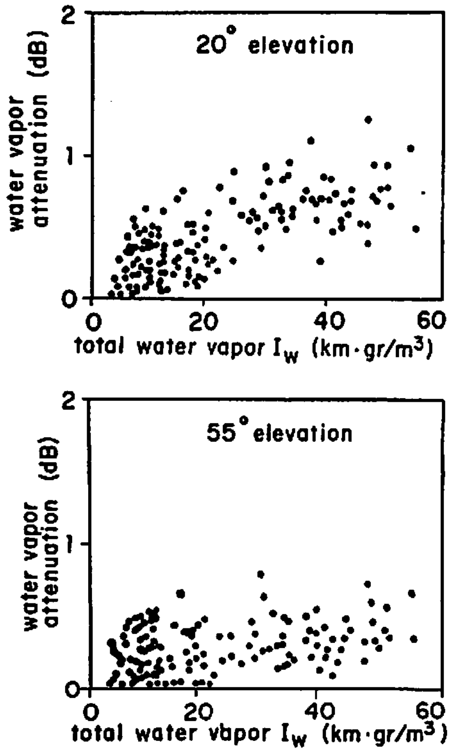

Fig.3 Scattergrams of water vapor attenuation and total water vapor along a vertical path, I_W for no rainy weather condition.

Coefficient α and constant β are listed in Table 2.

Table 2 Coefficient α and constant β for equation (3)

		α	β
clear weather	el. 20 deg.	0.0140	0.09
	el. 55 deg.	0.0055	0.07
no rainy weather	el. 20 deg.	0.0155	0.11
	el. 55 deg.	0.0065	0.09

6. Water vapor attenuation coefficient

It is found, from Table 2, that coefficient α of I_w is propotional to cosecθ (θ is the antenna elevation angle). Therefore, the water vapor attenuation coefficient at 18 GHz can be obtained from coefficient α listed in Table 2 and antenna elevation angles. Water vapor attenuation coefficients obtained in this way for clear weather condition are 0.0048 and 0.0045 (dB/km)/(gr/m^3) for 20 and 55 degree elevation angles, respectively. These values approximately agree with the water vapor attenuation coefficient, 0.0052 (dB/km)/(gr/m^3), proposed by the C.C.I.R.[3].

7. Conclusion

It was found, from water vapor attenuation measurement during one year, that water vapor attenuation at 18 GHz was correlated with total water vapor along a vertical path about 67 km from the radiometers horizontally. Water vapor attenuation coefficient was obtained from the regression equations between water vapor attenuation and total water vapor along a vertical path, and from antenna elevation angles. Obtained water vapor attenuation coefficients agree with the value proposed by the C.C.I.R..

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References

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