CHARACTERISTICS OF ATMOSPHERIC ATTENUATION AT 11, 18, 35 AND 48 GHz OBTAINED BY SUN-TRACKER MEASUREMENT

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1.Introduction

Even in the clear weather, millimeter-wave propagation is influenced by the resonance absorption caused by water vapor and oxygen ; which is called usually atmospheric attenuation. Recently, the detailed information on the atmospheric attenuation in the slant path has become most important in various fields of application, e.g., the radio astronomy, the remote sensing of the atmosphere and ocean, VLBI, etc.

To investigate the frequency dependence of atmospheric attenuation , here is performed an analysis on the data, obtained by sun-tracker measurements in Tokyo. This paper describes statistical results of the measured atmospheric attenuation at 11, 18, 35 and 48 GHz under the consideration of surface meteorological data. A new empirical formula is also obtained through the analysis of data ; which makes clear of the difference between actual attenuations, caused by water vapor and oxygen.

2. Experiment and Results

The measuring equipments used and periods of acquisition of data for each frequency are shown in Table 1 [1], [2], [3]. Assuming a horizontally stratified and stable atmosphere, the mean zenith atmospheric attenuation over the measuring time can be determined from the regression line slope of the logarithm antenna temperature to secant of zenith angle.

Daily data of the measured zenith atmospheric attenuation are plotted in Fig.1. In this figure, it is found for each frequency that remarkable annual variation of measured atmospheric attenuation is not seen, but seasonal variation of measured atmospheric attenuation is clearly appeared. The spring and fall values are nearly equal to the annual mean, though the summer value is 50 to 120 % higher and the winter value 20 to 50 % smaller. Table 2 shows the statistical parameters of measured atmospheric attenuation for the overall period.

Scatter plots of the measured atmospheric attenuation L_M (dB) and the surface water vapor density ρ_s(g/m^3) for each frequency are shown in Fig.2. We first establish the linear regression model

$$L_M = W_L \cdot \rho_s + O_L \qquad (1)$$

then perform regression analysis to estimate W_L and O_L. Obtained regression lines are drawn by solid line in each figure. Two dot-dashed lines in each figure denote the confidence limits for a 95 % level in the estimate of L_M from a new sample ρ_s using these linear regression formulas.

The linear regression model discussed above involves only one explanatory variable and is therefore simple and easy to apply. However, it is subject to question in that it assumes the variation of L_M is due only to the water vapor and the oxygen attenuation is constant. To know the variation aspect of oxygen attenuation, we calculate total oxygen attenuation by means of the specific attenuation formula proposed by B.R.Bean et al. [4] with the aerological data which was measured at Tateno for 9 AM of the same day of that attenuation measurements were made [5]. Figure 3 is an example of scatter plot of the calculated total oxygen attenuation Lo (dB) and the surface dry pressure over temperature Pd/Ts (mb/K), the latter quantity is selected so as to be proportional to the oxygen density. With the linear regression model

$$Lo = O_T \cdot (Pd/Ts) \qquad (2)$$

the regression coefficient O_T for each frequency is estimated.

Taking Pd/Ts as well as ρ_s as the explanatory variables, we assume a multiple regression model

$$L_M = W_M \cdot \rho_s + O_M \cdot (Pd/Ts) \qquad (3)$$

then perform a regression analysis and obtain W_M and O_M for each frequency. With respect to the obtained regression coefficients, the significance tests using the F-distribution show that the null hypothesis $Ho: W_M = O_M = 0$ can be rejected at a 5% significance level. This qualified the validation of the multiple regression model for each frequency.

Using this multiple regression formula, the measured atmospheric attenuation can be divided in two parts, one part is due to water vapor attenuation and the other to oxygen attenuation. And then it is possible to compare these values with the values of calculated water vapor attenuation or oxygen attenuation and to make reasonable estimation of atmospheric attenuation from surface meteorological data taking into consideration the variation of oxygen attenuation.

In Fig.4, the obtained multiple regression coefficients for each frequency are shown and are added for reference the calculated linear regression coefficients O_T for oxygen and W_T for water vapor.

With regard to the coefficient for water vapor attenuation, the regression coefficient calculated from the aerological data is smaller than the one from measured data, and the difference between these regression coefficients is almost the same value for each frequency. Therefore at the both sides of the 22 GHz water vapor absorption line, the theoretical specific attenuation formula used for water vapor attenuation can be considered to estimate water vapor attenuations but these values are smaller than the measured values, this discrepancy corresponds to W_M minus W_T multiplied by the water vapor density.

On the other hand, the difference appeared in regression coefficients for the oxygen is rather irregular but the regression coefficient calculated from the aerological data is larger than the one from the measured data except at 11 GHz. It seems that this discrepancy is mainly due to the theoretical formula used for oxygen attenuation.

3.Conclusion

The annual, seasonal variation characteristics of atmospheric attenuation at 11, 18, 35 and 48 GHz are measured and clarified.

The linear regression equation based on surface meteorological data is the most effective method to estimate the atmospheric attenuation. But the conventional simple linear regression equation appears to be insufficient from the results of this research. We conclude the estimation should be made based on a newly proposed (multiple regression) equation. Because it must be taken into consideration that the total attenuation contains the variational effect due to oxygen.

On the estimation of attenuation, obtained results suggest different weighting coefficients from the theoretical coefficients (induced, by the present authors, from the basic work of B. R. Bean) : the larger to water vapor and the smaller to oxygen.

Acknowledgment

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References

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Table 1 Measuring place, period and antenna system

Freq.(GHz)	Site	Measure period	Antenna system
11,18	Musashino	July1970-July1973	Dual parabola(1.5mφ)
35	Koganei	Dec.1970-Mar.1976	Dual parabola(1.1mφ)
48	Yotsuya	Oct.1971-Dec.1975	Single beam-switch cassegrain(1.2mφ)

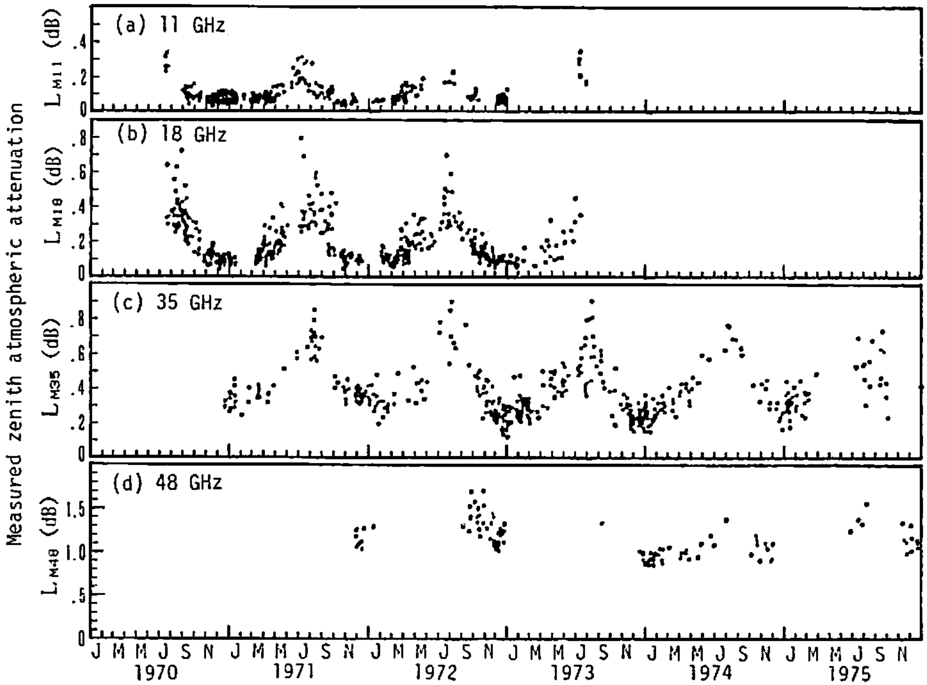

Fig. 1. Daily plots of measured zenith atmospheric attenuation.

Table 2 Statistics of measured zenith atmospheric attenuation for the overall period

Freq.	Mean value	Max. value	Min. value	Standard deviation
11(GHz)	0.101(dB)	0.349(dB)	0.037(dB)	0.057(dB)
18	0.200	0.796	0.047	0.127
35	0.365	0.906	0.119	0.148
48	1.130	1.700	0.850	0.190

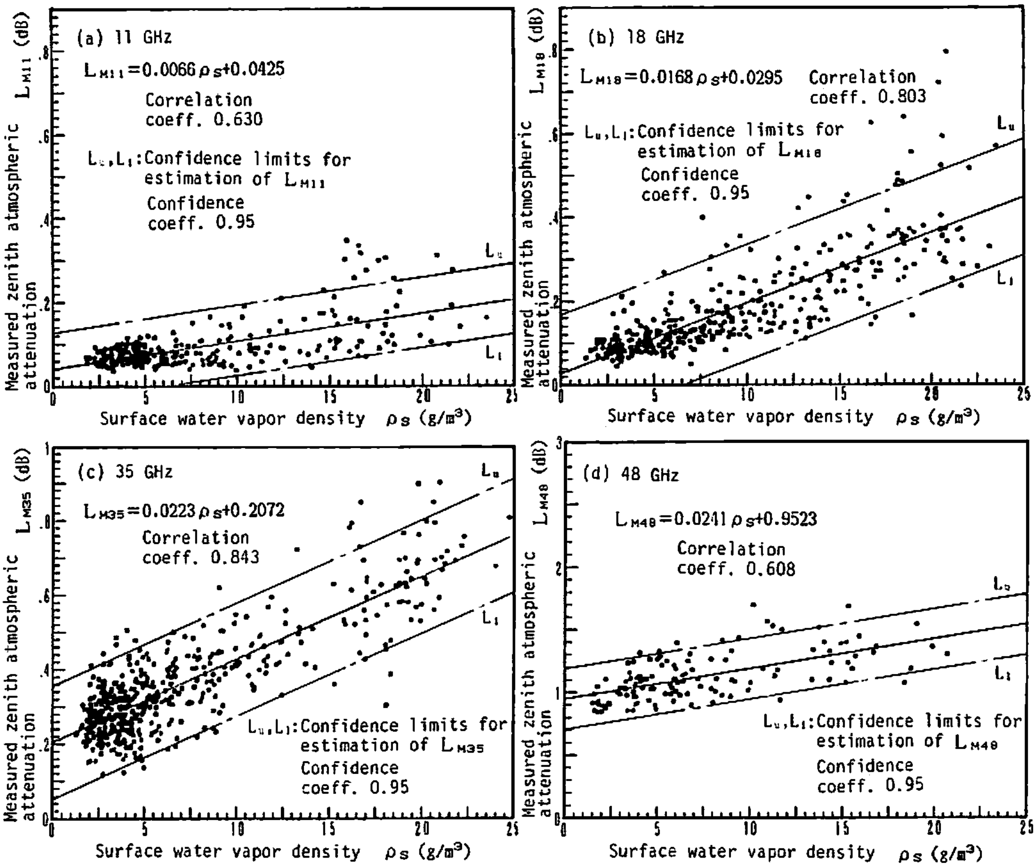

Fig. 2. Relation between measured zenith atmospheric attenuation and surface water vapor density.

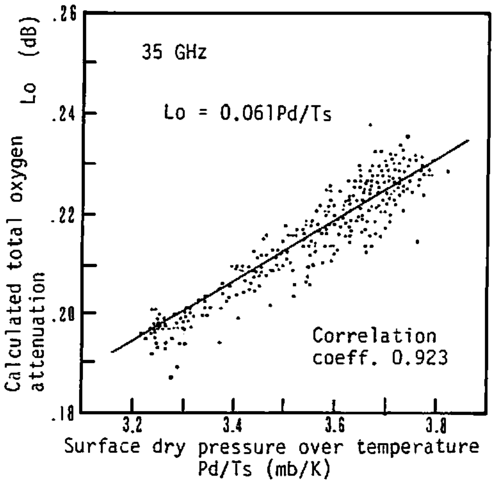

Fig. 3. An example of relation between calculated total oxygen attenuation and surface dry pressure over temperature.

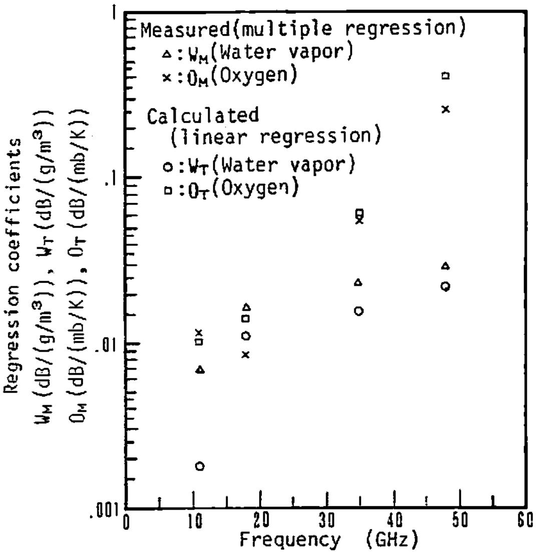

Fig. 4. Frequency dependence of regression coefficients for measured and calculated zenith atmospheric attenuation.