QUANTITATIVE MEASUREMENT OF AIR POLLUTION BY LASER

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ABSTRACT

1. Introduction

Air pollution can be quantified from attenuation of a electromagnetic wave which propagates through air. Many experiments using the transmission method have been reported. In the transmission method the transmitter and the receiver are located on a straight line and between them attenuation is measured. Air pollution is known to have various particle-size distributions Nr. Attenuation is therefore affected greatly by Nr. In this paper water droplets which are components of rain, fog, and clouds are chiefly considered. As a result it is found that Nr must be taken into consideration as one of main causes of the change of attenuation and that the fittest frequency must be needed to quantify air pollution accurately.

2. Theory

Attenuation α in dB/Km is given by

$$\alpha(R) = 0.4343\int_0^R\int_0^\infty N(r,R)\cdot Q(m,\lambda,r)\,dr\,dR$$

where $N_{(r,R)}$ is particle-size distribution at a path length of R from the transmitter, and $Q_{(m,\lambda,r)}$ is the extinction cross section of a particle with a radius of r and refractive index of m for the electromagnetic wave at a wavelength of λ.

The refractive index m can be approximately calculated from the theory by Debye provided that a particle is dielectric, but in the light region it is not valid. So the values of m used in this calculation are the ones by M.Centeno and L.D.Kislouskii. It is known that the imaginary part of m is important in the laser rader method but that it is unimportant in the transmission method.

On the other hand, Nr must be known in order to calculate α. Nr for rain, fog and clouds are represented in various models. For example, The equation of Nr for rain and the one for fog and clouds by Zuyev are given by

$$Nr(r) = A \cdot 10^{B - C \cdot r}$$

and

$$Nr(r) = \Gamma(u+1) \cdot \tau^{u+1} \cdot (\tau^{u}/a) \cdot e^{-u\tau}$$

respectively, where A,B,C,u and a are constants, and $\tau = r/a$. Nr is represented in three models in this paper. They are denoted by Nr^{min}, Nr^{mid}, and Nr^{max} which are particle-size distributions when r_m is small, middle, and large respectively, where r_m is the value of r at which Nr has a maximum. The relation between r_m and water vapor measured is shown in Fig.1, in which it is apparent that Nr^{min} and Nr^{max} give limitations to the range of real particle size distributions and that for a given water vapor r_m varies to a great extent. The calculation of α is therefore very uncertain if Nr is selected unjustly. For example, results of calculations for each Nr when water vapor is 20 mg/m^3 are shown in Table 1.

3. Existence of the fittest frequency

It is apprant from Table 1 that α is greatly dependent on Nr at a frequency. So it is desirable to use the frequency most independent on Nr. In order to get the fittest frequency α is calculated for each Nr and then $\alpha_{max}/\alpha_{min}$ is calculated. It is shown in Fig.2 with a few experimental data. If $\alpha_{max}/\alpha_{min}$ is nearly equal to 1, α may be got accurately without Nr being taken into consideration.

It is concluded from Fig.2 that CO_2 Laser is desirable in the transmission method.

Water Vapor in mg/m³	Nr	α in dB/km		
		He-Ne Laser	Xe Laser	CO_2 Laser
20	Nr^{min}	53	17	14
	Nr^{mid}	20	13	12
	Nr^{max}	7	9	8

Table 1. Attenuation calculated for each Nr.

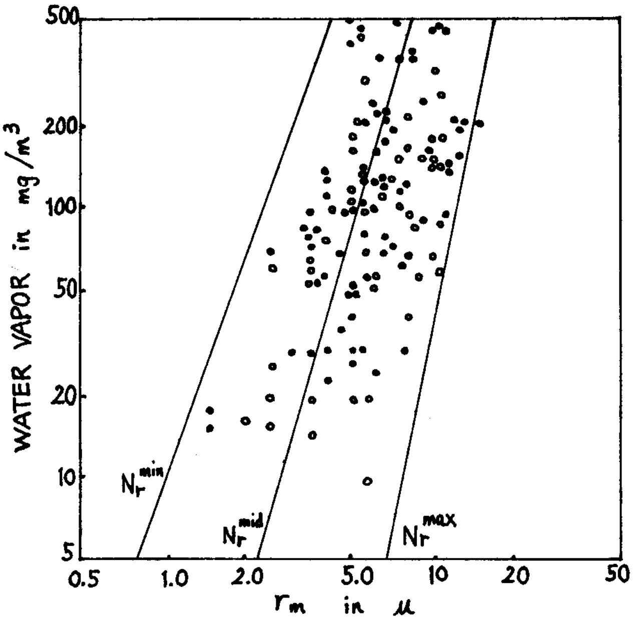

Fig. 1. Relation between r_m and water vapor

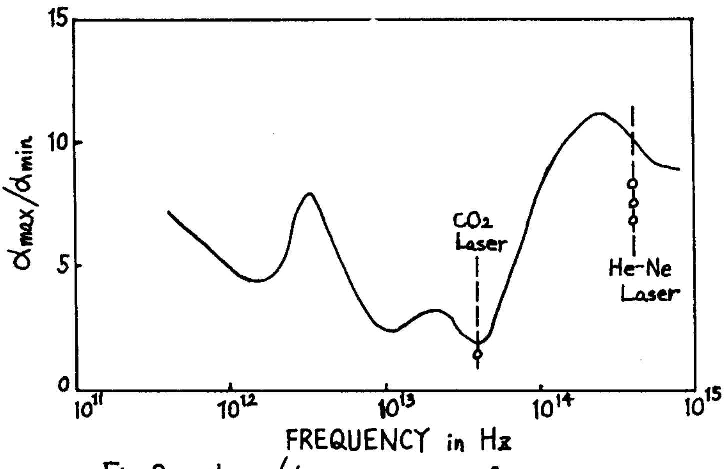

Fig. 2. $\alpha_{max}/\alpha_{min}$ versus frequency