RAIN INDUCED ATTENUATION AND PHASE SHIFT AT CM AND MM WAVES USING A TROPICAL RAINDROP SIZE DISTRIBUTION MODEL

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INTRODUCTION

Rainfall is a major cause of signal degradation for communication systems operating in the microwave and millimetre wave bands in the tropical region. The rain induced attenuation and phase shift are therefore essential parameters to be taken into consideration in the design of both terrestrial and earth-satellite communication links in these frequency bands. At present, the International Radio Consultative Committee (CCIR) adopts the Laws and Parsons (1943) law for the raindrop size distribution for scattering and attenuation applications. The lognormal model obtained from tropical raindrop data by Ajayi and Olsen, 1985, using a "systematic method of moment regression" has been shown to be more adequate for the tropical station than the Laws and Parsons distribution (and the similar Marshall and Palmer (1948) law), especially for scattering applications in the millimetre wave band.

In this paper, the rain induced attenuation and phase shift due to tropical rainfall have been computed for oblate spheroidal drops making use of the Ajayi - Olsen raindrop size distribution model. The results are compared with those obtained assuming the Laws and Parsons law. The computation was carried out for a temperature of 20°c.

THEORY

The rain induced specific attenuation (db/km) is given by

$$A = 4343 \frac{\lambda^2}{\pi} \sum \mathrm{Re}\,[S_{H,V}(0)]\, N(D)\, \Delta D \qquad \ldots\ldots \qquad (1)$$

and the rain induced specific phase shift in deg/km is given by

$$= 90 \frac{\lambda^2}{\pi^2} 10^3 \sum \mathrm{Im}\,[S_{H,V}(0)]\, N(D)\, \Delta D \qquad \ldots\ldots \qquad (2)$$

where λ is wavelength in meters, and $N(D)\Delta D$ is the number density per cubic meter, and $S_{H,V}(0)$ is the forward scattering amplitude function. H,V stand for horizontal and vertical polarizations respectively.

The Ajayi - Olsen raindrop size distribution model is given by

$$N(D) = \frac{N_T}{\sigma D\sqrt{2\pi}} \exp\left[-\tfrac{1}{2}\left\{\frac{\ln D - \mu}{\sigma}\right\}^2\right] \qquad \ldots\ldots \qquad (3)$$

where μ is the mean of ln D, σ is the standard deviation, and N_T is the total number of drops of all sizes. A detailed description of the modelling method can be found in Ajayi and Olsen, 1985. The two moments of the measured drop size data used in the modelling determine the parameters μ and σ. Using the 2nd and 3rd moments, Ajayi and Olsen obtained for rain rates from 0.25 mm/h to 150 mm/h considered,

$$\mu = -0.195 + 0.199 \ln R \qquad \ldots\ldots \qquad (4)$$

$$\sigma^2 = 0.137 - 0.013 \ln R \qquad \ldots\ldots \qquad (5)$$

RESULTS

Figure 1 shows the good agreement between the Ajayi - Olsen model and the measured tropical raindrop size data for a rain rate of 146 mm/h over the entire range of raindrop diameter. Similar agreement was obtained for rain rates from 0.25 mm/h to 146 mm/h. The Marshall and Palmer law over-estimates both the small diameter and the large diameter regions of the drop size distribution at this high rain rate.

For terrestrial path, figures 2 and 3 show the computed specific attenuation and phase shift respectively for horizontal and vertical polarizations using the Ajayi - Olsen model and the Laws and Parsons drop size distributions. At frequencies up to 60GHz, similar values of specific attenuation were obtained using the two raindrop size distributions. However, at higher frequencies, the attenuation obtained with the Laws and Parsons law becomes greater than the values given by the Ajayi - Olsen model. Appreciable difference exists in the attenuation values obtained from the two models at a frequency of 70GHz at the high rain rate of 150 mm/h, while at a rain rate of 0.25 mm/h, the corresponding frequency is 100GHz. At 400GHz, the percentage difference is 39% (0.21dB), and 32% (13.8dB) for rain rates of 0.25 mm/h and 150 mm/h respectively. Below the mode frequency in figures 3(a) and (b), the phase shift obtained using the two drop size distributions are similar. This mode frequency decreases from about 65GHz at a rain rate of 0.25 mm/h to 25 GHz at 150 mm/h. At frequencies above the mode frequency, there is a sharp increase in the difference between the two phase shifts with the Laws and Parsons distribution giving higher value of phase shift than the Ajayi - Olsen model. The frequency at which the phase shift becomes negative is lower when the Ajayi - Olsen model is utilized.

CONCLUSION

The Ajayi - Olsen raindrop size distribution is a more adequate representation for the rainfall in a tropical location than the Laws and Parsons law. The attenuation and phase shift obtained from the two models are similar up to the low millimetre wave frequencies. However, at the high frequencies in the millimetre wave band, the Laws and Parsons law will over-estimate rain induced attenuation and phase shift in a tropical location. This is as a result of the significant contribution at millimetre wave band from the small drops, which are over-estimated by the Laws and Parsons law. The effect of this observation on depolarization prediction is under investigation.

REFERENCES

1. Laws, J.O. and D.A. Parsons; The relation of rain dropsize to intensity, Trans, Amer, Geoph. Union, 24, pp. 452 - 460, 1943.
2. Ajayi, G.O. and R.L. Olsen; Modelling of a tropical raindrop size distribution for microwave and millimetre wave applications, accepted by Radio Science, to appear 1985.
3. Gunn, K.L.S. and G.D. Kinzer; The terminal velocity of fall of water droplets in stagnant air, J. Meteorol, 6, pp. 243 - 248, 1949.
4. Ray, P.S.; Broadband complex refractive indices of ice and water, Appl. Opt. 11, pp. 1836 - 1844, 1972.
5. Maggiori, O.; Computed transmission through rain in the 1-400GHz frequency range for spherical and elliptical drops and any polarization, Alta Frequenza L, pp. 262 - 273, 1981.
6. CCIR; XVth Plenary Assembly, Rep. 721 - 1, Vol. 5, pp. 167 - 181, ITU, Geneva, 1982.

REFERENCES CONTD.

7. Marshall, J.S., and W.M. Palmer: The distribution of raindrops with size, J. Meteorol. 5, pp. 165 - 166, 1948.

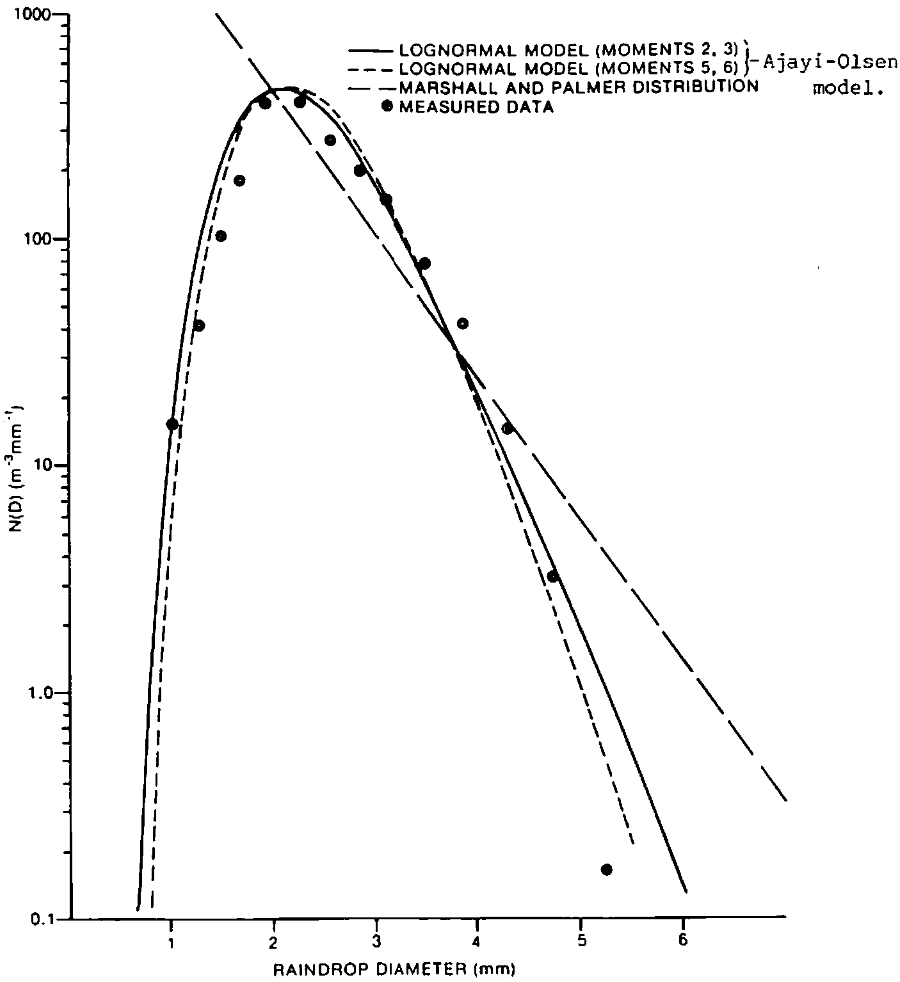

Figure 1: Comparison of Ajayi-Olsen, Marshall-Palmer, and the measured raindrop size distributions at 146 mm/h.

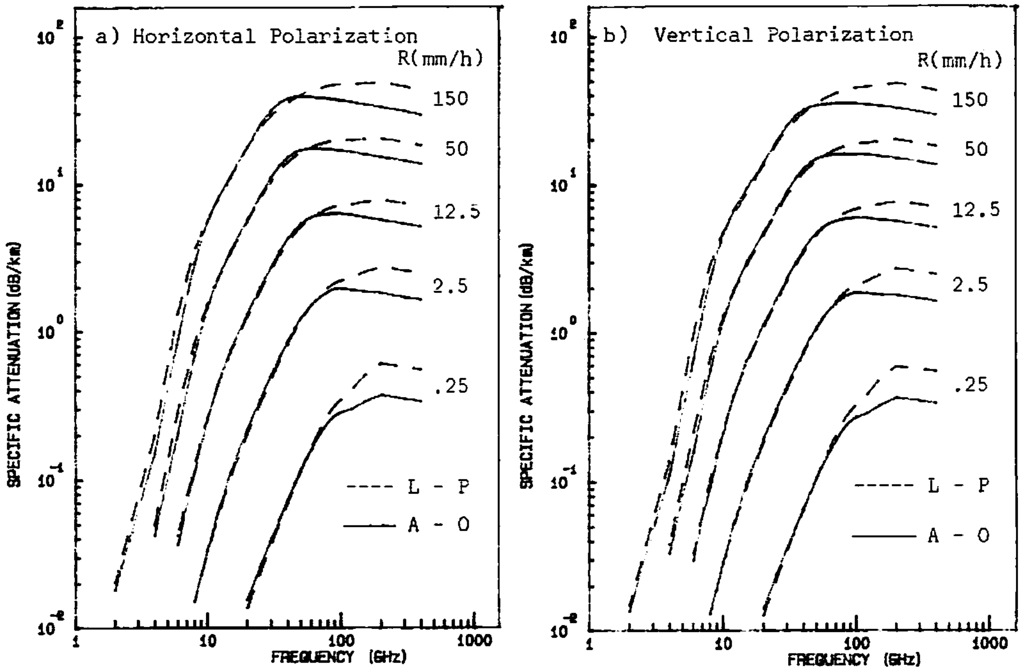

Figure 2: Specific Attenuation using Ajayi-Olsen (A - O) and Laws and Parsons (L - P) raindrop size distributions. Temperature of 20°c.

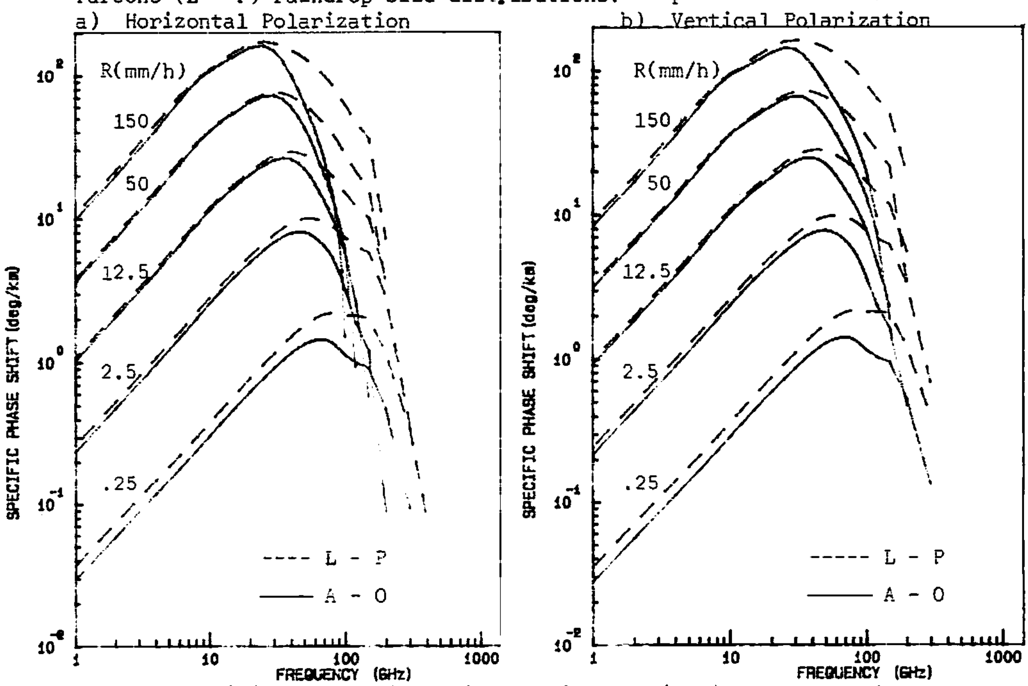

Figure 3: Specific Phase Shift using Ajayi-Olsen (A-O) and Laws and Parsons (L - P) raindrop size distributions. Temperature of 20°c.