ATTENUATION OF RADAR WAVES BY RAIN IN INDIA

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ABSTRACT

Rainfall in India considerably attenuates the Radar Waves in 3 cm. band. The decrease in the target range of an air force radar has been estimated for the type of rainfall common in most parts of India and a comparison is made between ranges obtained in 3 & 5 cm. bands. It is suggested that an all weather or reconnaissance radar working in the X-band will be very unsatisfactory during monsoons in India.

Introduction

The performance of radars is considerably affected in X and K bands by intervening rain which causes attenuation[1], distortion and shadowing of distant targets by nearby precipitation echoes. A front line of showers in India very often involves the passage of a radar beam through several hundred mm-hr^{-1} miles of rain which is quite strong to render 3 cm Radar equipment practically inoperative. Attenuation of radar waves by different intensities of rain in India, from the data available from the Indian Meteorological Department, has been calculated for different wave lengths and decrease in the target range of AN/APS-10 Radar is estimated. A comparison is made between ranges obtained in 3 and 5 cm bands for different rain intensities and it is pointed out that an all weather search or reconnaissance radar working in the X-band will be very unsatisfactory during monsoons in India.

Attenuation by Water Drops

Fundamental theoretical calculations of absorption and scattering of Radio waves in microwave region by rain drops have been carried out by Ryde and Ryde and Laws and Parsons[2]. The total attenuation suffered by the radar wave depends upon λ, the wavelength, the drop diameter D, the complex dielectric constant of water, and the temperature.

The classification of the intensity of rainfall adopted by the Indian Meteorological Department is different from the one adopted by Humphreys[3] because of the heavier intensities of rainfall in India for varying intervals of time. Some measurements on the raindrop terminal velocities for these intensities of rainfall common in India have been carried out and the droplet concentration N and the average diameter D have been estimated on the results of Best[4] as given in Table No. I. No experimental measurements on the actual sizes of drops and their distribution with altitude have yet been reported in this country. The type of rain and precipitation intensities in mm per hour usually encountered in this country is given in Table I. The scattering drops of average diameter are assumed to be distributed at random and effect of variations in drop sizes are neglected.

TABLE I

Grades of Rainfall in India

Type of Rain	Precipitation intensity mm/Hr	Mean diameter in cm. (D)	Mass of liquid water per cubic meter in gms. (M)	No. of droplets per cubic cm (N)
Drizzle	0·25	0·02	0·093	$2{\cdot}2\times10^{-2}$
Light rain	12	0·092	1·3	$3{\cdot}4\times10^{-3}$
Moderate rain	30	0·165	1·6	$7{\cdot}3\times10^{-4}$
Heavy Rain	50	0·183	2·3	$7{\cdot}6\times10^{-4}$
Excessive rain	125	0·5	9·2	$1{\cdot}4\times10^{-4}$

The attenuation, in decibels per unit length of path of microwave beam due to rain drops is given by the expression[1]

$$\sigma_{\text{db/km}} = 4{\cdot}343\times10^{5}\,\frac{\lambda^2}{2\pi}\,.N\alpha^{3}\left[C_1+C_2\alpha^2+C_3\alpha^3\right]$$

where $\alpha = \frac{\pi D}{\lambda}$, D is the diameter of the droplet

N = number of droplets/cm^3

and C_1, C_2, C_3 are functions of the real and imaginary components of the complex dielectric constant $\zeta=\zeta'-i\zeta''$ of water.

The values of ζ' and ζ'' and other constants of water have been taken from Saxtons[5] measurements.

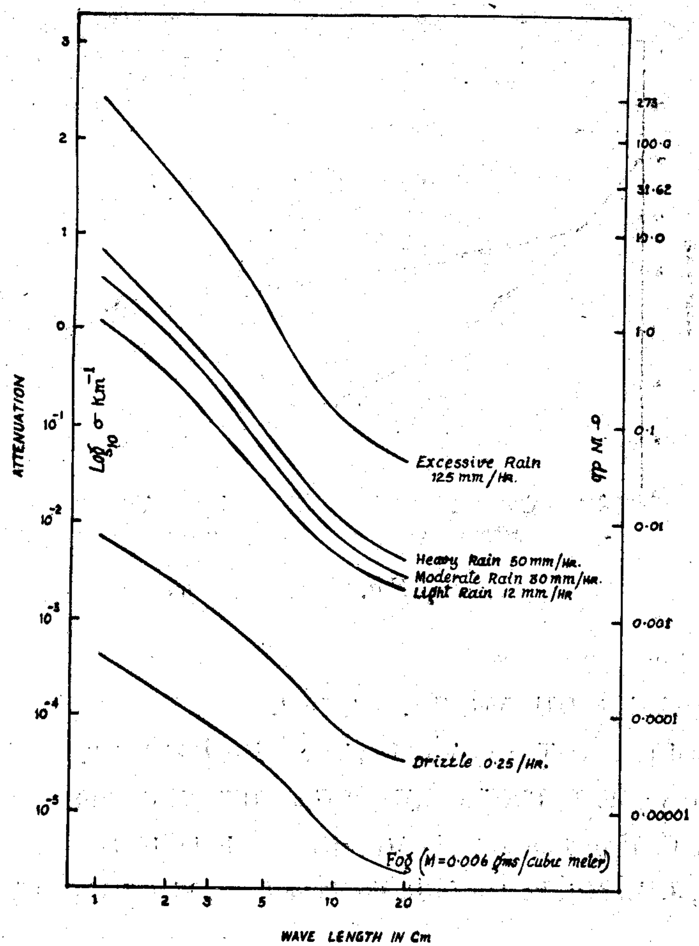
In the case of fogs and clouds composed of fine liquid water droplets whose diameter does not exceed 0·01 cm, the contribution of terms C_2 and C_3 is negligible and the expression reduces to

$$\sigma_{\text{db/km}} = 4{\cdot}093\,C_1\,\frac{M}{\lambda\rho}$$

where $M=10^6\times\frac{\pi}{6}\times ND_3$ is the mass concentration of droplets in gm. per cubic meter of air and ρ is the density of water.

Attenuation in Range

Attenuation due to various intensities of rainfall and fog in India for different radar wavelengths has been calculated and is shown in Fig. 1. The attenuation by rain of wavelengths 10 cm. and above is negligible. For 3-cm., in case of heavy rainfall, the attenuation is appreciable and for lower wavelength, even moderate rain will completely attenuate the beam. For short wavelengths echoes from rain mask, the echo from the target, and ranging is obscured by the shadows and the receiver saturation.



ATTENUATION OF RADAR WAVES DUE TO DIFFERENT GRADES OF RAIN FALL IN INDIA

FIG. 1

The decrease in range in AN/APS-10 radar for a moderate rainfall of 30 mm hr^{-1} has been calculated for varying depth of rain and is shown in Fig. 2, and the same is compared for the same radar on a wavelength of 5 cms. For a rain depth of 5 miles in heavy rainfall, the decrease in range is 30·3% for 3 cm and 7·4% at 5 cm. For moderate rain the figures are 20% and 4% for the two wavelengths respectively. The range calculated are for the minmum detectable power of the receiver for these two wavelengths for a point target of known area of cross-section. Attenuation of the atmospheric gases has been neglected.

It is seen that the range of a 3 cm radar is very much reduced in the moderate to heavy rains in India. For search and reconnaissance purposes, an all weather radar working in 5 cm. band is perhaps more desirable. It is also likely to be more useful for meteorological investigations, than the existing equipment in use.

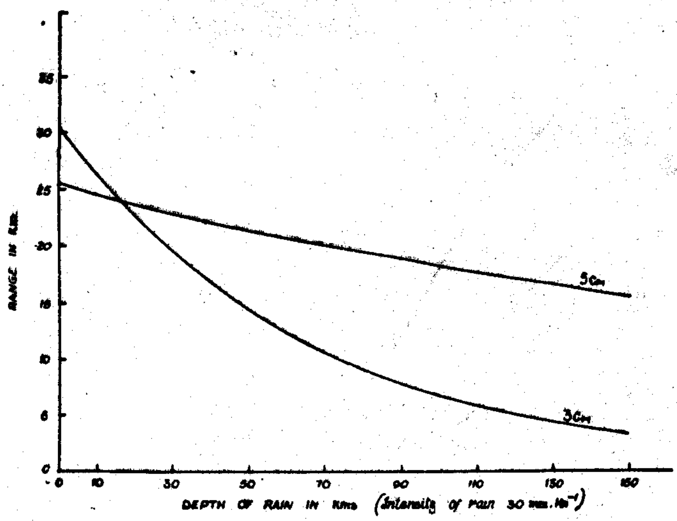


FIG. 2

Reference

1. Gunn and East, QJR Met. Soc. Oct. 1954.

2. Laws and Parsons, Trans., Am. Geophys. Union, (1943), 452.

3. Humphreys, W. J., Physics of Air, McGraw Hill, N. Y. 1940.

4. Best, A. C., Report on water in Atmosphere, July 18, 1944.

5. Saxton, J. A., Met. Factors in Radio Wave Prop., Phy. Soc. (1946), 202.