STUDY OF EFFECT OF RAIN AND DUST ON PROPAGATION OF RADIO WAVES AT MILLIMETER WAVELENGTH

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ABSTRACT

The propagation of Electromagnetic waves in millimeter band is severely affected by rain rate, drop size and dust particle size in terms of attenuation, de-polarization and noise. The vertical looking radiometers will give vertical path attenuation due to rain as well as dust and line of sight link will give horizontal path attenuation whereas the satellite link gives slant path attenuation. In this present paper the methodology of collecting data and methodology for obtaining slant path attenuation using data obtained from vertically looking radiometers and horizontal line of sight links will be given. Validation methodology for the slant path attenuation using beacon receiver will be given.

INTRODUCTION

The use of communication satellites is increasing rapidly and propagation studies at millimeter wave frequencies are of great importance as lower frequency spectrum is getting over crowded. For increasing the channel capacity, the use of ku and ka band is unavoidable. But the rain and dust attenuate the higher frequency signal operating above 10 GHz[1]. The drop size also has effect on the polarization of the radio waves propagating above 10 GHz. At higher frequencies, signal attenuation due to scattering and absorption by the dust particulate depends upon the size and shape of the particle. The frequencies above 30 GHz also have utilization potential in this part of the world for Satellite Communication. So far no significant studies related to effect of rain and dust have been carried out at 35 GHz. It is important to understand about losses in the link at this frequency by conducting experiments so that the link design could be made properly. ISRO is planning to put a beacon operation at 20/30 GHz in future communication satellite. This beacon could be used for propagation studies upto 30 GHz.

METHODOLOGY[2]

For obtaining slant path attenuation for planning of Satcom link one has to get two components of the attenuation of the signal. These components are the vertical path attenuation and horizontal path attenuation. In order to collect sufficient propagation data for both horizontal and vertical path attenuation at 35 GHz, the following experimental setup is proposed.

VERTICAL PATH ATTENUATION[3]

The vertical path attenuation is obtained with the help of a microwave radiometer. The radiometer is a microwave receiver, which is calibrated in terms of input noise temperature and the output voltage. The input noise temperature from clear sky in the normal conditions is measured and the output voltage recorded. The change in the output voltage in the presence of dust and rain gives the relationship between the attenuation of signal due to rain and presence of dust and rain.

RADIOMETER

The specification of the radiometer, which will be used for vertical path attenuation, is given in Table 1 and block diagram is given in Fig.1.

Table 1
Specifications of Radiometer

Frequency	35 GHz	RF bandwidth	500 MHz	Noise figure	8.0 dB
Pre detection Bandwidth	100 MHz	Integration time	10 sec	Integration time	10 sec
Brightness temperature	10-300° k	Temperature sensitivity	1°	Absolute accuracy	5° k
Antenna diameter	1.8	Beam width	1.1°	Polarization	linear
First side lobe better than	20 dB				

The instruments used for determination of physical parameters are: Radiometers with recorders, Rain gauges, Temperature sensors, Drop size-measuring setup, Dust particle size-measurement setup

FORMULATION FOR ESTIMATION OF ATTENUATION AND RAIN HEIGHT

The output voltage from radiometer is recorded for calculating the attenuation. This voltage is converted into equivalent sky noise temperature (T_{sky}) using calibration table. The relation between attenuation and sky noise temp is

$$T_{sky} = \left(T_c / A_t\right) + \left(1 - 1/A_t\right)^* T_{med} \qquad (1)$$

Where, T_c = Cosmic background temperature (2.7^o), A_t = Attenuation in dB, T_{med} = Medium Temperature

The vertical path attenuation due to rain is estimated by subtracting clear sky attenuation (free space) from excess attenuation (rainy medium) due to rain. The slant path attenuation can be calculated using the rain height (H_e). The rain rate remains invariant with rain height is assumed. The rain height H_G can be calculated as:

$$H_G = \left(A_H / \alpha\right) km \qquad (2)$$

Where A_H is the total zenith attenuation and α is specific attenuation

HORIZONTAL PATH ATTENUATION[4]

A LOS link is used for horizontal path attenuation. This link consists of a transmitter operating at 35 GHz and a receiver operating at same frequency. The instruments like rain gauge and dust particles size are kept near the receiver so that no shadowing effect is observed due to nearby objects. The LOS link can be designed at 35 GHz for study of attenuation due to raindrop size and scattering, absorption due to dust particles. The table 2 gives the specification of the transmitter to be used for LOS link. The block diagram for LOS link is given in Fig.2.

Table 2

Specifications of Transmitter

Frequency	35 GHz	Antenna diameter	1.8 ft.
Polarization	Linear	Frequency stability	±2 x 10^{-7} (0^o-50^o)
Discrimination	40 dB	Transmitter power	12 dBm
Aging	$1*10^{-6}$ per year		

The receiver specifications are given in Table 3.

Table 3

Specification of Receiver

Frequency	35 GHz	First IF	1000 MHz	Antenna Diameter	1.8 ft.
Second IF	60 MHz	Beam width	1.1^o	Predetermined	BW±14 KHz
Polarization					
Copolar	Linear vertical	Frequency Stability	$\pm 2*10^{-7}$(0^o-50^oC)	Cross polar	Linear Horizontal
Co-cross Isolation	50 dB	Nominal input	-52 dB	Dynamic range 55 dB	
Aging	$1*10^{-6}$ per year	Accuracy	0.5 dB		

PATH REDUCTION FACTOR ASSOCIATED WITH EFFECTIVE HORIZONTAL PATH[5]

The path reduction factor is related to the horizontal path length. The horizontal path length is defined as "That path length where a uniform rain measured at a point of reference to measure to produce attenuation equivalent to the attenuation measured on the link." In LOS link two receivers are used. One receiver receives coplanar signal and the cross polar signal is received on cross-polar receiver. The reduction in signal strength due to presence of rain or dust particles, as compared to clear sky condition gives attenuation due to rain, or dust particles and in two receivers the effect of tilt in axis of drop is monitored by co-polar and cross polar signals. The effective path length is computed using the attenuation in signal in copolar receiver and rain rate using following equation.

$$L_{eff} = L\, a_L R^{b_L} \qquad (3)$$

Where, L_{eff} is the effective path length in km, L is the link distance in km, R is the rain rate in mm/hr and, A_L and b_L are parameters which depend on link distance, rain rate and frequency Also

$$L_{eff} = (A / \alpha) km \qquad (4)$$

Where, A is the total path attenuation in dB and α is the specific attenuation in dB/km, Again

$$L_{eff} = \gamma L \qquad (5)$$

Where, γ is the path reduction factor. From equation 3 and 5 we get γ, the path reduction factor as

$$\gamma = a_L R^{b_L} \qquad (6)$$

SLANT PATH ATTENUATION

The geometry of slant path is shown in fig.3. The vertical path attenuation and horizontal path attenuation give the slant path attenuation. The equation

$$A_s = \int_0^L ds\,\alpha(s) \qquad (7)$$

gives slant path attenuation. Where A_s is the slant path attenuation along the path length L_s, S is the distance along the path and α(s) is the specific attenuation at distance s. Because of the difficulty of getting the point rain rate at number of points the concept of effective path length L_{eff} and the rain height H_G is used for determining slant path attenuation.

$$A_G = \alpha\, L_{eff} \qquad (8)$$

where, A_G is the attenuation on length L_G which is the horizontal projection of the slant path length.

$$A_G = A_s \cos\phi \qquad (9)$$

and

$$L_{eff} = \gamma\, L_G \qquad (10)$$

where

$$L_G = (H_G / \tan\phi) \qquad (11)$$

where ϕ is the elevation constant of the earth space path, H_G is the rain height above the ground level and γ is the path reduction factor. For the propagation studies at 35 GHz, the slant path attenuation will be obtained using vertically looking radiometers and line of sight links.

SAND DUST ATTENUATION[6]

SATCOM signals incident on dust particulate in the atmosphere undergo absorption and scattering, the degree of each being dependent upon the size, shape, and complex dielectric constant of the particulate as well as the wavelength (or frequency) of the signal. The maximum particle size observed in desert dust storms is on the order of .2 mm or approximately 50 times smaller than the minimum signal wavelength in the millimeter wave regime. In order to estimate the effects of a dust storm on the performance of a communications link, it is first necessary to develop a representative dust model. The varying sizes of the dust particles are often represented by a power law probability distribution of the form.

$$P(r) = kr^{-p} \qquad (12)$$

where r is the particle radius, p is the power law exponent, and k is chosen such that:

$$k \int_{r_{\min}}^{r_{\max}} r^{-p}\,dr = 1 \qquad (13)$$

Equation (12) above would be applied to each region and would provide the particulate distribution for that region. The particulate distribution would then be used to quantify the signal attenuation per kilometer of path length.

CONCLUSIONS

In this paper the slant path attenuation measurement at 35 GHz and the system design of equipments required for Vertical height attenuation measurement, which is done by radiometers and Horizontal path attenuation measurement is done by Line of Sight Link is described. The methodology for determination of slant path attenuation at 35 GHz is also presented. The author feels that the effect of precipitation on propagation at 35 GHz must be undertaken urgently in our country. The centre ICRS would propose that there should be a nation wide network of these equipment for collection of data to arrive at fade margins at these frequencies.

REFERENCES

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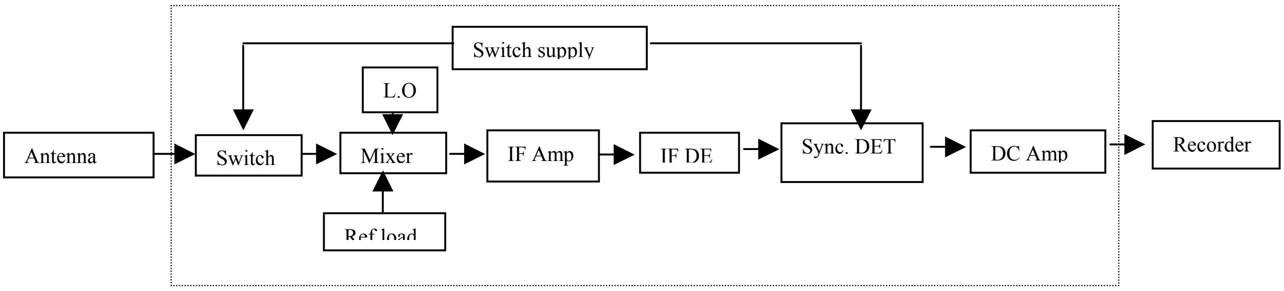

Fig 1. Block Schematic for Radiometer

1. Antenna
2. Polarization switch
3. Mixer
4. Local Oscillator
5. RF Amplifier
6. Mixer
7. Local Oscillator
8. IF Amplifier
9. IF Detector
10. DC Amplifier
11. DE multiplexer
12. Two Channel recorder

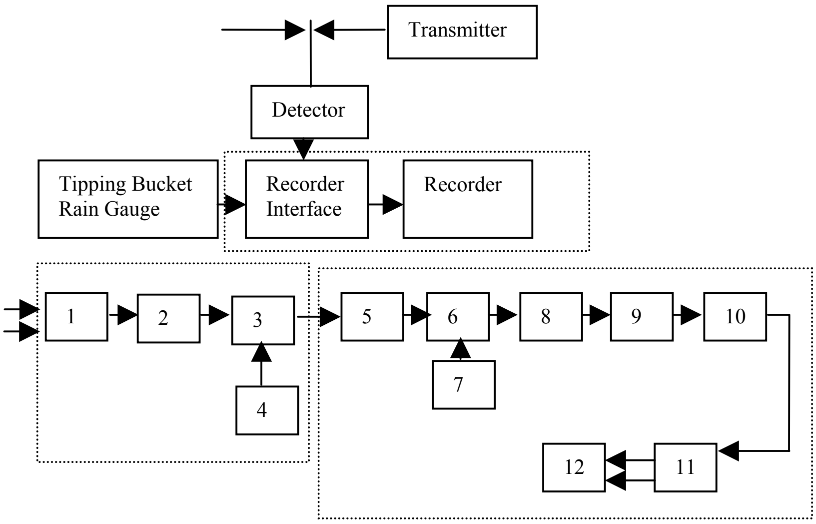

Fig. 2 Block Schematic for LOS System (a) Transmitter (b) Receiver

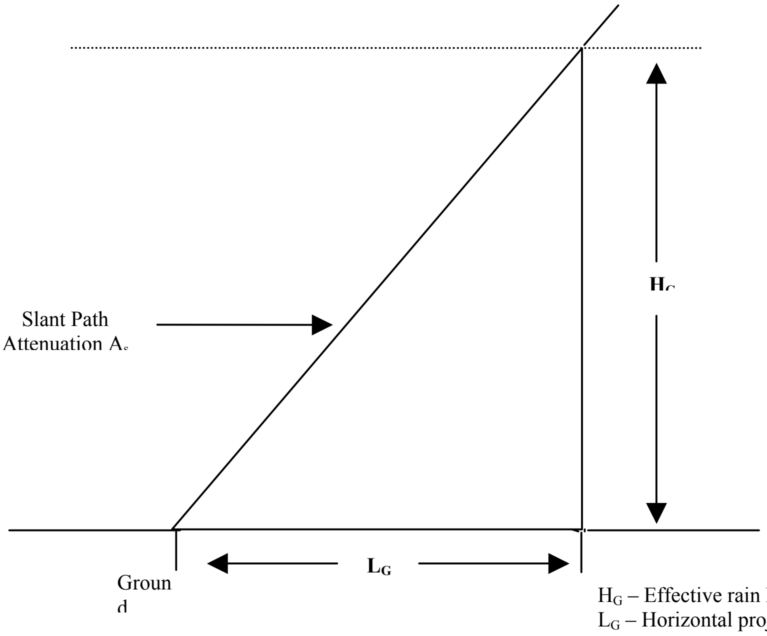

Fig.3 Schematic presentation of Earth – Space path

H_G – Effective rain height
L_G – Horizontal projection of slant path
ϕ - Elevation angle