Characterization of Coherent Scattering due to Foliage Depth at 35 Giga-Hertz Prevailing in Desert Region of India

Indu Bhuria, Rajeev Pourush, D. R Godara

***Abstract*: Millimeter wave range is of interest for scientist as demand of communication bandwidth and channel capacity are increasing day by day. By previous research it was concluded that rate of attenuation decreases with foliage depth. This decrement is due to coherent interference between scattered field components. In this paper, an attempt is made to compare actual attenuation with linear theoretical attenuation when signal prevails through foliage depth in desert region. An outdoor set-up is installed in desert region of Thar, India to measure attenuation in millimeter wave of 35GHz. By computations using Simpsons one-third method it is observed that 25.5 % of scattered signal exhibits coherency when environmental conditions are in dry phase while in wet environmental conditions (after 2 hours of rain) 21.07 % of total scattered signal exhibits coherency. In phase relation in scattered field components is due to collectiveness of leaves which scatters the signal.**

Index Terms: Millimeter wave, coherent Scattering

I. INTRODUCTION

Millimeter wave range is of interest for communication scientist as it may fulfill the requirement of 5G communication. Microwave upto 10 GHz. can be easily used for line-of-sight communication as atmosphere as well as foliage is considered to be homogeneous layer but above 10 GHz., electromagnetic waves are subject to molecular absorption [9]. Besides atmospheric attenuation by gases, signal may undergo attenuation due to scattering by obstacle encountered in LOS. Foliage is one of the main attenuator of signal used for communication in LOS mode. By studies conducted by Schwering and Godara at millimeter wave, it was concluded that rate of attenuation decreases when foliage depth increases [1][2]. As foliage is collective in nature it scatters the signal, such as wavelength became larger then distance between neighboring incident site and scattered components will not remain independent. Hence, signal due to coherent interference are responsible for decrement in rate of attenuation of signal in foliage depth. Scattering which creates coherent interference of scattered field component is known as coherent scattering. In this paper, an attempt is made to calculate the portion of coherently scattered signal. This coherency in scattered signal may allow millimeter wave to be used for line-of-sight communication.

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II. EXPERIMENTAL SET-UP AND OBSERVATIONAL SIGHT

Outdoor experimental setup for attenuation measurement at 35 GHz. consists of transmitter and receiver. At transmitting end, horn antenna is fed with signal generated by Gunn oscillator and at receiving end received signal firstly down converted by a mixer then analyzed by spectrum analyzer.

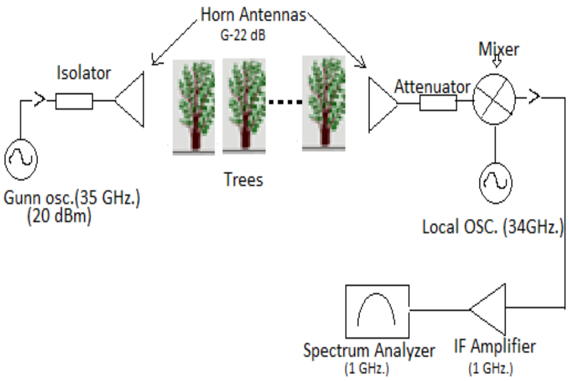

Figure 1. Block diagram of outdoor set-up

Observations are taken at Bikaner (Rajasthan) which is part of Thar desert of India. Neem tree is part of natural vegetation of the *Thar Desert*. Observations are taken on continuous planted neem (Methaazadircta) trees separated by equal distance and are of same age as well as comparatively similar height and canopy size. Trees are placed in line of sight of transmitter and receiver. Attenuation is then measured at foliage depth increased by step size of one tree.

Figure 2 Observational sight

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Trees, for observation are having average height of 5 meters with average trunk height of 2.7 meters with average leaf size of 5 cms

III. OBSERVATIONS

Temperature: 24° C
Wind speed: 5 Kmph.
Humidity: 25%
Antenna height: 2.74m
Distance between Tx & Rx: Adjustable
Bias voltage: 2.54 volt.
Bias current: 0.54 A

Table 1 Attenuation by experimentation

No .of trees	Attenuation (dB) in Dry condition	Attenuation (dB) in Wet condition
1	5.6	7.4
2	12.3	16.2
3	19.3	25.4
4	24.3	31.9
5	28.5	38.2
6	30.6	42.5
7	32.0	45.0
8	33.7	47.8
9	34.3	52.1
10	35.1	54.3

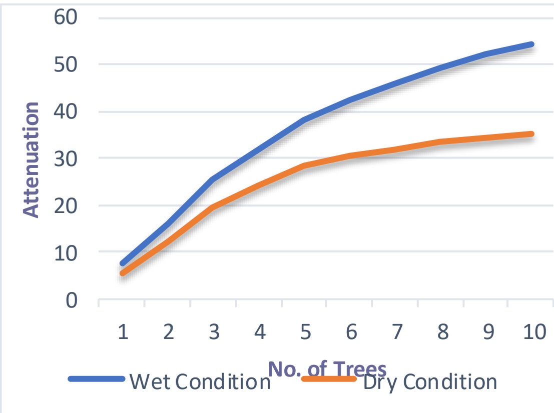

Figure 3 Attenuation (in dB) Vs No. of Trees

Above graph justifies previous research which says that rate of attenuation decreases with foliage depth.

III. COMPUTATON OF COHERENCY

If instead of dependent field components, independent scattering had taken place then there would be linearity in attenuation with increased depth of foliage. That linearity between attenuation and number of trees (Foliage depth) can be modeled by equation of line as-

$$y = 6.7x - 1.1$$

where attenuation is measured on y coordinate and number of trees is placed as x coordinate for dry environmental conditions. If observations are taken after 2-3 hours of rain, additional attenuation will be offered by rain droplet which is modeled as

$$y = 8.8x - 1.4$$

From above equations observation table for theoretical attenuation can drawn as-

Table 2 Theoretical Attenuation (Dry)

No. of trees	Calculated Attenuation (dB) in dry condition	Calculated Attenuation (dB) in wet condition
1	5.6	7.4
2	12.3	16.2
3	19	25
4	25.7	33.8
5	32.4	42.6
6	39.1	51.4
7	45.8	60.2
8	52.5	69
9	59.2	77.8
10	65.9	86.6

If we have discrete points on axis, integral function can be calculated by Simpson's one-third rule formula which can define the integral value of the function.

$$\int_{1}^{10} y dx = \frac{1}{3}[(y_0 + y_9) + 4(y_1 + y_3 + y_5 + y_7) + 2(y_2 + y_4 + y_6 + y_8)]$$

So the integral of attenuation function(y) which depends on number of trees(x) is 224.166 units for the dry condition but theoretically it is calculated a 300.9 units. Relative difference in both quantities indicate the portion of coherent scattered part of the signal. By calculations it can be said that part of coherent scattered signal is 25.5 % of total scattered signal.

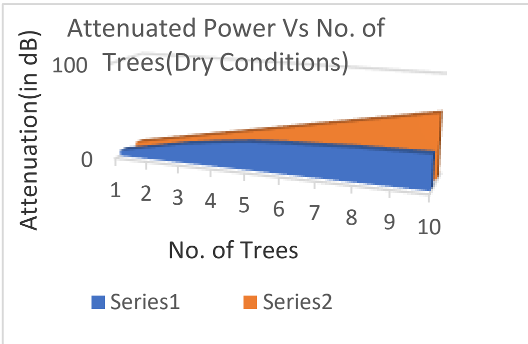

Figure 4 Portion of coherent Scattering (orange) in Dry environmental conditions

While for wet conditions actual attenuation is 312.23 units and theoretical is 395.6 units which say the difference of 21.07% of signal is coherently scattered. Coherency in dry environmental conditions is more than wet conditions due to absorption of signal by water molecules.

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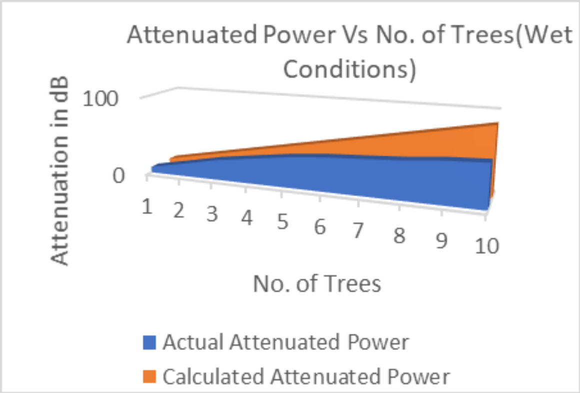

Figure 5 Portion of coherent Scattering (orange) in Wet environmental conditions

VI. CONCLUSIONS

When a signal scatters, traditional theory says that scattered field components are independent of each other. But if signal encounter on object which is collective in nature like foliage which consist of bunch of leaves and branches, scattered field components scatters in such a manner that there will be some in phase components under the effect of coherent scattering. Rate of attenuation decreases in foliage depth due to coherent scattering. By computing difference between actual and theoretical attenuation it is concluded that 25.5% of signal is coherently scattered in dry environmental conditions and 21.1% in wet environmental conditions. So for the application of millimeter wave for line of sight communication through foliage depth, above coherency can play significant role.

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