STUDY THE EFFECT OF RAIN ON TELECOMMUNICATION AND PROPOSE A METHOD TO GUARD AGAINST IT

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Abstract— **As we all know that there has been a sudden boom of the telecommunication industry and there are perhaps some discrepancies which are still not taken care of. One such topic of discussion is the impact of weather conditions on the telecommunication signals. Taking the case of rain, the following research paper will focus on the attenuation by rain on telecommunication signals with special focus on the effect of polarization of the signals. The research paper will further include a method to guard against the attenuation caused by rain on communication**

Index Terms— **Effect of Polarization on attenuation by rain, Attenuation by rain, vertical polarization, effect of rain on telecommunication**

1. INTRODUCTION

The emphasis on telecommunication started as early as the 1950s when a feasibility study on using the millimeter-wave band in radio communications started at the Radio Research Laboratory (currently the National Institute of Information and Communications Technology) to meet the ever-increasing demand for frequency resources. In 1956, the first author of this paper initiated research on millimeter-wave propagation in rain in the 35-GHz band.

The theoretical work by Ryde and Ryde in the early 1940s represents seminal research in this field. They calculated the electromagnetic cross sections of spherical raindrops, without restrictions in the ratio of drop size to wavelength (Mie scattering regime), and, using microphysical parameters of rain, derived the relation between rainfall rate and attenuation. The experimental results obtained back then have generally confirmed the predictions

Then again a vigorous effort in this field was done by Sogo Okamura and Tomohiro Oguchi, both of whom studied the impact of rain and attenuation caused by it with emphasis on polarization of the signals. During their research they came up with an eccentric observation that when the signals where vertically polarized the attenuation by rain was much less as compared to when they were horizontally polarized. This particular effect was not accounted for in the theory and seemed very odd at first. But by careful analysis of this difference it was figured out that the rain drop is not completely spherical and its base gets flattened with increasing radius. This was the reason for the comparatively more attenuation on the horizontally polarized signals. Although the effect of polarization was found to be small, this has later become of practical importance, because terrestrial and earth-space communication systems have used two orthogonal polarizations at an identical frequency to increase the capacity of communications; the coupling between two orthogonal polarization channels, if it occurs, will greatly limit the efficient use of these orthogonal channels.

This study deals with re-examination of the published data and taking advantage of the particular eccentric result and converting it into a meaningful hypothesis.

1.1 ORGANIZATION OF THE PAPER

This paper is organized as follows. Section 2 lists the ways of calculating the attenuation and establishing a relationship between rainfall rate and attenuation caused by it. Section 3 deals with studying the impact of attenuation by rain on both horizontal as well as vertical polarization. Section 4 proposes a technique to counter the attenuation caused by rain. Section 5 lists the effectiveness of the proposed system. Section 6 enlists the areas of application of the proposed technique. Section 7 enlists the future scope and conclusion. Section 8 acknowledges the mentor for his constant support and section 9 lists the references used.

2. CALCULATION OF ATTENUATION AND RELATIONSHIP BETWEEN RAINFALL RATE AND ATTENUATION

This section first outlines the general procedure for calculating the attenuation of electromagnetic waves travelling in a rain-filled medium. Then, assuming that the raindrops are spheres, we will give estimated attenuation values as a function of the frequency to find the significance of rain effects in the microwave and millimeter-wave regions.

Assuming that the incident wave with unit amplitude and frequency f is propagating in direction $\hat{\mathbf{K}}_1$, the scattered electric field, $\mathbf{E}^s$, toward direction $\hat{\mathbf{K}}_2$ may be written in the

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far-field region as:

$$\mathbf{E^S = f\ (K_1, K_2)\ r^{-1}\ exp\ (-ik_0r)} \quad [1]$$

where vector function $\mathbf{f}(\hat{\mathbf{K}}_1, \hat{\mathbf{K}}_2)$, often referred to as "scattering amplitude", denotes the amplitude, phase, and the state of polarization of the scattered field, *r* is the distance from the origin to the observation point, and k_0 is the free-space propagation constant defined by $2\pi f/c_0$, where c_0 is the speed of light in free space. An exp ($+i2\pi ft$) time convention is assumed and is suppressed.

The propagation constant, *k*, in a space containing many raindrops is given by

$$\mathbf{k = k_0 + (2\pi/k_0) \int \hat{e} \cdot f\ (K_1, K_1, a)\ n\ (a)\ da} \quad [2]$$

Where $\mathbf{f}(\hat{\mathbf{K}}_1, \hat{\mathbf{K}}_1, a)$ denotes the forward scattering amplitude of a raindrop with radius *a*, and $n\ (a)da$ is the number of drops per cubic meter in space with radius *a* in range *da* and is a function of rainfall rate *R*. Since the propagation factor in a rain medium is exp ($-ikr$), the real and imaginary parts of *k* are respectively responsible for the phase shift and attenuation of the wave propagating in the rain medium.

In the attenuation measurements, the attenuation, *A*, is often given in dB/km and is written in the following form:

$$\mathbf{A = 4.343 \times 10^3 \times \int Q_t\ (a)\ n\ (a)\ da} \quad [3]$$

Where Q_t, commonly termed the "total cross section", is the sum of the power scattered in all directions from a raindrop and the power absorbed in the drop, when it is radiated by a plane wave of unit power per unit area. There is a well-known relation between Q_t and the scattering amplitude, **f**, in the forward direction

$$\mathbf{Q_t = -\ (4\pi/k_0)\ Im[\ \hat{e} \cdot f(K_1, K_1)\ ]} \quad [4]$$

Naturally, the attenuation formula obtained from the imaginary part of the propagation constant, *k*, agrees with Eq. [3], when Eq. [4] is referred to.

Drop-size distribution $n(a)$ can be obtained by measuring the size distribution of raindrops reaching the ground, and converting it to a distribution in space with the aid of the fall velocity of raindrops. The drop-size distribution is a function of the rainfall rate, and depends on rain types. The rainfall rate,*R*, in millimeters per hour is related to both drop-size distribution and fall velocity expressed by

$$\mathbf{R = 4.8\pi \times 10^{-3} \times \int v(a)\ a^3\ n(a)\ da} \quad [5]$$

Where $v(a)$ is the terminal fall velocity in meters per second and *a* is the drop radius in millimeters

The above provided equations signify a relationship between rainfall rate and attenuation. That is higher the rainfall rate more is the attenuation. The relationship was further justified by Sogo Okamura and the following graph (FIG. 1) was plotted to verify the direct relationship between attenuation and rainfall rate.

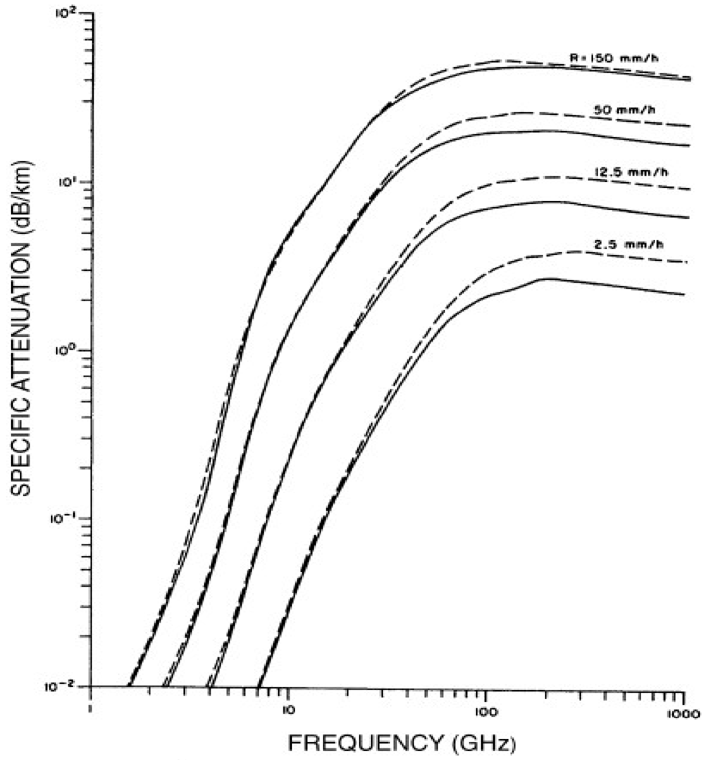

FIGURE 1

The dashed line is the then published data of the Ryde and Ryde and the solid line represents the data of Sogo Okamura.

This is the relationship that we will look to exploit in the proposed method in section 4.

3. EFFECT OF ATTENUATION ON HORIZONTAL AND VERTICAL POLARIZATION

Theoretically the rain drops were assumed to be spherical in shape but that usually is not the case. With increasing radius the base of the spherical rain drop tends to get more flattened which leads to variations in the impact of rain on horizontal and vertical attenuation. The following diagram (FIG. 2) will give a clearer image of the rain drops.

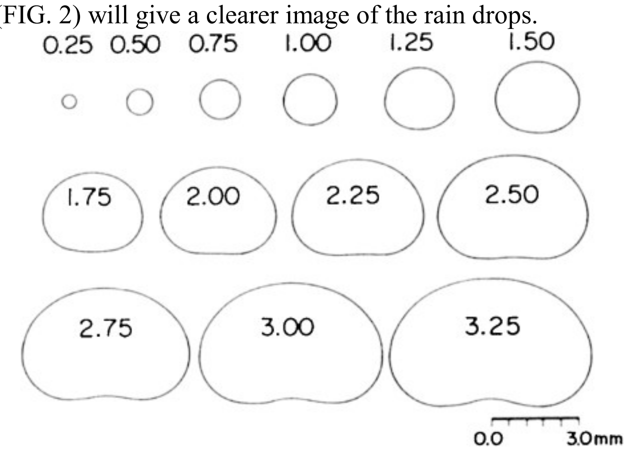

FIGURE 2

Thus, as seen from the figure above as the radius of the rain drop keeps on increasing the base becomes more flattened.

The equipment used by me in the attenuation measurements was frequency-modulated radar operating at 34.8 GHz, similar to that used by Crawford and Hogg of Bell Laboratories and to Sogo Okamura. The transmitter-and-receiver polarization could be changed by replacing the short straight-waveguide section, connected just behind the circular primary horn, by using a 90° twist section.

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A trihedral corner reflector with a cross-sectional area of 1.7 m^2 was located on the top of a building 400 m from the radar site. A very simple rain gauge was placed at the radar site. A rain collection funnel with a diameter of 0.35 m was attached to a graduated cylinder, and the rise in the water level was measured every 30 sec or 1 min, depending on the rain intensity. The measured values were then converted into corresponding values in mm/h units. Preliminary measurements were made during heavy rainfall, first in vertical polarization, and then in horizontal polarization.

The results obtained were mostly in accordance with the theoretical calculations with a minor variation in case of vertical polarization. The attenuation in case of vertical polarization was much less as compared to attenuation in horizontal polarization. This was due to the above mentioned fact that in theory the rain drops were assumed to be purely spherical in shape but in reality with increasing radius there shape undergoes changes as seen in the figure above.

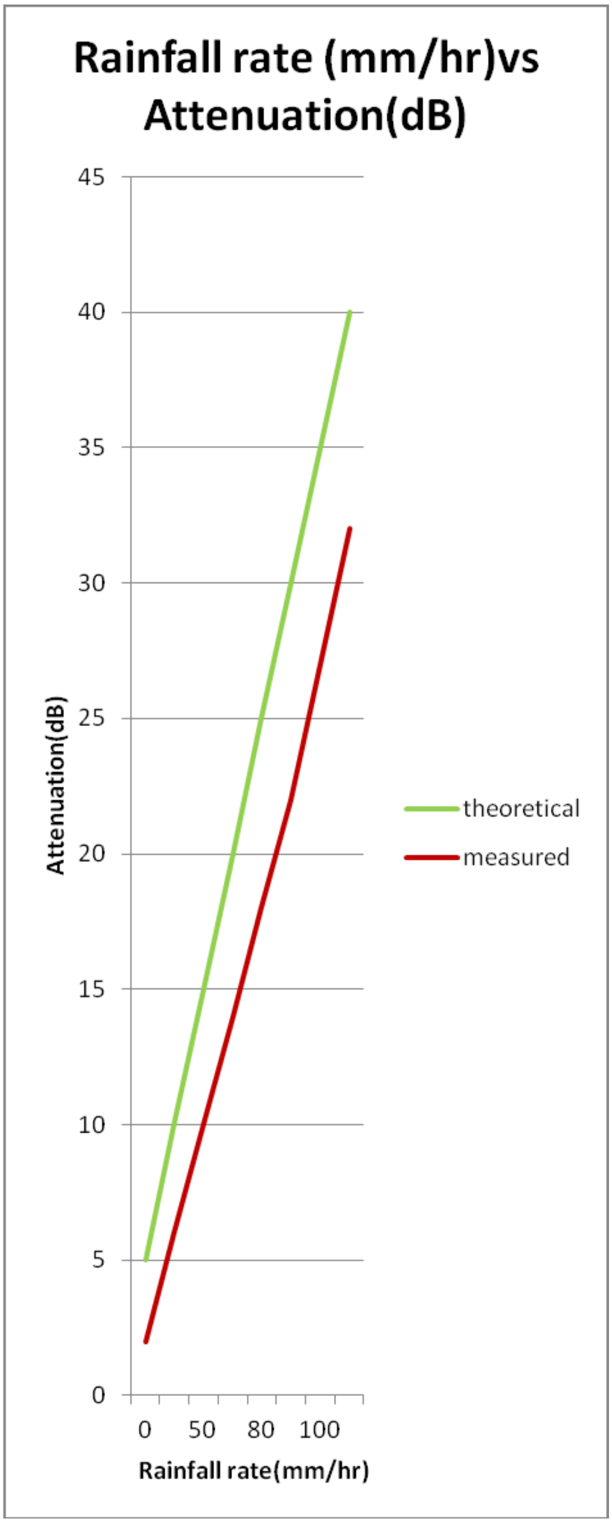

FIGURE 3(a)

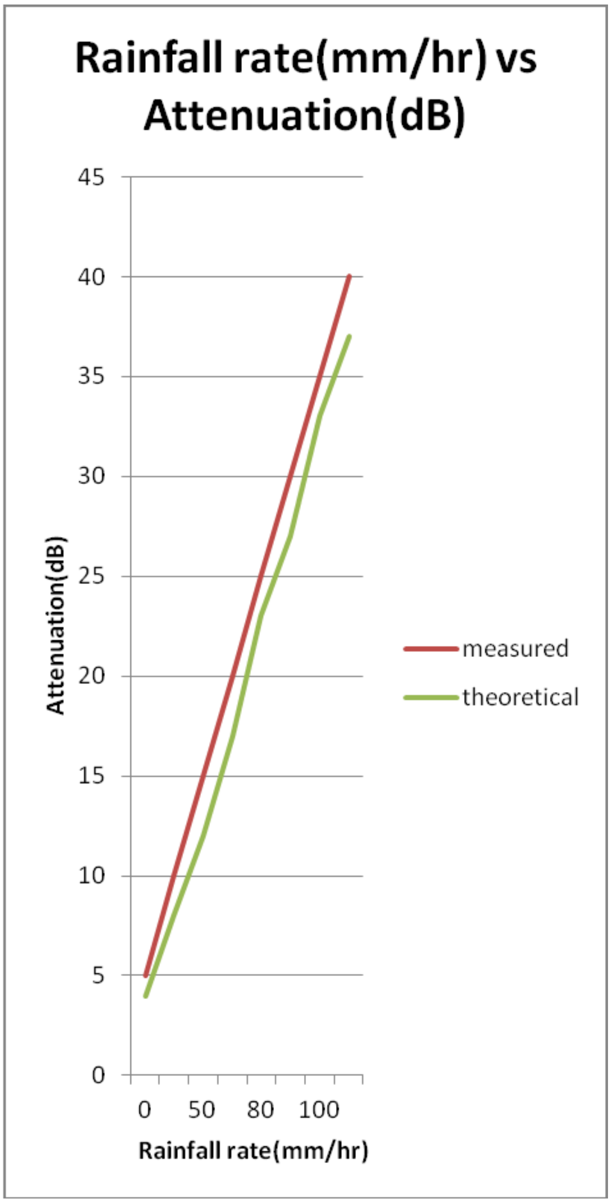

FIGURE 3(B)

Figure 3 (a) is for vertical polarization and Figure 3 (b) is for horizontal polarization.

As seen from the figure above the values in case of horizontal polarization are in complete accordance with the observation of Ryde and Ryde but it is evident that in case of vertical polarization the measured attenuation is much less as compared to the theoretical attenuation.

4. PROPOSED METHOD TO COUNTER ATTENUATION BY RAIN

In USA and some other parts of the world horizontal polarization is being used for Television and other purposes. While horizontal polarization has its own unique advantage over vertical polarization, the shortcoming on the basis of attenuation cannot be overlooked. The method proposed takes advantage of both horizontal as well as vertical polarization by making them work in close coordination with each other.

We have seen that a direct relationship exists between the attenuation caused by rain and rainfall rate (R) from section 2. Utilizing this relation, Suppose we create a system which calculates the attenuation by rain between time interval (say t_1 and t_2) from the method stated in Section 2 and thus the corresponding Rainfall rate. Now as we have both the values in hand and we know for a fact that vertical polarization performs better in rain due to a lesser impact of attenuation by rain on it, we can polarize the signals to vertical polarization for that particular time interval. That is for the time interval between t_1 and t_2 when the attenuation by rain is high enough to cause a large variation between horizontal and vertical polarization, we polarize the signals vertically to improve the quality of the signal reception. In this way we take advantage of horizontal polarization for the better part of the signal but only during the times of rainfall strong enough to cause a stark variation of attenuation between vertical and horizontal polarization, we polarize them vertically.

The proposed system would be equipped with a rain collecting funnel that would be large enough to estimate the rainfall rate. The amount of rain can be measured by the reading from the graduated cylinder (in mm) attached to the funnel and the rate (in mm/hr) can be calculated with the help of a clock fitted. The transmitter as well as the receiver will be fitted with dual polarization system so that the switch from horizontal to vertical polarization and vice-versa could be made easily. From the procedure described in Section 2 the attenuation by rain can be calculated. Now that the system has the values of both rainfall rate as well as the attenuation by rain, a predefined logic will be incorporated in the system keeping in the mind the graph plotted between rainfall rate and attenuation in both horizontal and vertical polarization to automatically convert the polarization from horizontal to vertical when the difference in attenuation is beyond a set threshold value.

5. EFFECTIVENESS OF THE PROPOSED SYSTEM

The proposed method tries to incorporate the advantages of both horizontal and vertical polarization into one system. The limitation of horizontal polarization in rain is accounted for by converting it into vertical polarization only for that particular interval of time. As there is less attenuation, the strength of the signal received even in rainy conditions will be up to the mark. The main advantage of the system lies in the fact that for the better part of the time the system remains in its original state that is when there is little or no rain or when there is a less effect of rain on communication then there is no need to convert horizontal polarization to vertical polarization. The only complexity of the system lies in the fact that both the transmitter as well as the receiver has to be equipped with dual polarized systems to convert or to receive both horizontal and vertical polarization.

6. AREA OF APPLICATION

Television transmission in the United States of America is horizontally polarized. This is one such possible area of application. Since there is no shortage of rainfall in USA the above proposed system can be easily implemented to counter the attenuation by rain. The signal strength will be boosted even in adverse conditions. The transmission in the countries which uses horizontal polarization like the USA will certainly benefit from the proposed method.

7. CONCLUSION

The future scope of the research includes assessment and designing of the proposed system in rainy conditions and the feasibility to develop such a system. The proposed system once implemented could solve the problem of the television operators to a great extent.

Numbers of enthusiasts have successfully presented the impact of rain on both horizontal as well as the vertical polarization. This paper focuses on utilizing that research and transforming it into a meaningful hypothesis. Taking the advantage of the already done research, the research paper proposes a method to limit the attenuation by rain of telecommunication signals. The above mentioned method logically concludes the use of vertical polarization during rainfall high enough to cause stark attenuation difference between the two states of polarization. The proposed method if implemented will solve the frustrations of many unsatisfied user of telecommunications during the rainy weather.

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