International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Rain Attenuation Prediction in Tropical Regions using Site Diversity Technique

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Abstract: ***Rain attenuation is the main cause for the loss of signals throughout sending or reception over earth's atmosphere. Moreover raindrops converts the direction of the signal. Rain attenuation changes with change in the frequency and change in the rain rate. As the prediction of rainfall in tropical regions is difficult, design of a terrestrial satellite link without attenuation is a big challenge. In order to design such links, it is essential to predict the attenuation caused by the rain at different frequencies for different rain rates with respect to the regions where the link is to be established. One of the most significant job to examine the impact of rain on the function of the terrestrial microwave link and to estimate the link size required to compensate for this negative impact. This paper presents the analysis of different Rain attenuation prediction models and derives the results for each model with respect to elevation angle. The measured values are compared with the standard ITU-R rain attenuation prediction models. All the observed values can be used to apply site diversity technique and the attenuation value is reduced using site diversity technique.***

Keywords—ITUR-R, Rain Attenuation, Terrestrial, Site Diversity, Microwave, Frequency, Prediction.

I. INTRODUCTION

Based on seasonal symptoms and location, rain or stream form may be rain or critical rain. In strati form, rainfall is low to medium and displays great spatial homogeneity. On the other hand, thermodynamic rain has a radius of 5 km radius, with high rainfall. Rain cells are enclosed by broader zones of strati form rain. Inhomogeneity of rainfall in rain cells occurs in a very decline, which leads to a cooperative attenuation of signals that follow dissimilar paths. So, if the signal is received by different means, only one of them may be deep fade, which will have little impact on others. Rainfall in both horizontal and vertical directions can predict the complexity of uncontrolled progression. The result is a decrease of satellite-earth microwave signal dissipation, depolarization, and receiver antenna sound. Signal decline for radio-communications schemes working in centimeters and millimeter wave bands Rainfall is one of the main causes, especially in the tropical climate. Rain decline is crucial to designing a ground-satellite radio link at frequencies above 7GHz. These spots can be determined by spots, uniformity and just statistically or experimental rainfall measurements.

There are two methods of assessing rain deterioration:

- **Physical approach:** This method involves the calculation of the rain attenuation decrease by the practical measure in the laboratory.
- **Empirical approach:** This method uses an effective way of using data from various data bases and uses the length and rainfall rate.

Manuscript published on 30 June 2019.
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II. PREDICTION OF RAIN ATTENUATION

The brightness of the signal reduces its power when it passes through its medium. It is usually measured in decibels. Spots are adverse when rain is positive. The flow of rain can be calculated from the proportions of the electrically charged flow, which generates the flow of energy as

$P(r) = P(0)e^{-\alpha r}$

The following equations are represent in dBs for the above equation.

$P1=p(0)/p(r)$

$\text{Loss} = 10 \log(p1)$

$= 4.434\alpha\gamma$

It is called the specific attenuation, γ(dB/Km). If you know the size and shape distributions [3] from electromagnetic theory, easy to straighten the typical model depends on the rainfall rate:

$\gamma = pR^q$

Here p and q constants are provided in the table below.

F in GHz	P	Q
1	0.0000387	0.917
10	0.0101	1.276
20	0.0751	1.099
30	0.187	1.021
40	0.350	0.939

Table 1: Values of p and q at different frequencies

The value of p increases while frequency increases, but the Q is low, the rain deterioration is higher at high frequencies. Some of the symptoms of rain deterioration are as follows:

- Rain attenuation is directly related to improved communication.
- Rain deterioration can be estimated

III. ANALYSIS OF EXISTING PREDICTION MODELS

Rain attenuation patterns for experimentation follow simple procedure. Rain data is collected using a rain gauge.

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Receives signal from receiver, and explores using spectrum analysis.

A. MOUPFOUMA'S METHOD

The method has been established by using mostly tropical data. The method requirements elevation angle of the slant path, site height from sea level, etc. Here, the Rain rate is also required for 0.01% and other percent of time to present the idea of modification factor. Predicted attenuation is given by

$$A(dB)=\frac{kR^{\alpha}u(p)(R_{0.01}/R_{pu})^{0.38/(L_s-0.25)}}{1+\eta(p/0.01)^{-0.36}{L_s}^{m}}\times L_s \quad (1)$$

where,

$$m = 1+1.4\times 10^{-4} f^{1.76} log_e(L_s) \quad (2)$$

f = frequency (GHz)

L_s = slantpath length in kms

η = 0, if 1 < 5 km and f < 25 GHz

η= 0.03 otherwis.

k, α= those coefficients stated in Garcia-Lopez' method.

P=percentage of time

$R_{0.01}$=rainrate 0.01% of time

R_p=rainrate for p%

Moupfouma has providing the values of α for different locations throughout the world. Slant path formula is given by,

$$L_s = \frac{H_R - H_0}{\left[\sin^2\theta + 2\left[\frac{H_R - H_0}{8500}\right]\right]^{1/2} + \sin\theta} \quad for\ \theta \geq 5^0 \quad (3)$$

Here,

θ angle of elevation;

H_0 location height from sea level;

H_R is 0° C height of isotherm.

It should be pointed out that Crane has planned a technique using revised two-component model. However, the method is valid for slant paths only[4].

B. ITU-R MODEL

International telecommunication union radio model is the generally used technique designed for calculating effect of rain and slant path. Main input for these models is time at 0.01% (A0.01)rainfall, which is used to estimate the scarring at other percentages. Since this model accepts a constant reduction factor in calculating the sustained rain altitude and slant path, it will not be an operative method to measure tropical and intermediate regions, as rainfall is potentially variable rainfall with rain intensity. For satellite arguments in different places, rain-specific attention and rain will be calculated using the ITU-R model for changes in the route slant.

Calculation of Rain Attenuation

- ***step* 1:** calculate the following

  hR = h0 + 0.36 (4)

- ***step* 2:** length of Slantpath

  Ls = (hR – hs) /sinθ (5)

  θ = angle of Elevation

  hs = station height

  hR = Horizontal projection of rain height

  LG = Ls cosθ (6)

- ***step* 3:** Rainfall, R0.01, exceeds 0.01%, with 1-min integration time.
- ***step* 4:** Specific attenuation

  γ R = K ($R_{0.01}$)α (7)

where K and α shown below and depends mainly on raindrop size distribution, polarization, frequency and heat.

$$k = [k_H + k_V + (k_H + k_V)cos2\theta\cos(2t)]/2 \quad (8)$$

$$\alpha = [k_H\alpha_H + k_V\alpha_V + (k_H\alpha_H - k_V\alpha_V)cos2\theta\cos(2t)]/2k \quad (9)$$

- ***step* 5:** horizontal path adjustment factor is calculated using

  $$r_{0.01} = 1/1+0.78\sqrt{(\frac{k_V k_V}{f} - 0.38(1-e^{-2L_G})}) \quad (10)$$

  f = frequency(GHz).

- ***step 6*:** Familiar rain-path length

  $L_R = L_G r_{0.01}/\ cos\theta$ for $\varepsilon > \theta$ (11)

  $L_s = (h_r - h_{s)}/\ sin\theta$ for $\varepsilon \leq \theta$ (12)

  $\varepsilon = tan^{-1}[(h_r - h_{s)}/L_s r_{0.01}]$ (13)

- ***step* 7:** Vertical reduction factor

  $$V_{0.01} = 1/(1+\sqrt{(sin\theta[31(1-e^{-\frac{\theta}{1+\chi}})}\sqrt{(\frac{L_R\gamma_R}{f^2} - 0.45)]})$$

  (14)

  $\chi = 36 - |\Phi|$ for $|\Phi| < 36^0$ (15)

  $\chi = 0$ for $|\Phi| \geq 36^0$ (16)

- ***step* 8:** The effective path length through rain

  $L_E = L_R V_{0.01}$ (17)

- ***step* 9:** Attenuation exceeded for 0.01percentage

  A0.01 = γR L_E (18)

- ***step* 10:** For the calculation of attenuation at 0.001% to 10% using

$$A_P = A_{0.01}(P/0.01)^{-(0.065+0.033\ln(P)-0.045\ln(P_{0.01})-\beta(1-P)sin\theta}$$

(19)

C. GARCIA LOPEZ MODEL

GL Model is a easy design depending on good database. Rainfall decline and rain intensity are calculated by regressive methods depends on terrestrial regions. Special values are given for different calculations in tropical countries [1].

A(dB)= kRα Ls / [a1+ {Ls (bR + cLs+ d1)/e1}] (20)

R = rainrate (millimetre/hour)

Ls= Corresponding path length in km

Ls= (hFr –hs) /sin θ (21)

θ = Elevation perspective

hs = distance between ground and station in kms

hFr= 0° C which is isotome height in kms

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a = 0.72
b = 76
c = -4.75
d = 2408
e = 10000

these are the values for India [1].

D. SIMPLE ATTENUATION MODEL

SAM is a generally used slant path, clearing indicator models, strati type and tropical varieties of rainfall. In addition to the rate of rainfall at the soil, the deterioration is used to calculate. The rate of rainfall is the simplified logarithmic relationship. In complex rainfall, R> 10 mm / h, when effective rainfall height, HR increases the length of the path slow.

A(dB)= γLs if Rp ≤10mm/hr (22)

Ls = $H_R - H_0$/ sinθ (23)

a=1-exp[(-a1)]

a1= γ*bln(Rp/10

A= γ*a*Lscosθ / a1* cosθ) (24)

b=0.04545455

HR = H0 for R ≤ 10

HR = H0 +log(R/10) for R>10 [1]. (25)

E. HORIZONTAL AND VERTICAL REDUCTION FACTORS

The horizontal and vertical reduction factors to assess the predictability of the unexpected nature of rainfall events. The horizontal reduction factor of the model is based on the concept of Goddard, each has a virtual link along the radial line, which can propagate a signal to the transmission path.

The vertical and horizontal reduction factors r_V and r_H are given as

$$r_{v0.01} = 1.429\exp\left(-\left(\left(\frac{\frac{1}{\gamma R_{0.01} L_s} - 0.0251}{0.0108}\right)^2\right)\right) \quad (26)$$

$$r_{h0.01} = aL_g^b + c \quad (27)$$

$$a = 2.989\exp\left(-\left(\left(\frac{f - 45083}{23.61}\right)^2\right)\right) \quad (28)$$

$$b = -8128f^{-3.329} - 0.1432 \quad (29)$$

$$c = -0.00006553f^3 - 0.005906f^2 + 0.08657f + .1513 \quad (30)$$

$$L_g = L_s\cos(\theta) \quad (31)$$

$$L_s = \frac{H_R - H_S}{\sin(\theta)} \quad (32)$$

$$A_{0.01} = \gamma R_{0.01} L_s r_{v0.01} r_{h0.01} \quad (33)$$

for the percentages 0.001 to 1% the attenuation is

$$\frac{A_p}{A_{0.01}} = 0.117p^{-(0.637+0.0371\log(p))} \quad [3] \quad (34)$$

IV. PROPOSED DIVERSITY TECHNIQUE

To decrease the effect of rain on communication lines, many prediction models have been evaluated to include fade-mitigation models that have been evaluated. In all the fade mitigation models, site diversity has been recognizes to be the more efficient. The site diversity method is depends on the perception of incomparable nature of rainfall, which happens in the restricted rain cell for a limited kilometers in the horizontal and vertical range.

SITE DIVERSITY

Severe rain particles that cause large degrees of value on the ground-empty link often have more than one kilo meter parallel dimensions. Differential systems that can be transmitted with satellite access to alternative land stations At more than 20 GHz frequencies, losses in other ways than rain may also affect site diversity performance[2].

The prediction method defined below applies for balanced and unbalanced methods and computes the common probability beyond the limitations of attenuation. This assessment method is highly accurate and given priority[2].

Prediction of outage probability due to rain attenuation with site diversity:

The probabilities given as

$$P_r(A_1 \geq a_1, A_2 \geq a_2) = 100 * P_r * P_a\% \quad (35)$$

These probabilities are:

$$P_r = \frac{1}{2\pi\sqrt{1-\rho_r^2}} \int_{R_1}^{\infty}\int_{R_2}^{\infty} \exp\left[-\left(\frac{r_1^2 - 2\rho_r r_1 r_2 + r_2^2}{2(1-\rho_r^2)}\right)\right] dr_2\, dr_1 \quad (36)$$

Where

$$\rho_r = 0.7\exp(-d/60) + 0.3\exp[-(d/700)^2] \quad (37)$$

$$P_a = \frac{1}{2\pi\sqrt{1-\rho_a^2}} \int_{\frac{\ln a_1 - m\ln A_1}{\sigma \ln A_1}}^{\infty}\int_{\frac{\ln a_2 - m\ln A_2}{\sigma \ln A_2}}^{\infty} \exp\left[-\left(\frac{b_1^2 - 2\rho_a b_1 b_2 + b_2^2}{2(1-\rho_a^2)}\right)\right] db_2\, db_1$$

(38)

Where

$$\rho_a = 0.94\exp(-d/30) + 0.06\exp[-(d/500)^2] \quad (39)$$

And P_a and P_r are complementary bivariate normal distributions.

$$P_k^{rain} = 100 * Q(R_k) = 100 * \frac{1}{\sqrt{2\pi}} \int_{R_k}^{\infty} \exp\left(-\frac{r^2}{2}\right) dr \quad (40)$$

i.e.:

$$R_k = Q^{-1}\left(\frac{P_k^{rain}}{100}\right) \quad (41)$$

$$P_i = P_k^{rain} Q\left(\frac{\ln A_i - m\ln A_i}{\sigma \ln A_i}\right) \quad (42)$$

These limitations can be found for every separate position, or a single position can be used. The rain attenuation vs. annual probability of incidence can be predicted using in this technique defined above.

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1. Determine P_k^{rain} (% of time), the probability of rain on the k-th path.
2. Construct the set of pairs $[P_i, A_i]$ $P_i \leq P_k^{rain}$.
3. Transform the set of pairs $[P_i, A_i]$ to $\left[Q^{-1}\left(\frac{P_i}{P_k^{rain}}\right), \ln A_i\right]$

Where

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{t^2}{2}} dt \qquad (43)$$

Step 4: Determine the variables $mlnA_i$, σlnA_i by performing a least-squares fit to:

$$mlnA_i = \sigma lnA_i Q^{-1}\left(\frac{P_i}{P_k^{rain}}\right) + mlnA_i \text{ for all i.[2]} \qquad (44)$$

V. RESULTS

The five different models and the exceedance percentage rate taken as input for the corresponding standards values as shown below.

WITHOUT USING SITE DIVERSITY TECHNIQUE

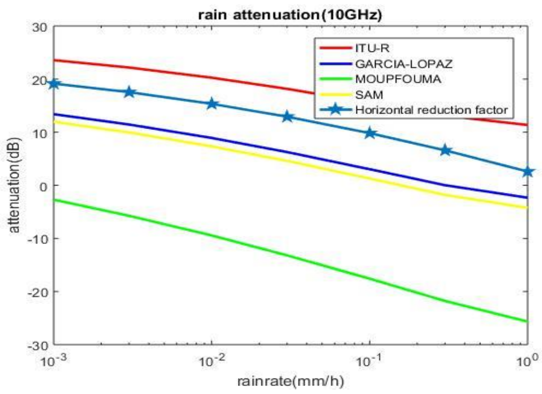

Fig:1 Rain attenuation at 10GHz.

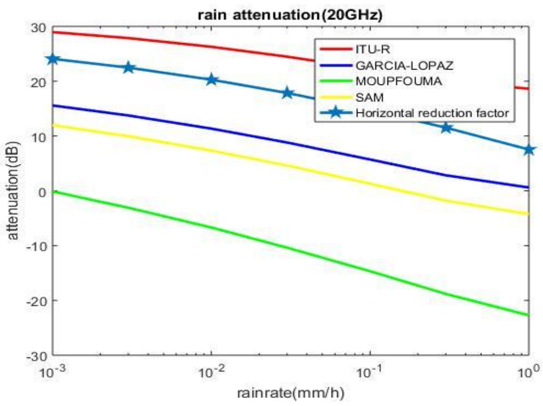

Fig:2 Rain attenuation at 20GHz

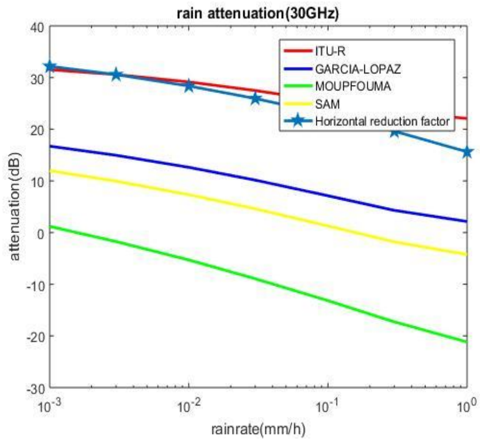

Fig:3 Rain attenuation at 30GHz

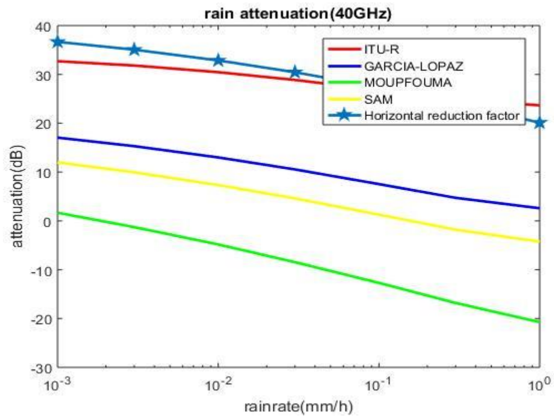

Fig:4 Rain attenuation at 40GHz

From figs 1, 2, 3, & 4, SAM models have been shown to have a similar performance for almost all frequencies above 10GHz. Attenuation for high rain rates is practically stable. ITU-R model simultaneously develop the attenuation for high the rate of rain. Attenuation increased for low rate of rain and almost stable for 30millimeter per hour rate of rain in Garcia- Lopez. The high attenuation values for the models at 40GHz frequency are 37, 33, 17, 12 and 2dB for HORIZONTAL AND VERTICAL REDUCTION FACTORS, ITU-R, GARCIA-LOPAZ, SAM and MOUPFOUMA models respectively.

In the observations from the figs, significantly increases the values exceeding 50mm / h rain rate. The Moupfouma model gives a good downturn to all rainfall. SAM, approximately 70mm/hr rainfall rate for Garcia-Lopez techniques is almost the same values of fatigue. From this figures one think is observes that is ITU R and HAVRF models are the best for the communication. Because they have highest attenuation values compared to the others. By using diversity technique we can reduce this high attenuation.

USING SITE DIVERSITY TECHNIQUE

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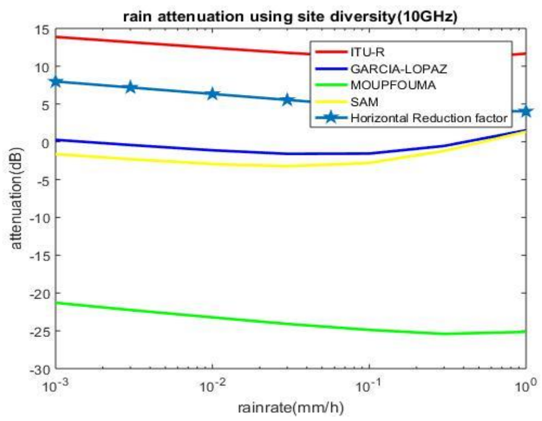

Fig:5 Rain attenuation at 10GHz using site diversity technique

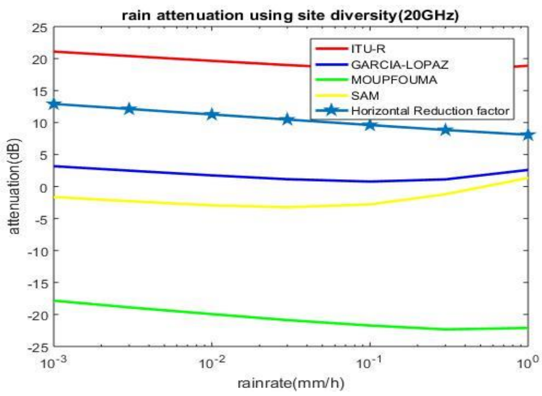

Fig:6 Rain attenuation at 20GHz using site diversity technique

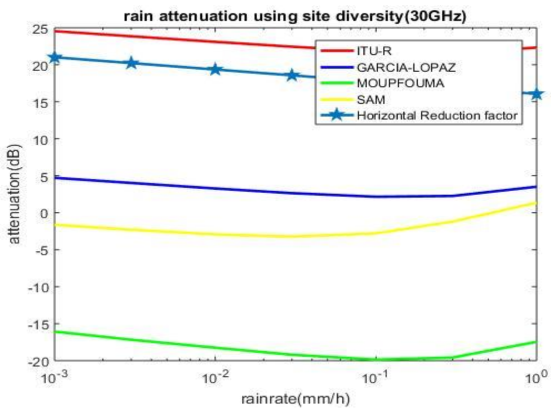

Fig:7 Rain attenuation at 30GHz using site diversity technique

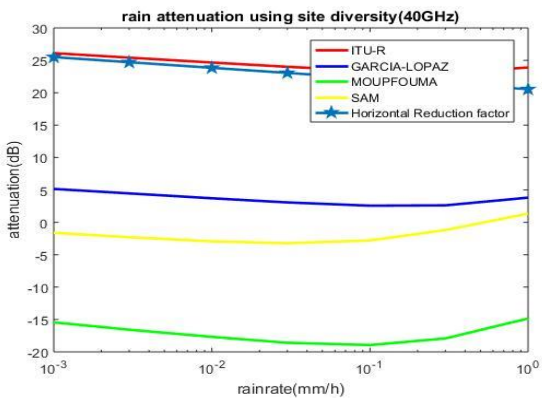

Fig:8 Rain attenuation at 40GHz using site diversity technique

From figs 5, 6, 7 & 8, it can be observed that, using site diversity technique the attenuation value is less compared with the plots from figs 1, 2, 3, & 4.

VI. CONCLUSION

This paper presented a comparison between 5 different models to predict the rain attenuation. The best performing model is Moupfouma model where attenuation is less compared to other models. Three successive year's data in Andhra Pradesh is considered. As frequency increases rain attenuation also increases. This can be reduced by choosing various diversity methods. Site diversity is the best method to be employed. Moupfouma, SAM, ITUR, HAVRF and Garcia-Lopez models are observed for various frequencies. If the frequency increase then the attenuation increasing with the frequency. Compared to the ITU-R model, the Moupfouma model offered a great deal of disadvantage for various frequencies. The SAM model role is roughly approximate to about 10GHz frequencies. All the five attenuation prediction models can be used to apply site diversity technique to reduce the value of attenuation, it will be reduce the impact of attenuation on microwave signal. The attenuation value is successfully reduced by applying site diversity technique to the prediction models. However, only a three-year rainfall rate can be considered for good results require more data to be monitored and more research is needed to reduce the high rainfall.

REFERENCES

1. A.Usha, G. Karunakar. "Performance analysis of rain attenuation for 2 GHz and 10 GHz using different models for satellite applications", 2018 Conference on Signal Processing And Communication Engineering Systems (SPACES), 2018.
2. RECOMMENDATION ITU-R P.618-13,Propagation data and prediction methods required for the design of Earth-space telecommunication systems.
3. F.A.Semire1, R.Mohmad-Mokhtar1, W.Ismail1, N. Mohamad1, and J.S.Mandeep," Modeling of rain attenuation and site diversity predictions for tropical regions" 17 March 2015.
4. Ch. Srinivasa Rao and M. Sridhar, Padma Raju "Estimation of Rain Attenuation based on ITU-R Model in Guntur (A.P), India", ACEEE International Journal on Communications, Vol. 03, No. 02, Nov 2012.
5. JS Madeep, "Slant path rain attenuation comparison of prediction models for satellite applications in Malaysia", J.Geoophys res 114, 2009.
6. R.Bhattacharya,R.Guha,S.DebBarman,R.Das and AB.Bhattacharya, "Variability of millimetrewave rain attenuation and rain rate prediction: A survey", Indian Journal of Radio & Space Physics Vol. 36, August 2007, pp. 325-344.
7. Recommendation ITU-R P.838-3 "Specific Attenuation Model for Rain for Use in Prediction Methods," 2005."
8. K.I.Timothy, E.B.L.Chooand J.T.Ong "Raindrop Size Distribution Using Method of Moments for Terrestrial and Satellite Communication Applications in Singapore", IEEE Transactions on Antennas and Propagation, Vol. 15, No. 10 October 2002.
9. G.Eason,I.N.Sneddon and B.Noble,"On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955.
10. C.P.Bean and I.S.Jacobs, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

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11. R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
12. Y.Yorozu,Y.Tagawa,M.Hirano and K.Oka "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
13. Recommendation ITU-R P.837-6 "Characteristics of precipitation for propagation modelling
14. J. J. Biebuma, B.O.Omijeh and J. U. Azegba, " Reducing Propagation Losses in Ku-Band Satellite Communication Using ITUR Model" , International Journal of Engineering Innovation & Research Volume 3, Issue 6, ISSN: 2277 – 5668.
15. R.Olsen,D.Hodge and D. Rogers "The aRb Relation in the Calculation of Rain Attenuation", IEEE Transaction Antennas Propagation. Vol. 26 (2), 1978.

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