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Microwave Attenuation Studies Impacted by Rain for Communication Links Operatingat Tropical Region: A Survey

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Abstract: This paper reviews the literature on attenuation of microwave due to rain rate predictions methods to analyze performance of the various systems proposed by different researchers at different parts of globe under varying meteorological and topographical conditions, situations with an emphasis on the observation reports made in the tropics, particularly in the Indian subcontinent. In this comprehensive review, besides considering the various features related to rain rate, the various methods proposed for prediction of rain attenuation have been examined and there by a comparison of those predictions methods are made.

Keywords*: Rain Attenuation, Satellite communication, Tropical region, Uttarakhand, Microwave signals.*

INTRODUCTION

Larger number of users, especially mobile users, has resulted in network planners increasing system capacity by locating transmission antennas at heights lower than surrounding trees and buildings [Graham, 1998]. Propagation algorithms that determine path loss and signal coverage are critical for successful wireless network planning and deployment. Radio wave propagation is a complex phenomenon. International regulations for microwave communication are based on set of proposed propagation models. Such models are developed by making physical and statistical analyses of collected data. The more we become rich in understanding of different phenomena involved in atmosphere causes attenuation, the more we can improve our models. There are many models for frequencies above 1 GHz can be found in literature. Rain plays a significant role in the undesired absorption of microwave, millimetre and centimeter wave propagation in the lower atmosphere. Besides rain, other major contributors are water vapour, liquid water clouds and fog. Such absorptions cause variations in the signal strengths. Attenuation value exceeded less than 2% of the year is due to rain or cloud except at 22 GHz water vapour absorption line and 60 GHz oxygen line. The model cloud gives attenuation comparable to rain at 2% of the year. At smaller percentages, rain is considered as the sole cause of attenuation to the communication system designer.

REVIEW OF PAST MODELS

In the past, several theoretical and experimental studies were made in respect of rain attenuation to obtain better service reliability in communication.

R K Crane [1] theoretically calculated attenuation for a known rainfall intensity along a path. During 1980 and onwards, prediction techniques for statistical estimation of attenuation probability for a particular path have been studied. Two approaches are made − one based on the use of large number of attenuation statistics at different frequencies, locations and path geometries and the other based on the synthesis of attenuation values from meteorological data. Latter approach is of great interest in modelling since a large number of data are available. There is no established theory of statistical variations of rainfall intensity, specific attenuation and attenuation along a path which are linked with each other in a complex manner. Rice and Holmberg [2], Lee [3] and Dutton and Dougherty [4] carried out statistical analysis of U.S. National Weather Service rain accumulation data and provided an estimate of year-to-year variations of rain rate distribution. Rain shows prominent spatial and temporal variation along a horizontal path, which prompts statistical estimation of instantaneous rain rate profile along the path. Several workers have proposed different models for calculation of attenuation along a path. Most of the models were developed using point rain rate and path attenuation measurements.

M L Meeks edited R K Crane Model [5] and proposed a paper entitled Refraction effect in the natural atmosphere in method of experimental physics, in his work Model rains storms have also been developed from weather radar data analysis to convert point rainfall statistics to path attenuation estimates . A very useful new technique, viz., 'observation of phase delay from GPS satellites' has emerged; it allows continuous monitoring of atmospheric water vapour content along a

slant path using millimetrewave radio propagation which was later followed by many researchers [6-11]. Water vapour, rain, cloud and oxygen attenuate radio waves very significantly. Attenuation due to water vapour along earth-space radio links increase prominently above 50 GHz and becomes higher than the peak absorption found at 22.235 GHz water vapour resonance line [12]. Moreover, oxygen, cloud and rain (especially, light rain) play a very important role

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on propagation above 50 GHz. Water vapour contributes to both attenuation and troposphere scintillation on earth-space paths [13]. Later in 1990 E Salonne*et al.* [14] studied propagation phenomena for low availabilities and published a report; he also proposed a relation that has been established between the occurrence of water vapour and cloud attenuation. Due to continuous presence of water vapour in the atmosphere and a greater occurrence rate of cloud than rain, these two factors need to be properly assessed.O T Davies *et al.* [15] worked on GPS Phase delay measurement technique for the calibration and analysis in millimeter wave radio propagation studies, which was published in IEEE in 1990 Using GPS technique, a comparison of attenuation has been made between the radiosonde and radiometer data which was then to support millimetrewave propagation in the study of attenuation. Lastly, a suitable model is needed for predicting the attenuation on a slant path with the variation of rain intensity.Below 60 GHz, the attenuation due to snow or ice is very small and hence neglected concluded by J R Joss *et al.* [16]. Liquid rain drop is the only cause of attenuation. Studies on the variation of attenuation with height show that major attenuation occurs below the height of the bright band (0˚C isotherm); this fact is also supported from comparisons between radar based attenuation prediction and simultaneous path attenuation measurements by K S McCormick *et al.* [17] & J Goldhirsh [18]. J Goldhrish*et al*. [19-20] in his experiments and work also concluded that The rain intensity, on the average, does not vary with height between the surface and the base of the bright band as evident from weather radar data, he did many experiments for earth satellite rain modelling and provided useful models and methods for rain attenuation using radar which were tested against 28 GHz COMSTAR beacon signal. This leads one to model the specific attenuation as constant from the surface up to a height near 0˚C isotherm level which also needs to be estimated statistically. An attenuation prediction model should contain estimates of expected year-to-year and station-to-station variation and also expected attenuation at the same exceedence probability. A model on such estimates has been developed by R K Crane [21] predicting the effects of rain on satellite communication system. The attenuation was compared between predictions from model and available attenuation observations made on a number of propagation paths and obtained agreement within expected uncertainty. The growing demand of communication services has congested the currently available radio spectrum to such an extent that a need has been felt for larger bandwidth and new frequency band above 20 GHz is being explored.

However, the rain attenuates the upper spectrum and frequencies suffer strong impairment as the rain drop diameter approaches the size of operating wavelength. In tropical countries like India, a great diversity of climatic conditions has been witnessed in the recent past and a search is on to find out a prediction model, useful for all ranges of rain fall rate. Another part of rain scatter process is the attenuation of signal by rain along the scatter path.

Way back in 1947 J W Ryde [22] presented a rain attenuation model, he worked on the attenuation caused by rain and his worked was also focused on the radar echoes produced at centimeter wavelengths by various meteorological factor like rain , cloud , air, temperature in radio wave propagation and its impact on it. After two decades R G Medhurst [23] published a revised model of J W Ryde [22] and he concluded that *"… (the) agreement is not entirely satisfactory; there is a tendency for the measured attenuations to exceed the maximum possible levels predicted by the theory"*. A decade later, R K Crane [24] looked afresh at the model predictions and compared them with the measured values taking the data available to R G Medhurst [23] and new data published after that. He found an average matching between model predictions and measurements on which basis he reviewed the attenuation due to rain in the signals.A B Bhattacharya et al [25-27] worked on the Indian stations to measure the estimated rain attenuation; they also proposed the effect of rate of decay of rain path profile on microwave and studied the basis relation between the attenuation and atmosphere for water vapour measurement in India. Initially, the models were physical observation based, but with after the availability of attenuation statistics such models were adjusted. Today, enough data are available for standards models. However, the practical methods, which are adopted to measure the attenuation do not give a reliable model and compels one to turn back to the models that are physical in nature. Development and evaluation of models require a method to control the quality of data observation in the model [25-27].

The ITU-R gathers round the clock global data, which measures attenuation. R K Crane [28] used such data & did a comparative evaluation of several theoretical and practical rain attenuation model and noticed that the statistical deviation of attenuation from model predictions were log-normal and the parameters used in log normal process practically did not change significantly for different models. The ITU-R (CCIR) recommended models did show the smallest deviations.

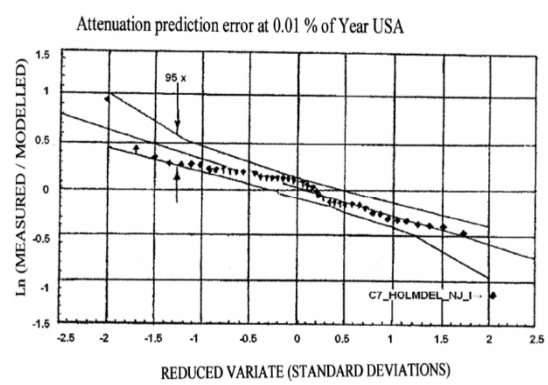

Fig. 1: Cumulative distribution of attenuation prediction for all observation in the CCIR data bank from USA (after Crane, 1996)

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The Deviations of observations from USA in the CCIR database were analyzed for a physically based model by R K Crane [29]. Figure 1 shows the cumulative distribution function (CDF) for log ratio of measured and modeled attenuation at 0.01% of a year. As the statistical distribution for path-to-path variation is log-normal, the log-normal hypothesis is correct. In order to display all the observation on a single graph, the attenuation predictions models were used to normalize the data. The same general results are valid for a different prediction model. Only the basis value changes, but the slopes of best fit curve to the deviation remain unchanged.

A Y Abdulrahman*et al.* [30][31-34] published several article, research paper, short latter, and has carried out many research experiments related to prediction and comparison of rain attenuation and ITU-R in Malaysia and Nigeria. On experimental and theoretical basis he did many predictions for microwave signal of terrestrial location. His main work includes radio propagation and rain attenuation studies especially in the tropic. Currently working on development of a transformation model for inverting terrestrial rain attenuation data for satellite application at Ku-band in tropical regions. He published and co author many papers related to rain attenuation issues in tropical regions and antenna design measurement. In his research work he presented the experimental results of rain rate and rain attenuation measurement on six terrestrial microwave links in tropical Malaysia [33]. Results were compared with ITU-R method and other existing rain attenuation prediction models. He had focused mainly on ITU-R prediction methods, which underestimate the measured rain attenuation, more especially at extremely higher rain rates. The relationship between ITU-R prediction errors and rainfall rates were studied and points out that there are mainly variation in ITU-R and real models [32].He also proposed an improved ITU-R rain attenuation prediction model over terrestrial microwave links in tropical region [30]. On CD basis he proposed the model which offers a better extrapolation approach for determining the values of rain attenuation at different exceedance probability from the measurement attenuation at 0.01% of time. He derived new set of numerical coefficient to improve the rain attenuation CD prediction in Malaysia tropical climate. He also validate the model from five Brazilian and seven Nigerian tropical locations. In his experiments his methods seems to provide a significant improvement over the current extrapolation method adopted by ITU-R P530.14 for prediction of rain attenuation CD over tropical regions [31]. In his work he concluded that proposed approach seems to provide better and more reliable alternative to the ITU-R method in tropical Malaysia, and probably other tropical climates, regardless of links operating frequencies and polarizations.

Also seems like ITU-R predictions error are tolerable at lower rain rates and lower frequencies. One of the reason was given for the difference might be because the 0.01% rain rate recommended by ITU-R P 837-5 is smaller compared to the actual measured value. He also demonstrated in his work that the the deviation could be modeled as a function of rain rate, and the regression coefficients depends on microwave links under study [34].

ITU-R PREDICTION OF RAINFALL OVER TROPICAL REGION

In tropical countries communication for higher frequencies are distributed due to high rain rate. Rain strongly attenuates the radio waves above 10 GHz which is a main impediment to satellite link performance [35].

A B Bhattacharya *et al.* [26] Studies the variations of rainfall pattern which were helpful for predicting propagation conditions. Distribution of rain attenuation at 11.7 GHz and 13.4 GHz for 56˚ elevation angle over Delhi showed that CCIR model underestimates the attenuation over India. It is also found by F Moupfouma [36] that excess attenuation due to rainfall above a certain threshold frequencies limits the LOS links and he in his research work mentioned that there is a need to improve the rain attenuation prediction model for terrestrial microwave links on which basis he provided many new steps and results.G H Bryant *et al.* [37] worked on the rain cell diameters. His study reveals that Deterioration of a communication link at 13 GHz in monsoon month revealed that the communication link did not serve the purpose 5% of time. Full Communication link can be achieved during monsoon months if an extra gain of 12-15 dB is provided to the transmitting system. The attenuation is found to be 0.5 dB/km at 22.235 GHz during monsoon months.

According to ITU-R (CCIR) rain climatic zones have been designed following the characteristics of precipitation of path propagation modeling [38]. Prediction of path attenuation by ITU-R underestimates the radio metrically derived cumulative distributions (CDs) of path attenuation, in general. Also the ITU-R procedure may not match well with the rainfall rate characteristics. The model only predicts rain induced attenuation. Figure 3 shows total attenuation statistical for measured annual, worst month and predicted (ITU-R method) cumulative statistics. It needs knowledge of the rain rate exceeded 0.01% of the time as measured using a gauge with one minute integration of time. These factors contribute to overestimation of attenuation by ITU-R model. Other factors may also be responsible for the difference between the measured and predicted attenuations.

K C Allen [39] points out that at EHF there is a range of more than a factor of 2 in specific attenuation for different drop size distributions used by Olsen *et al.* and a range of a factor of 4 for the different climate regions used by E J Dutton *et al.* [40]. The resulting uncertainty is the most critical limitation to reliable prediction of EHF system availability. This would indicate that drop-size distributions dependent upon climate or type of rain will need to be developed to improve predictions of the cumulative distributions of EHF attenuation. For the geographical regions under consideration in this report (San Francisco and Los Angeles, California) the low rain rate

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distributions are applicable. In some sense, the L-PL distribution provides an upper bound on attenuation based on commonly used drop-size distributions for low rain rates (< 25 mm/hr) and was used for the link budget calculations provided in this report.

F Moupfouma [36] points out in his work that In tropical latitudes where rain rate is high, communication link at higher frequencies is a major problem. Severe attenuation and depolarization of radio waves occur above 10 GHz. For setting up of links above 10 GHz at places where rain plays havoc, study of meteorological variations of humidity and rainfall is essential for reliable communication. Most of the attenuation studies so far for earth space links were confined mostly to the temperate regions of the world. However, very few measurements have been carried out in tropical region like India, Singapore, Brazil where rain characteristics (both Horizontal and vertical rain structure) are different from those of temperate climate.

In India, experiments were conducted at 20/30 GHz for LOS link distance of 6 km for prediction of horizontal characteristics of rain attenuation [41]. Similarly radiometeter were used at the same frequency for vertical characteristics of rain and rain height for prediction of slant path attenuation.

F Fabry*at al* [42] worked for the long term and observed the melting layer of precipititation and interpreted them, also points out that tremendous use of satellites in telecommunication demands further study of attenuation in the tropics where rain plays major role compared to other hydrometeors. Since the nature of precipitation in the temperate regions varies widely from that at the tropics, the

system design of one place will both be suitable for the other.

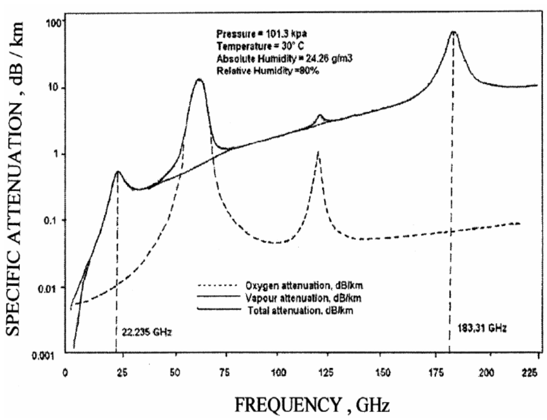

Fig. 2: Electromagnetic wave attenuation profile due to water vapour and oxygen as a function of frequency in the millimeter wave band (after Karmakeret. Al. 2002)

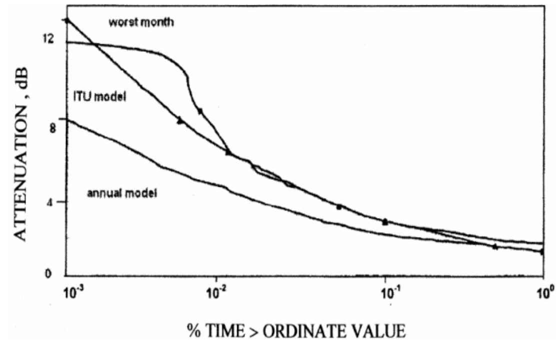

Fig.3: Cumulative attenuation statistics (after ITU-R Recommendation, 1992)

The causes which make system design different at two places are:

1. Rain drop size distribution which is usually larger in the tropics.
2. 0˚C isotherm height at the tropics is greater than that at temperate regions.
3. The lack of reliable rain study at the tropics; even the recent ITU-R recommendations for rain attenuation measurement at the tropics failed to give satisfactory results [43].

For a reliable prediction of rain attenuation, rainfall characteristics of a particular region are to be investigated properly for system design. Two constraints are there for such investigation – one is the lack of availability of geographical rain rate probability in the tropics, and the other is the lack of a valid model for estimation of rain attenuation in the tropics. Hence, attenuation is directly measured from satellites and margins for the future satellite systems are estimated. Predictions models of rain attenuation are available, but those are based upon the results obtained mainly in temperate climates.

The prediction model of rain attenuation developed by Verma and Jha [44] based on the experiments conducted in India are available for communication system designers for providing appropriate fade margin for reliable communication above 10 GHz; otherwise the communication system designed, based on rain attenuation data of temperate climate can provide outage of radio signals leading to link failure for higher rain rate as experienced in Singapore by Singapore Telecommunication, which lead to the detailed study of rain attenuation. Raina and Uppal[45] have also collected some data from radiometric studies over New Delhi, although these are not enough for a good understanding of propagation mechanism in the tropics as concluded by the S V B Rao*et al*. [46].

R L Olsen *et al.* [47] provided the relation between attenuation and rain fall rate for prediction of rain attenuation, this model was defined as the specific attenuation model and for engineering applications, the specific attenuation and phase shift are expressed by a power law relationship given by

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$$Attenuation = aR^b \tag{1}$$

Values of parameters *a* and *b* are available for a widespread rain which was also used by R K Crane [48] for prediction of attenuation by rain for a wide range of frequencies. Mie calculations of spherical raindrops were applied to get the values of a and b and hence do not differentiate between vertical and horizontal polarization. B N Harden *et al.* [49] and F Fedi [50]used log-normal drop size distribution to obtain the values *a* and*b* for spherical raindrops. The specific rain attenuation has been evaluated based on rain drop size data collected from India during 1989 by Verma and Jha [51]. All such calculations give the value of specific attenuation only. In case of depolarization effect, values of parameters *a* and*b* for both specific attenuation and specific phase shift are required.

The relationship between the rain-rates for two different integration times can be obtained by using power law [47],

$$R_t = aR_T^b \tag{2}$$

Where R is the rain intensity in mm/hr, t is the integration time at which rain rate is calculated, T the integration time at which rain rate is available and a, b are parameters which depend on the frequency and microphysical properties of rain.

A B Bhattacharya *et al.* [52] by Using 10s and 13 min integration times empirically tested the power law which comes out as:

$$R_{10s} = 2.567R_{15\,min}^{0.852} \tag{3}$$

Simple power law and two segment power law fit for a particular phase shift. In case of shower and thunderstorms, such phase shift is a significant for communication studied over a limited range of rain and hence a simple power law shift is enough. R L Olsen [47] calculated specific attenuation using Laws and Parson distribution for spherical drop at 0˚C and 10˚C. They observed the horizontal and vertical polarization results averaged at 10˚C. Moreover, with the increase in frequency, parameters *a* and *b* may become insensitive to the temperature.

Adel A Ali *et al.* [53] proposed rain attenuation & Rain Map For Radio-wave Propagation In Saudi Arabia (1986). He also mentioned that Performance of radio wireless communication system is depend on the time which link is available to us and for the time for link is out of service either because of equipment failure or propagation condition, In 1986 Adel A. Ali Mohammad published his paper and developed a rain map for radio propagation in Saudi Arabia based on 18-year rainfall data for all region of Saudi Arabia. In his work he mention that CCIR (Consultative Committee on International Radio) divided the entire globe in 5 different rain climates zones which represent rain climates zone of those found within United States (Terrestrial region) but underestimate the more intense rain rate region which comes in the west tropical regions of Africa, South America, India [54], and Indonesia or the much less intense region found in Arctic. For the communication purpose globe is divided into 8 rain climate region to represent the variation in rain rate and now in 15, but United States is still spanned by the 5 regions and hence this classification still does not reflect the real cumulative distribution of rainfall rate for tropical region, while developing rain map he also concluded that the rainfall rate varies from region to region within country and hence a regional rain map has to be developed to enable accurate radio link design at millimetric wave lengths, where attenuation due to rain is major source of propagation outage.

J.S. Marshall and W. Mck. Palmer (McGill University, Montreal), “Shorter Contributions the Distribution of Raindrops with size,” Shorter Contribution, Journal of Metrology, pp. 165-166, Vol-5, August 1948. Empirical study on the rain DSD model for Rain Attenuation Calculations: Natural rain drop size distribution is highly variable in different climatic zones and they are modeled using distributions like exponential, gamma, lognormal, and weibull. In this paper, the extended generalized gamma distribution is introduced to represent the rain drop size distribution based on the measurement performed in Chungnam National University. He concluded that the lognormal distribution is most adequate than other distributions and also compared the measured data at 40 GHz with calculated data using DSD.

J Joss *et al.* [55] worked on rain drop size distribution and sampling errors. Stated that Rain DSD can be calculated by many different techniques, generally for practical ease path loss exponential model is used which is for smaller distance. In this paper the author uses the same technique, as derivation is based on the assumption that the distribution of raindrop size follows a negative exponential law. He concluded that a large sample is necessary to get a good estimate of rainfall rate and attenuation level. Mathematical expression for this modal is $A = aR^b$ where A is the attenuation, a and b are the constants and R is rainfall rate per hour. A is measures in mm^6m^{-3} which shows the considerable variations, even during the same rainfall. This paper gives a rough estimate of standard deviation of quantities R and A due to limited sample size.

C L Ruthroff[56] designed the model for rain attenuation and radio path. While in his published research article he mentioned that Attenuation due to rain fall mostly affect the frequencies greater than 10 GHz, heavy rainfall on a radio path absorbs and scatters power transmitted at these frequencies and causes a large fading of received signals. Rain attenuation is so serve that for some applications transmission path must b restricted for few kilometers which cause increase in number of repeaters and hence cost increases, so to maximize the path length, the outage due to rain must be predicted. This paper describes the application of rain attenuation theory of Rade and Ryde to the design of radio systems; he concluded that upper bound on outage time due to rain attenuation can be computed from a measured point of rain rate distribution.

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Evolution of Raindrop size distribution by coalescence, Breakup, and evaporation theory and observations was presented by Zailiang Hu *et al.* [57]. The evolution of rain DSD by coalescence, collisional breakup, and evaporation is studied using the low and list parameterization for collisions. In this paper work the author consider two basic model for development of rain DSD, spatially homogeneous, time-dependent model and ID (vertical) time dependent model. Governing equations for the drop size distribution, balance equations for rain water content and rainfall rate and scaling relationship is presented in this paper. He compare his calculated drop size distribution with observed raindrop size distribution, found that average observed raindrop size distribution in heavy rain tend to be parallel to each other strongly supporting the view that the distribution were shaped by collosional processes (perhaps evaporation) and were in equilibrium and concluded that the future observation of rain drop size distribution in heavy rain be performed over short intervals of time and that adequate sampling be obtain by increasing sampling area rather than sampling time.

Guifu Zhang *et al.* [58-59] gives A Method for Estimating Rain Rate and Drop Size Distribution from Polari metric Radar Measurements. Author proposed and demonstrates a method for retrieving DSD parameters for calculating rain rate and the characteristic particle size by using Polari metric radar because of its high sensitivity to the shape, size and orientation of rain which was first proposed for rain estimation by Seliga and Bringi in 1976. DSD is assumed to be a Gamma distribution and this method shows improvement over the existing models and techniques because it can retrieve all three parameters of the Gamma distributions. Deficiency of work: The constrained relation used in this paper was derived from disdrometer observations taken from Florida rain events. This relation may change for different locations or seasons, in which case the coefficient might have to be adjusted. DSD measurements have shown that exponential distribution does not capture "instantaneous" rain DSDs and hence a more general method is needed. In 1983 Ulbrich suggest gamma distribution for representing rain DSD which can be mathematically expressed as,

$$n(D) = NoD^{\mu}\exp(\wedge D). \qquad (4)$$

In a rain drop size distribution the three parameter (N_0, μ, $\wedge$) of gamma distribution play an important role. Here μ and $\wedge$ correspond to the shape and slope of the DSD. In this paper, detailed analyses of error propagation from moment estimated gamma DSD parameters were performed. Errors in moment estimators do cause correlations among the estimated DSD parameters and cause a linear relation between estimators μ and$\wedge$. However, the slope and intercept of the error-induced relation depend on the expected values μ and $\wedge$and it differs from the $\mu - \wedge$relation derived from disdrometer measurements. Relation improves retrievals of rain parameters from a pair of remote measurements such as reflectivity and differential reflectivity or attenuation, and it reduces the bias and standard error in retrieved rain parameters [59].

NazarElfadil, Zia Nadirl*et al.*[60] performed the experiments on Malaysia lication mentioning and pointing out the results also concluded that ITU-R model was developed from propagation measurement performed at UHF, its proposed model for prediction of rain attenuation gives a good estimation for the microwave propagation loss caused by rain for temperature region but it underestimate the rain attenuation prediction for the tropical region. Because of rain, fog, smoke water vapor and oxygen in lower atmosphere the radio link (RF) can extremely effected for line of sight propagation and can produce extremely significant effect in energy absorption. For computing rain attenuation data MATLAB prediction program 'Rainsoft.m' is used, he also compared the two model ITU-R and Global crane model with his data for Malaysia and concluded and recommended the ITU-R prediction model of rain attenuation for communication link design in Malaysia because of 99.99% of link availability with respect to Global Crane prediction model.

A B Bhattaachary*et al.* [61] did a survey pointing out all expedition of the rainfall models and the reason. This was a review paper, which analyze the performance of the various systems performance of the various systems proposed by different workers at different parts of the globe under varying metrological conditions with an emphasis on the observational reports made in tropics, particularly in the Indian subcontinent, and also examined and comparison of those prediction method is made, and scope for the future investigation have been critically focused.

Prediction of Electromagnetic Waves Attenuation due to Rain in the Localities of Lithuania by M Tamosiunaite*et al.* [62]. Author mentioned that Prediction of rain attenuation can be grouped into two types: the physical (exact) models and the empirical ones. In this paper work the author has developed a rain map for the Lithuanian, rainfall rate values estimated rainfall from 0.25 mm/h up to 150 mm/h between the years 1999 to 2004. he compare the microwave attenuation due to rainfall data of long and short duration, and also mention the importance of integration time of rainfall measurement and analyze the rainfall data measured in Lithuanian weather stations starting from 2003 to 2007, he also concluded that the measure and obtain value of attenuation due to rain is 2 times higher than the ITU-R value.

Microwave Attenuation and Prediction of Rain Outage for Wireless Networks in Pakistan's Tropical Region by UzzmaSiddiquie*et al.* [63] (2011): As compared to other countries, microwave attenuation due to rain fall in tropical region has not been very widely studied yet. In this paper experimental results are presented for the Pakistan region over line of sight microwave communication link and rainfall rate and attenuation caused by rain is compared. On the basis of these details a rain outage prediction model is proposed which not only predicts microwave link performance but will also be useful in

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calculating the link degradation due to interface issues. This paper also concluded that rainfall rain, microwave propagation characteristics and outage prediction in Pakistan differ from ITU-R and CCIR recommendations.

Computation of Rain Attenuation in Tropical Region with Multiple Scattering and Multiple Absorption Effects Using Exponential Drop Size Distribution, Fikih F. Amrullah*et al.* [64] (2011): In this paper, raindrop was modeled using exponential raindrop size distribution and computed with multiple scattering and multiple absorption effect previously derived and assumed that raindrop shape is spherical and has dielectric constant following the Double Debye Model as rain attenuation causes scattering and absorption of electromagnetic waves and could be a significant problem in radio propagation, especially in tropical region which has high rainfall rate.. Based on the analysis, rain attenuation effects become significant for frequencies above 10 GHz and reach the peak at about 125 GHz.

Measurements of Rain Drop size Distribution from radar Reflectivity and Associated Rain Attenuation of Radio Waves research article AB Bhattacharya *et al.* [65](2011): In this paper radar measurements of rainfall at different climatologically conditions have been taken into account emphasizing rain rate and associated radar reflectivity, it is observed from the analysis that the reflectivity measurement is being consistent at high rain intensities, from his analysis he concluded that the most probable rain drop size vary exponentially with radar reflectivity and also with rain rate which has the similar kind of variation as in the theoretical model for tropical zones. He has taken frequencies 11 to 14 GHz separatelyand 0 degree C isotherm height as 5.0 Km the effective rain height is evaluated.

Analysis of Cumulative Distribution Function of 2-year Rainfall Measurements in Ogbomoso, Nigeri (2012): Attenuation due to rain has long been known to be major atmospheric effect that limits the path length over which reliable radio communication systems can be established, to analysis and compare the data with the ITU-R 2 year rainfall data at Ogbomosho station between the periods of 2009 and 2010 have been used. Here a and b are slightly different from the ITU-R recommendation, Wireless communication system operating at frequency below 10 GHz are least affected by the rain, however at millimeter, high frequencies rain induced attenuation (due to absorption & scattering) is one of the principle factor that increase the over path loss, limit the coverage area and consequently degrade system performance for the terrestrial microwave point to point as well as satellite communication. In this paper author also concluded that different conversion factor are also required for different location even within the same climatic region and rainfall pattern in the tropic region and all over the world is changing rapidly because of global warming and hence it need attention, efforts and appropriate action should be take so that its effect can be reduce on atmospheric conditions and consequently on environments and human [66].

ATTENUATION ABSORPTIONS AND SCATTERING

Gaseous absorption and emission of communication waves by the atmosphere were calculated by CCIR (International Radio Consultative Committee) employing radioactive transfer programme as described by J W Walters [67]. The role of atmospheric emission in communication and role of relationship between absorption and emission have been given by E K Smith [68]. The atmospheric emission (i.e brightness temperature) and attenuation model were discussed and comparisons with respect to measurements and other model were made.

At radio frequencies, scattering is insignificant and hence attenuation in the gaseous atmosphere will be absorption only.For Frequencies up to 340 GHz, the gaseous atmospheric emission ia a major source of external noise in the earth-space communication system [69]. Since NASA was interested in low noise receivers, attenuation was given on noise source also.

Earth's atmosphere (dry state) consisting of oxygen (20.946 %), nitrogen (78.084%) and argon (0.934%) all by volume and totaling to 99.964 % is well mixed at nearly 80 m height where dissociation of O_2 molecules to atomic oxygen takes place. Carbon dioxide accounts for the rest and mixes well in the atmosphere. However, water vapour is the main variable component in the atmosphere. The saturation vapour pressure is directly proportional to temperature. Centimeter and millimeter waves are absorbed chiefly by oxygen and water vapour. In fact, water vapour lines occur at 22.235 GHz, 183.31 GHz and 325.152 GHz. Tails at higher frequencies need lso to be considered; information's on these lines are given by McClatchey [70] Rothman and McClatchey [71] and Rothman [72-73]. Oxygen and water vapour absorption in the window region has a remarkable effect. Ozone has spectral lines in the microwave region, which are neglected to a first approximation. J W Waters [67] has discussed about stronger O_3 lines and those of other minor constituents.

The absorption coefficient which is a function of pressure, temperature and frequency can also be a function of earth's magnetic field in the upper atmosphere. Total absorption for a path through the atmosphere is given by:

$$A = \int_0^{\infty} \sum \gamma_i \, dl \qquad (5)$$

Where γ_i is the absorption co-efficient for the i-th gaseous constituent. In almost all communication purposes, two gaseous absorbers are taken – one for water vapour and the other for molecular oxygen. Thus, A is rewritten as,

$$A = \int_0^{\infty} (\gamma_0 + \gamma_\omega) \, dl = \int_0^{\infty} \gamma_{0,\omega} \, dl \qquad (6)$$

Where $\gamma_0$and γ_ω are the absorption coefficients for oxygen and water vapour, respectively, and $\gamma_{0.\omega}$ is their joint absorption coefficient. Since we know by thermodynamics equilibrium

(LTE) the emission from a gas must be equal to its absorption at each frequency. This leads to the earth's atmosphere to be LTE. Rayleigh-Jeans law states that brightness is proportional to temperature at radio frequencies.

DISCUSSION AND CONCLUSIONS

Sometimes, measurement and model development run simultaneously. Any departure from model prediction leads to a new thought about the process and consequent refinement of the experiment, when several propagation mechanisms are present in the iterative model, each one need to be iterated separately. After a model matures, the development process must continue to explore the estimation of variability and maintenance of data quality. Prasad [74] observed radiometric attenuation at 10˚ and 90˚ angles of elevation and compared their results with the attenuation predicted by other methods. They deduced rain heights using the empirical relation of CCIR [75] which is latitude dependent. They tested four CDFs and out of these only one showed good agreement with the, CCIR techniques. In case of 10˚ elevation angle, CCIR methods gave more deviation. Garcia- Lopex's method was well agreement for all the four cdfs followed by Moupfouma's technique. Moreover, Garcia-Lopez's method showed minimum r.m.s. variation (0.3834). Although cdf's tested were few in number, but still the study reveals that Gracia- Lopez's method is very much useful in predicting rain attenuation over the northern India. Calculations of attenuation with a great accuracy provided the cdfs of rain rate are available. The Plus pint of this method are that it is simple, easy computable and with large number of data the coefficients can be suitable changes according to regional needs. For calculation of attenuation at other percentage of time (0.01% and onwards), the scaling equation of CCIR [75] model is re-adjusted depending upon the attenuation values, which are observed experimentally. From the above study, one gets a choice for picking up rain attenuation prediction techniques over northern part of India and can carry out analysis with whatever database is available.

Performance of a dual polarized satellite system degraded above 10 GHz due to rain attenuation and ice depolarization. Although rain attenuation is common to both single and dual polarized systems by reducing the received signal power, but ice depolarization is unique to the latter. Depolarization is defined as the change in the state of polarization of transmitted signal [76]. Performance

Capability of the wireless communication systems has reached its zenith today. It has brought the whole world at the fingertips of the mankind, yet the communication systems have many shortcomings to overcome. There are lot of impediments which radiowaves suffer in its journey and thereby hampering reliable communication. In the Previous research article we have elaborate how rain impacted Microwave for Uttarakhand (India) region, and concluded that it is also possible to measure rainfall intensity by monitoring the signal strength with proper means and methods [77]. Researchers have solved several problems to obtain a faithful link but much more work is needed to be done and required in order to overcome all the problems and to use maximum efficiency of link.

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