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Rain rate intensity model for communication link design across the Indian region

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ABSTRACT

A study on rain statistical parameters such as one minute rain intensity, possible number of minute occurrences with respective percentage of time in a year has been evaluated for the purpose of communication link design at Ka, Q, V bands as well as at Free-Space Optical communication links (FSO). To understand possible outage period of a communication links due to rainfall and to investigate rainfall pattern, Automatic Weather Station (AWS) rainfall data is analysed due its ample presence across India. The climates of the examined AWS regions vary from desert to cold climate, heavy rainfall to variable rainfall regions, cyclone effective regions, mountain and coastal regions. In this way a complete and unbiased picture of the rainfall statistics for Indian region is evaluated. The analysed AWS data gives insight into yearly accumulated rainfall, maximum hourly accumulated rainfall, mean hourly accumulated rainfall, number of rainy days and number of rainy hours from 668 AWS locations. Using probability density function the one minute rainfall measurements at KL University is integrated with AWS measurements for estimating number of rain occurrences in terms of one minute rain intensity for annual rainfall accumulated between 100 mm and 5000 mm to give an insight into possible one minute accumulation pattern in an hour for comprehensive analysis of rainfall influence on a communication link for design engineers. So that low availability communications links at higher frequencies can be transformed into a reliable and economically feasible communication links for implementing High Throughput Services (HTS).

1. Introduction

The study of rain statistics is significant for designing a reliable, maximum availability and economically feasible communication link at Ka, Q, V bands as well as Free-space optical communication link at the wavelengths of 819 nm, 847 nm, 1064 nm and 1550 nm. At these wavelengths meteorological parameters like rain and cloud have maximum impact on link availability. Rain induced absorption and scattering are major factors for signal degradation which leads to loss of signal and affects the link margins directly. Anticipating possible one minute rainfall accumulation is essential to predict rain induced absorption, scattering on RF signal for designing a reliable and economically sustainable communication link (Sujimol et al., 2015).

Rainfall and its associated parameters are non-homogeneous in nature and tend to vary locally, regionally, climatically and temporally (year on year). The ITU-R recommends the use of one minute accumulated rainfall recordings in order to estimate the effect on the link (ITU-R Recommendation P.837-6, 2012). However, one minute accumulated rainfall recordings are not usually available for all regions. In order to fill the gap satellite communications researchers formulated models to predict such measures using parametric and non-parametric distribution models with available Meteorological Department (MetD) hourly or annual rainfall data (ITU-R Recommendation P.837-6, 2012; Singh and Saeed AIDweik, 2013; Mandeep, 2011). This process proved an effective way to predict and maintain link margin of the communication systems.

During the propagation campaigns of COST 205, COST 255, COST 280, ACTS, NAPEX, OPEX, OLYMPUS, ITALSAT F1 and CEPIT etc., (Aldo Paraboni, 2002; R.A. Harris, 2002) one minute rain rate intensity models were put forward and widely used across the world since then. Among them ITU-R Recomendation P.837-6 (2012) is used to establish link budget calculations. Other models which are widely used are Rice and Holmberg (1973); Segal

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(1986); Chebil and Rahman (1999); Crane (1980); Moupfouma and Martin (1995). All the above models are formulated using physical measurements and their performance at various climatical regions has been studied. Models are validated against rain measurements at their respective locations (Chun and Mandeep, 2013; Emiliani et al., 2010; Karasawa and Matsudo, 1991; Kilaru et al., 2014; Maitra and Chakravarty, 2005; Ojo and Falodun, 2012; Ojo and Owolawi, 2014; Restrepo et al., 2002). For effective modelling of rain rate intensity, rainfall is divided into stratiform < 10 mm/hr and convective rain > 10 mm/hr (Capsoni et al., 2009). Where rain measurements stations are not available, satellite rainfall data obtained from TRMM is used in order to predict one minute rainfall accumulation (Sulochana et al., 2014).

Although rain intensity models are successful in predicting possible rain intensity but none of the available models give expected intensity occurrences with respective number of minutes in a year. Estimation of rain intensity occurrences statistics is significant for designing a link with maximum availability and the information is vital and cannot be substituted mainly due to the non-homogeneous nature of rain. Rainfall measurements at specific climatical locations with one minute integration time are still important and give better picture of rainfall statistics than one minute rain intensity models. In a diverse region such as the Indian subcontinent which consists of temperate and tropical climates, its rainfall varies climatically as well as year on year.

2. Dataset

The rainfall data utilised for this study is obtained from three sources and integrated for evaluating yearly accumulated rainfall, hourly accumulated rainfall pattern, mean hourly accumulated rainfall, number of rainy days, number of rainy hours and one minute accumulation pattern in an hour across Indian region.

1. The AWS across India record hourly incremental accumulated rainfall (mm) using tipping bucket rain gauge with a magnet and reed switch and an error rate less than 1 mm of the overall recordings (Kumar et al., 2014) and was installed by Indian Space Research Organisation (ISRO) across India and the data is available through Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC). AWS were installed in 1120 locations across India out of which 668 AWS locations have recorded usable hourly accumulated rainfall data which is used for this study. In the evaluated data around 3% of the stations have recordings since 2006 and remaining since 2009. The locations chosen for the study are presented in Fig. 2.
2. The AWS data from MOSDAC is not been evaluated so far, to validate the recorded data it is compared with Indian Meteorological Department (IMD) grid data with resolution 0.5*0.5 and the validated AWS locations are presented in Fig. 2.
3. For designing communication link at Ka, Q, V and at FSO bands one minute rainfall accumulation patterns are vital. For that purpose OTT Pluvio rain gauge was installed at KL University it's a weight based rain gauge which logs accumulated rainfall with respective time period. It records minute, hourly and daily accumulation of rainfall data (OTT Pluvio Precipitation Gauge - Operating Instructions, 2014). The examined dataset is in between 2014 and 2015 with a total of 7768 one minute rainfall measurements.

In propagation studies for calculating signal attenuation due to rain, input parameter called rain intensity (mm/hr) is required. It is obtained from one minute rainfall measurements and the conversion is presented in Fig. 1. (Ofcom Report on Modelling of Rain Attenuation, 2008)

3. Methodology

The AWS data obtained through MOSDAC is processed through a custom written matlab programme to extract hourly incremental accumulated rainfall by eliminating other instrument readings. The data is further processed to obtain hourly accumulated rainfall by deducting two hourly consecutive data sets additionally programme computes averaged, maximum hourly accumulated rainfall, measured daily rainfall, measured monthly rainfall, number of rainy days in each month, number of monthly rain events and total yearly accumulated rainfall from the processed data for each AWS location.

The programme also computes number of measurements in a year, number of hourly measurements and number of recorded days for each AWS for evaluating data quality. AWS across India records 24 hourly measurements per day and 8760 hourly measurements in a year. Out of 1120 AWS locations only 668 AWS locations data was utilised for this study for having more than 80% of hourly recorded measurements.

As the AWS data not been evaluated so far, to validate recorded data it is compared with IMD grid data with resolution 0.5*0.5. The mean annual rainfall from IMD grid data covering same years as the AWS data set is validated against AWS locations and presented in Fig. 2. As one of the AWS is located at KL University that particular AWS data set is further compared with OTT Pluvio rain gauge recorded data.

The analysed one minute accumulation patterns in an hour from OTT Pluvio is integrated with AWS data using probability density function for estimating number of rain occurrences and rain intensity for annual rainfall accumulated between 100 mm and 5000 mm. The integrated data is presented in a mathematical model for improving communication link design across Indian region.

4. Results

In this section the AWS rainfall data from 668 locations and the OTT Pluvio rain gauge minute rainfall data were analysed and presented for improving communication link design. The AWS data was documented in case 1, case 2 and case 3 and the data set was presented in Figs. 3, 4, 5 and 6 and the related pattern is corresponded in a form of mathematical equations representing (1)–(6).

The one minute rainfall data from the measurement campaign using OTT Pluvio rain gauge was presented in Figs. 7, 8 and integrated with AWS data using probability density function for estimating probability of occurrences, rain intensity for respective annual accumulation between $100 \le x \le 5000$ mm. The related pattern for obtaining rain intensity is corresponded in mathematical Eq. (7) and the parameters are presented in Table 1 for an annual accumulation between $100 \le x \le 5000$ mm and the same can be obtained using matlab GUI software model which is attached with this paper.

Note: in all cases, 'x' is an input parameter representing annual accumulated rainfall between $100 \le x \le 5000$ mm.

Case 1: (*Outage time due to rain*)

In order to calculate possible outage time due to rain in communication links annual rainfall accumulation time is required. The AWS data presented in Fig. 3 and Fig. 4 gives possible number of rainy days and possible number of rainy hours for an annual rainfall accumulation between $100 \le x \le 5000$ mm. The AWS data in Fig. 3 and Fig. 4 is collected across Indian region. Due to ample number of locations the data is categorized into three modules