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Rain attenuation prediction during rain events in different climatic regions

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ABSTRACT

A rain attenuation prediction method has been applied to different climatic regions to test the validity of the model. The significant difference in rain rate and attenuation statistics for the tropical and temperate region needs to be considered in developing channel model to predict time series of rain attenuation for earth space communication links. Model parameters obtained for a tropical location has been successfully applied to predict time series of rain attenuation at other tropical locations. Separate model parameters are derived from the experimental data obtained at a temperate location and these are used to predict rain attenuation during rain events for other temperate locations showing the effectiveness of the technique.

1. Introduction

Due to the congestion at the lower frequency bands, the satellite communication systems are now operating at the higher frequency Ku or Ka bands (Ku or Ka). However in these bands, mainly above 10 GHz, rain events cause severe attenuation to the propagating signal along earth space communication link. If time series prediction of rain attenuation during rain events is possible, fade countermeasure techniques such as adaptive control of signal power, coding and data rate can be effectively implemented to mitigate this attenuation effect. Channel models in the form of time series generators of rain rate and attenuation have been developed previously (Alassur et al., 2004; Fontan et al., 2007; Heder and Bito, 2008; Carrie et al., 2011; Lemorton et al., 2007). So far, they have not been used to predict rain attenuation or rain rate during rain events at different points of time. There exist various short term rain attenuation prediction methods (Castanet, 2001; Gremont, 1997; Van de Kamp, 2002; Montera et al., 2008; Bolea-Alamanac et al., 2003), all of which predict a single attenuation value a short time before the actual occurrence, but not the time series of attenuation values for the entire rain event. The above mentioned models are validated on long term basis and not on event by event basis. In the present study, a channel model has been developed to predict time series of rain attenuation during the entire rain event.

This model is not only tested on long term basis but also event wise. In our earlier paper (Das and Maitra, 2012a, 2012b), the same method has been discussed for rain attenuation and rain rate prediction for experimental data obtained at Kolkata, a tropical location. However, the effectiveness of the methodology needs to be tested for any locations in the globe. In this paper, rain rate and attenuation statistics obtained at tropical and temperate regions are compared. From the measured data set, model parameters are developed separately for tropical and temperate regions which are being used to predict the time series of rain attenuation for both the regions.

2. Comparision between tropical and temperate region

Data sets from different sites in tropical region as well as in temperate region are taken to check the validity of our model. The details of the measurement links are given in (Maitra et al., 2007; Chakravarty and Mitra, 2010; Adhikari et al., 2011; Riva, 2004; Propagation data and prediction methods required for the design of Earth-space telecommunication systems, 2009; Sánchez-Lago et al., 2007) and also in Table 1 in a short form. To get proper comparison of attenuation statistics, for Spino d' Adda and Kolkata measurements are taken at the frequency 11.6 GHz and 11.172 GHz respectively. But to test the validity of the model in temperate region, at Spino d' adda, attenuation measurements are also taken at 18.7 GHz as the other station data are at frequencies very near

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Table 1
Parameters of the measurement links.

Site location	Country	Lattitude (°N)	Longitude (°E)	Elevation (deg)	Frequency (GHz)	Data used
Kolkata	India	22.57	88.48	63°	11.172	2007
Douala	Cameroon	4.05	9.7	47°	11.6	1987
Hongkong	China	22.2	114.2	20°	11.6	1981
Singapore	Singapore	1.3	103.9	41°	11.6	1980
Spino d' Adda	Italy	45.4	9.5	37.7°	11.6, 18.7	1994
Oberpfaffenhofen	Germany	48.08	11.28	27.6°	18.99	1994
Blacksburg	Virginia	37.2	279.5	45°	19	1979
Ottawa	California	45.34	284.1	21.185°	19	1997
Waltham	Massachusetts	42.4	288.78	38°	19	1979

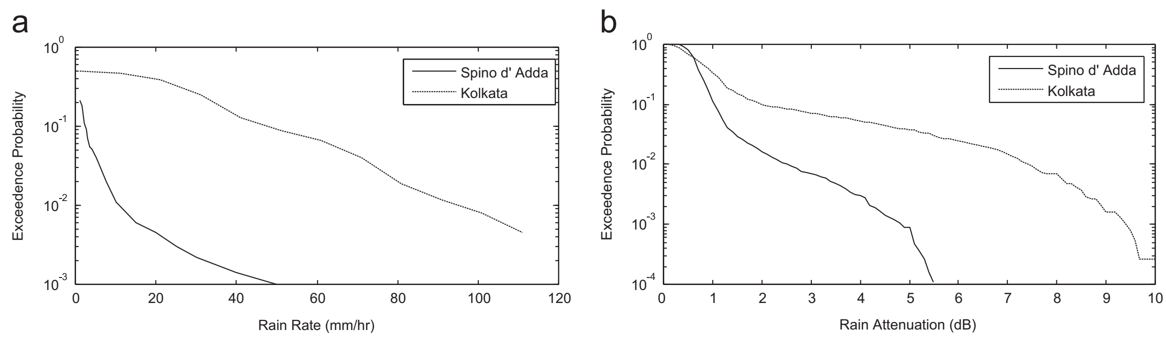

Fig. 1. Comparison between the cumulative distributions of measured (a) rain rate and (b) rain attenuation data at Spino d' Adda (1994) and Kolkata (2007).

Table 2
Coefficients of polynomial expressions for mean and standard deviation of conditional distributions of rain attenuation at 11.172 GHz for Kolkata.

Region	Segment	a_0/b_0	a_1/b_1	a_2/b_2
Tropical (Kolkata)	C	0.061/ .22	0.98/ .031	0.00073/ −.0026
	D	0.032/ .27	0.97/ .043	0.0017/ −.0036
	U	0.23/ .3	0.98/ .032	0.00066/ −.0033
	No segmentation	0.12/ .18	0.96/ .12	0.0021/ −.0093

to 18.7 GHz. This frequency (18.7 GHz) is also chosen to show the efficacy of our model at the high frequency range. All the recorded rain rate and attenuation data are passed through a raised square cosine filter with cutoff frequency 0.025 Hz to eliminate the scintillation effects and other fast fluctuations.

Fig. 1 gives the comparison of the yearly cumulative distributions of measured rain rate (a) and attenuation (b) data for Kolkata (2007) and Spino d' Adda (1994).The distributions for tropical region show higher occurrences of rain rate and attenuation values compared to temperate region. As the rain climatology is different in the two regions, separate model parameters are required for the temperate and tropical regions.

3. Rain attenuation predictor

The measured attenuation values are divided into three segments namely, constant (C), down (D) and up (U) segment according to the following criteria

$$\Delta(kT_s) = \begin{array}{lll} \text{C(constant)} & \text{if } \left|a(kT_s)\text{–}a((k-1)T_s)\right| & \le 1\text{dB} \\ \text{D(down)} & \text{if } a(kT_s)\text{–}a((k-1)T_s) & < -1\text{dB} \\ \text{U(up)} & \text{if } a(kT_s)\text{–}a((k-1)T_s) & > 1\text{dB} \end{array} \quad (1)$$

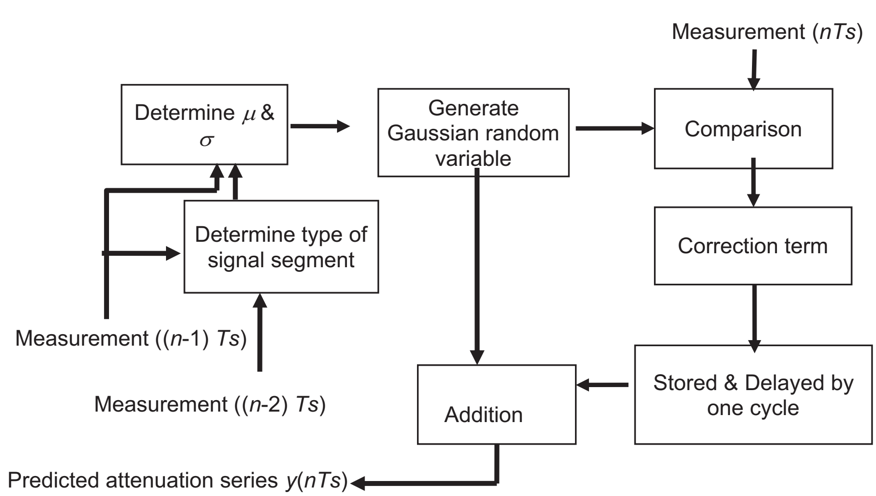

Fig. 2. Block diagram representation of time series rain attenuation predictor.