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Rain Attenuation over Terrestrial Microwave Links at 18 GHz as Compared with Prediction by ITU-R Model

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Abstract

Absorption of microwave radio frequency signal by atmospheric rain is prevalent at frequencies above 10 GHz. This paper presents the studies on rain attenuation at 18 GHz for 3.2 km experimental link between Khumdang (Korea Telecom, KT station) and Icheon (National Radio Research Agency, RRA station). The received signal data for rain attenuation and rain rate were collected at 10 second intervals over a three year periods from 2013 to 2015. Out of several models, the paper present discussion and comparison of ITU-R P.530-16 model, Moupfouma model, Da Silva Mello model along with suitable rain attenuation prediction method. The limitation of research lies on the experimental system that is set up in only one location, however, the preliminary results indicate the application of suitable 1-minute rain attenuation model for specific site. The method provides useful information for microwave engineers and researchers in making decision over the choice of most suitable rain attenuation prediction in terrestrial links.

Index Terms: ITU-R P.530-16, Microwave propagation, Rain attenuation

I. INTRODUCTION

The microwave and satellite links operating beyond 10 GHz is affected by the rain, which is considered as a prime factor for the degradation of the signal strength [1]. The rain attenuation is predicted from the shorter integration time of 1-minute rain rate values, where the local prediction models are studied in the South Korea that proposed the modified polynomial model [2-4]. Most of the prediction models applicable for the terrestrial links considered the path reduction factor, which features both path length and rain rate. Similarly, the effective path length is the intersection between the rain cell and propagation path, which is noticed to be smaller than the actual physical path length [5]. The comprehensive study of 1-minute rain rate statistics have been studied considering the measurement results from Korea Meteorological Agency and National Radio Research Agency [6]. Moreover, the rain attenuation has been studied in the satellite links over the South Korea region [7-10]. Additionally, the rain induced attenuation effect is considered for higher operating microwave links particularly, in 38 and 75 GHz [11]. The suitable prediction error margin is proposed against the ITU-R P.530-16 method [12]. For the purpose of this paper, three established attenuation models have been utilized for the prediction of rain attenuation which are ITU-R P.530-16 [13], Da Silva Mello et al. model [14] and Moupfouma's model [15]. The remainder of the paper is organized as follows: Section II depicts the selected techniques adopted for the analyses of rain attenuation in the microwave link. Section III shows the experimental set up. The proposed method is described in Section IV with numerical results and discussion. Finally,

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conclusions are provided in Section V.

II. RAIN ATTENUATION PREDICTION MODELS FOR TERRESTRIAL MICROWAVE LINK

The product of specific attenuation (dB/km) and the effective propagation path length (km) result in the rain attenuation over a terrestrial path. The effective path length depends on the link length and the horizontal distribution of the rain along the path. The attenuation induced by rain which is exceeded at *p* percent of time is given as,

$$A = \gamma_R \, d_{eff} = \gamma_R \, dr. \tag{1}$$

ITU-R P.838-3 [16] gives the method for the analyses of specific attenuation, γ_R (dB/km), from the rain rate R (mm/hr) exceeded at p percent of time, where the two quantities are related as,

$$\gamma_R = kR^{\alpha}, \tag{2}$$

where k and α relies on the frequency and polarization of the electromagnetic wave. These can be calculated by interpolation considering a logarithmic scale for k and linear for α. The frequency range is considered from 1 to 1,000 GHz. Similarly, the path reduction factor is r and d is the radio link path length in km for p time percentage.

A. ITU-R P.530-16

ITU-R P.530-16 [13] describes the method for the calculation of rain attenuation over the terrestrial LOS radio systems. This method relies on the calculation of path attenuation exceeded for 0.01% of the time, which is the product of specific attenuation, γ_R (dB/km) and effective path length, d_{eff}. The recommendation ITU-R P.838-3 [16] gives the specific attenuation γ_R. Additionally, effective path length, d_{eff}, depends on the product of actual path length, d and a distance factor, r. The power law is used to deduce the attenuation exceeded for other percentage of time from 0.001% to 1%, whose estimation of factor, r is given in the recommendation ITU-R P.530-16 [13]. This recommend-dation have been analyzed and tested in 18 GHz link under horizontal and vertical polarization.

B. Da Silva Mello Model

According to Da Silva Mello Model, equivalent rain cell can intercept the link at any position with equal probability which uses the full rainfall rate distribution as input for predicting the rain attenuation cumulative distribution and is given by [14]:

$$A = \gamma_R \, d_{eff} = k\,[R_{eff}(R,d)]^{\alpha} \left[\frac{1}{1+\left(\frac{d}{d_0(R)}\right)}\right] \times d, \tag{3}$$

where R_{eff} is the effective rain rate which is a function of, d in km, and rainfall rate, R. The expression for R_{eff} and equivalent rain cell diameter, d_0 are given by:

$$R_{eff}=1.763\, R^{\,0.753+(0.197/d)} \tag{4}$$

and

$$d_0 = 119\, R^{-0.244}. \tag{5}$$

The numerical coefficients in Eqs. (4) and (5) where obtained by multiple nonlinear regressions from the measured data available in the ITU-R databanks.

C. Moupfouma's Model

The space between the two ground stations, L, determines a terrestrial microwave link. As the first step, this model takes the rainfall rate value at 0.01% of the time for the determination of rain attenuation exceeded for the same percentage of time. The rain attenuation is defined as [15]:

$$A_{0.01}=kR_{0.01}^{\ \alpha} L_{eq}(R_{0.01}, L), \tag{6}$$

where $R_{0.01}$ and $A_{0.01}$ are the rainfall rate and path attenuation at 0.01% of time. L_{eq} is the propagation path length given as:

$$L_{eq}(R_{0.01}, L) = L \times exp\left(\frac{-R_{0.01}}{1+\zeta(L)\times R_{0.01}}\right), \tag{7}$$

where $\zeta(L)$ = -100 for any $L \leq 7$ km; and $\zeta(L)$ =[44.2/L]$^{0.78}$ for any $L > 7$ km.

Additionally, the occurrence of attenuation due to rain on a given microwave link are determined as:

$$P(A_{0.01} \geq a) = 0.01 \times \left(\frac{A_{0.01}+1}{a+1}\right)^{\phi(a)} \times exp(9.21 \times (1-(a/A_{0.01})) \times \eta(a)), \tag{8}$$

where

$$\phi(a) = \left(\frac{a}{A_{0.01}} - 1\right) \times ln\left(1 + \frac{a}{A_{0.01}}\right) \tag{9}$$

$\eta(a)$ is calculated using ITU-R database and is defined as:

$$\eta(a) = \frac{1}{1+2.75\times\left(\frac{a}{A_{0.01}}\right)^{0.8}}. \tag{10}$$

III. ANALYSES OF EXPERIMENTAL DATA

The microwave link of 18 GHz is set up at Icheon, South Korea where the link is set between Khumdang ($37^0$8'8.41"N $127^0$30'56.16"E, Korea Telecom, KT station) tower and Icheon (37⁰8'49.57"N 127⁰32'54.82"E, National Radio Research Agency, RRA station) tower, in 3.2 km separation distance, with the link availability of 99.95%. During the month of July and August, the city has relatively higher precipitation of above 300 mm. The detail description of the link is given in Table 1.

As shown in Table 1, the one antenna at Khumdang, KT Station tower is vertically polarized and out of two antennas at Icheon, RRA Station tower, one antenna is vertically polarized and another is horizontally polarized. The radome is used to cover the antenna which prevents the wetting condition. During no rain condition, the maximum signal strength for horizontal and vertical polarization are -52.34 dBm and -32.81 dBm, respectively. Similarly, rainfall rate data are measured via OTT Parsivel, a laser-based optical disdrometer for simultaneous measurement of particle size and velocity of all liquid and solid precipitation, for every 10 seconds interval over 3 years period. The 1-minute rain rate is derived from the method stated in [9] using the instantaneous rain rate values. OTT Parsivel is a laser sensor that produces a horizontal strip of light in which the emitter and receiver are integrated into a single protective housing. The measured signal output voltage changes whenever a hydrometeor falls through the laser beam anywhere within the measurement area. This will determine the particle size. In addition, to determine the particle speed, the duration of the signal is measured. A signal begins as soon as a precipitation particle enters the light strip and ends when it has completely left the light strip. After determining these two quantities, Parsivel disdrometers bin measured particles into particle counts per velocity and diameter class.

There are 32 velocity classes and 32 diameter classes, with varying widths. Parsivel determines the rain rate from the classification of precipitation particles. The corresponding software ASDO monitors the outdoor precipitation event to comfortable indoor evaluation with windows performance. The sensor on OTT Parsivel transmits all data to a PC through RS485 interface which are stored in a powerful database and can be retrieved by a browser with related date and time. An automatic heating system prevents ice buildup on the sensor heads. The heating system is adjusted by the temperature sensor which measures the temperature each second. The simultaneous measurement of precipitation and rain attenuation data was recorded at 10 seconds interval. The schematic diagram for system set up is shown in Fig. 1.

As depicted in Fig. 1, the front-fed parabolic antenna is mounted on 35 m height Khumdang, KT Station tower. The outdoor unit is connected to the indoor unit via a 30 m coaxial cable. Similarly, two front fed parabolic antennas are mounted on 20 m height Icheon, RRA Station tower which is connected to two separate outdoor units which are in turn connected to two indoor units via 40 m coaxial cable. The data logger unit along with OTT Parsivel rain gauge is setup in Icheon, RRA Station. The received signal level (RSL) for any terrestrial microwave link is given as [1]:

$$RSL=P_T+G_T+G_R-L_{fs}-A_G-A_R-A_W-L_R-L_t\,, \quad (11)$$

where P_T (dBm) is the transmit power, L_t (dB) is the loss in the transmit system, G_T (dB) is the transmit antenna gain, L_{fs} (dB) is the free space loss, A_G (dB) is loss due to gaseous absorption, G_R (dB) is the receive antenna gain, L_R (dB) is

Table 1. Specifications of the 18 GHz link [17]

Description	Specification
Antenna type	Front-fed parabolic
Frequency band (GHz)	17.7–18.2
Polarization tower	
@Khumdang, KT Station	Vertical
@Icheon, RRA Station	Vertical for antenna 1, Horizontal for antenna 2
Maximum transmit power	0.16 W (+22 dBm)
Reception method	Super heterodyne
Modulation	QPSK
Maximum modulation degree	8 bit/Hz
BER received threshold (dBm)	
For horizontal polarization	-52.3438
For vertical polarization	-32.8125
Half power beam width	1.9^0
Antenna for both transmit and receive side	
Size (m)	0.6
Gain (dBi)	38.8

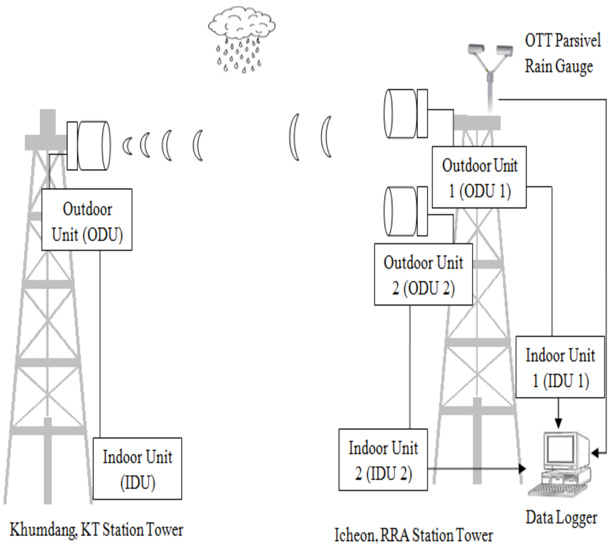


Fig. 1. Experimental setup for rain attenuation and rain rate measurement [17].

the loss in receiver systems, A_R (dB) is the excess attenuation due to rain on propagation path and A_W (dB) is the wet antenna loss on both antennas during rain ($A_{W,transmit}$ + $A_{W,receive}$). Among all the factors, free space loss, gaseous absorptions, and excess rain attenuation are all dependent on operating frequency, propagation path length, and the location of the link. The free space loss can be obtained from the Friis expression:

$$L_{fs} = 32.4+20 \log_{10}(d_{km}) + 20 \log_{10} (F_{MHz}), \qquad (12)$$

where d_{km} is path length in km and F_{MHz} is the operating frequency. Gaseous absorptions are negligible at frequencies below 30 GHz. For instance, the vapor absorption at 22 GHz is 0.16 dB/km. Therefore, the gaseous absorption A_G can be neglected in (11). Similarly, the losses in transmit (L_t) and receive (L_R) systems can also be neglected in (11) since it is not significant with respect to free space loss and excess attenuation due to rain. The wet antenna loss is also varied with antenna size, radomes materials so this loss has not been considered during calculation. Hence, the corresponding path attenuation is calculated by finding the difference between the RSL during clear sky conditions and the RSL during rain for horizontal and vertical polarized received signal at various rain rates as:

$$\text{Attenuation (dB)} = RSL_{\text{clear sky}} - RSL_{\text{rainy}} . \qquad (13)$$

Similar approach as for determining 1-minute rain rate in [9] is adopted for determining the rain attenuation value for the 1-minute interval. The cumulative distribution of rain rate measured for 3 years (2013 till 2015) of the studied location is shown in Fig. 2. This figure indicates that at 0.01% of the time the measured rain rate value is 49.79 mm/hr for Icheon site. Furthermore, rain rate values decreases and tends to be smaller for higher time percentages, for example, at 0.5% and 1% of the time, rain rate are observed to be 1.99 mm/hr and 0.65 mm/hr respectively. Similarly, at lower time percentage rain rate is increased, for example, at 0.001% of the time, rain rate observed is 98.57 mm/hr.

As depicted in Fig. 3, rainfall results in greater attenuation for horizontal polarization as compared to vertical polarization. During horizontal polarization, at 0.01% of the time, the obtained rain attenuation value is 33.38 dB and for vertical polarization at the same percentage of time, the obtained rain attenuation value is 21.88 dB. Similarly, the rain attenuation values get increased for lower time percentage which reached up to 43.21 dB and 38.36 dB at 0.001% of the time for horizontal and vertical polarization respectively.

Conversely, at higher time percentage as such for 1% of the time, the rain attenuation value gets decreased to 0.41 dB and 0.42 dB for horizontal and vertical polarization, respectively.

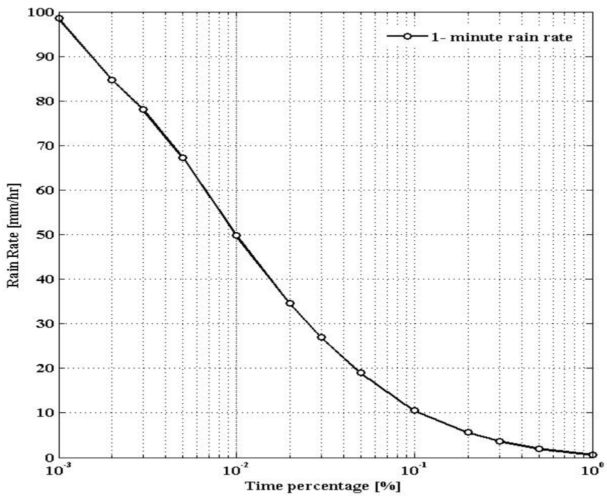


Fig. 2. Rainfall rate distribution at Icheon [17].

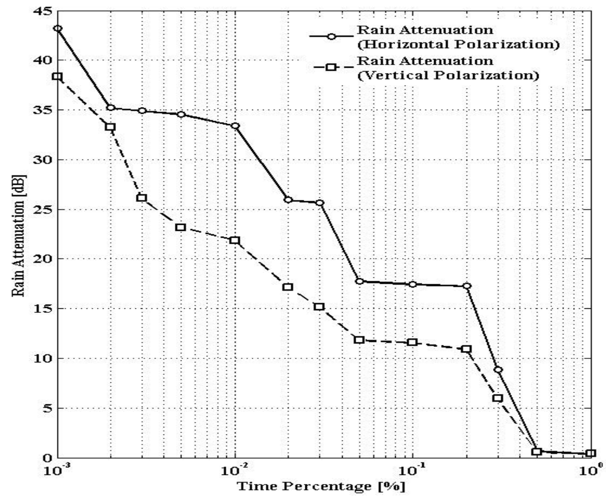


Fig. 3. Distribution of rain attenuation at Icheon [17].

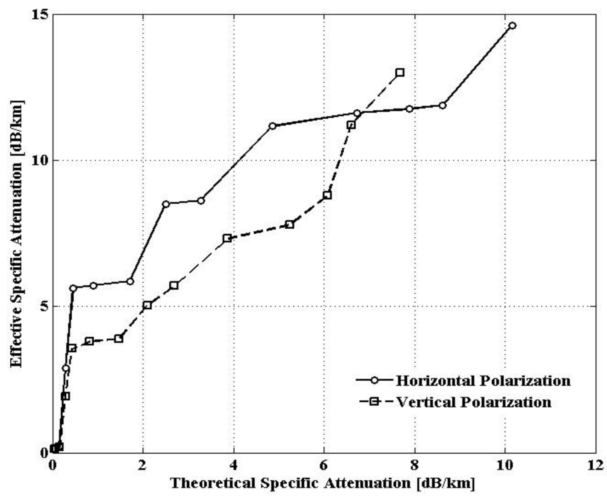


Fig. 4. Comparison of effective and theoretical specific rain attenuation.

IV. RESULT AND DISCUSSION

The relationship between theoretical specific rain attenuation, $\gamma_{\%p}$ and effective specific rain attenuation, γ_{eff} are studied through the statistical analyses of experimental data presented in Figs. 2 and 3. The plot between these two parameters is shown in Fig. 4 which shows the increasing curve nature for both horizontal and vertical polarizations. The empirical relationship between these two quantities is given by the following ratio:

$$\frac{\gamma_{\text{eff}}}{\gamma_{\%\text{p}}} = \frac{kR_{eff}^{\alpha}}{kR_{\%p}^{\alpha}}. \quad (14)$$

Solving equation (14), we get the effective rain rate as,

$$R_{\text{eff}} = \left(\frac{1}{\text{k}}\gamma_{\text{ eff}}\right)^{\frac{1}{\alpha}} = R_{\%\text{p}}\left(\frac{\gamma_{\text{ eff}}}{\gamma_{\ \%\text{p}}}\right)^{\frac{1}{\alpha}}\ . \quad (15)$$

Alternatively, effective rain rate can be expressed as a function of measured rain rate by power law as follows:
Proposed Method:

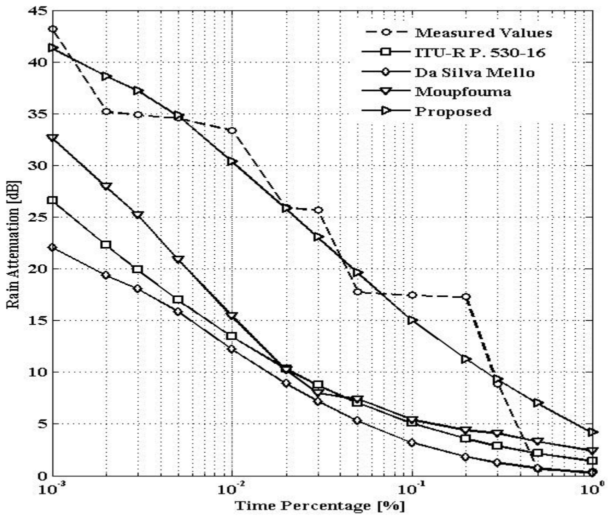
$$R_{eff} = aR_{\%p}^{b}\ , \quad (16)$$

where a and b are derived empirically with the values of a=18.24 and b=0.4318 for horizontal polarization and a=8.719 and b=0.6162 for vertical polarization. Under the presence of effective specific rain attenuation, Eq. (15) can be used for derivation of effective rain rate. The effective specific rain attenuation can be calculated by dividing the experimentally derived rain attenuation values with the product of actual link distance and path correction factor. The path correction factor, r, is given by:

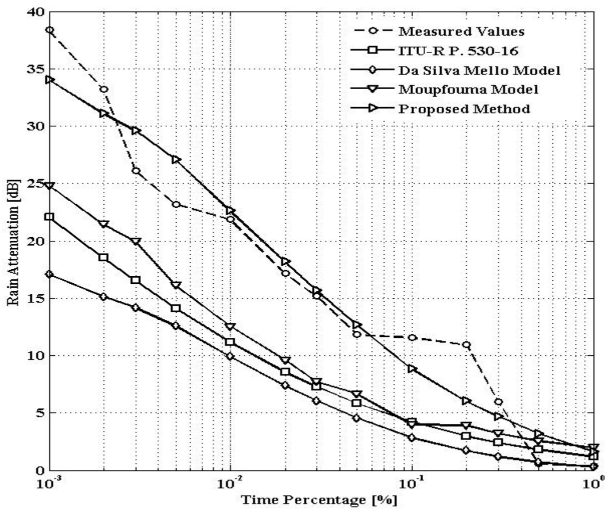
$$r = \frac{1}{1+\left(\frac{d}{d_0(Rp)}\right)}, \quad (17)$$

where d is the actual link distance and $d_0(R_p)$ is equivalent rain cell diameter given by Eq. (5) which depend on the 1-minute rain rate exceeded at p% of the time. In addition, proposed method as represented by Eq. (16) can be used to derive effective rain rate from 1-minute rain rate values for %p time percentage. This approach is adopted for further analyses because it utilizes the full 1-minute rain rate distribution over 0.001% ≤ %p ≤ 1%. The rain rate considered for the further part is the 1-minute rain rate distribution. Therefore, the attenuation exceeded at %p of the time can be expressed as given in Eq. (18):

$$A_{\%p} = \gamma_{\text{eff}}\, d_{\text{eff}} = k\,[R_{\text{eff}}\,(R_{\%\text{p}},\, d)]^{\alpha}\left[\frac{d}{1+\left(\frac{d}{d_0(R_{\%p})}\right)}\right]. \quad (18)$$



(a)



(b)

Fig. 5. Comparison of measured and predicted attenuation for (a) horizontal polarization and (b) vertical polarization.

Fig. 5(a) and (b) shows the plot of proposed method and those of the ITU-R P.530-16, Da Silva Mello and Moupfouma Models for horizontal and vertical polarization, respectively. The proposed method closely matched the measured rain attenuation values when 0.001% ≤ %p ≤ 1%. For instance, for horizontal polarization, the measured and predicted values at 0.01% of the time are 33.38dB and 30.39dB respectively, whereas at 0.001% the corresponding values are 43.21 dB and 41.33 dB. Similarly, for vertical polarization, attenuation values of 21.88 dB and 22.59 dB are obtained for measured and predicted values at 0.01% of the time, respectively, whereas at 0.001% the corresponding values are 38.36 dB and 34.05 dB. The goodness of fit for proposed method is done through the calculation of relative error variables (ε(P)), standard deviation (STD) and root mean square (RMS) values, where they are compared to the performance of the ITU-R P.530-16, Da Silva Mello and Moupfouma Models. Data for proposed approaches are tabulated at fixed probability levels when $0.001\% \leq \%p \leq 1\%$ as recommended in ITU-R P.311-15 [18]. The relative error probability used to access the proposed approaches is given by:

$$\varepsilon(P)_T = \frac{A_{\%p,predicted} - A_{\%p,measured}}{A_{\%p,measured}} \times 100\ [\%], \quad (19)$$

where $A_{\%p,\ predicted}$ and $A_{\%p,\ measured}$ are the predicted and measured rain attenuation values respectively, at the same probability level p, with percentage interval $10^{-3}\% < p < 1\%$. Similarly, for STD and RMS calculation, the approach followed in [2] have been adopted. The calculated ε(P), STD and RMS values of the test variable for each method are listed in Tables 2 and 3 for horizontal and vertical polarization respectively.

In case of horizontal polarization, as noted from Table 2, ITU-R P.530-16, Moupfouma Model, Proposed Method result in higher relative error when $0.5\% \leq p \leq 1\%$ which is justified from increased STD and RMS values whereas for lower time percentage when $0.001\% \leq p \leq 0.3\%$, there is lower values of relative error probabilities which are supported by the decreasing STD and RMS values. In order hand, Da Silva Mello Model gives the lower relative error when $0.5\% \leq p \leq 1\%$ which is justified from decreased STD and RMS values. Thus, for higher time percentage Da Silva Mello Model can be used. In addition, for lower time percentage, ITU-R P.530-16, Da Silva Mello Model and Moupfouma Model give higher relative error values which underestimate the measured cumulative rain attenuation statistics. ITU-R P.530-16 shows the relative error percentage of 71%, 60%, 38% while it is 82%, 63%, 49%; 69%, 54%, 24% for Da Silva Mello Model and Moupfouma Model at 0.1%, 0.01% and 0.001% of the time respectively. Thus, these models seem to be not effective at lower time percentage. Additionally, proposed method shows relatively lower relative error percentage values which are justified

Table 2. Percentage error obtained after testing over the interval [0.001% to 1%] for horizontal polarization

Methods (For Horizontal Polarization)	Parameters	Time Percentage (%p)												
		1	0.5	0.3	0.2	0.1	0.05	0.03	0.02	0.01	0.005	0.003	0.002	0.001
ITU-R P. 530-16	ε(P)	2.56	2.35	-0.67	-0.79	-0.71	-0.60	-0.66	-0.60	-0.60	-0.51	-0.43	-0.37	-0.38
	STD	2.67	2.46	0.57	0.68	0.60	0.50	0.55	0.49	0.49	0.40	0.32	0.26	0.28
	RMS	1.04	1.53	5.99	13.68	12.35	10.74	16.91	15.58	19.91	17.55	14.99	12.89	16.61
Da Silva Mello Model	ε(P)	-0.31	0.14	-0.86	-0.89	-0.82	-0.70	-0.72	-0.66	-0.63	-0.54	-0.48	-0.45	-0.49
	STD	0.26	0.71	0.29	0.32	0.25	0.13	0.15	0.08	0.06	0.03	0.09	0.12	0.08
	RMS	0.13	0.09	7.60	15.44	14.26	12.46	18.47	16.98	21.14	18.68	16.84	15.84	21.13
Moupfouma Model	ε(P)	5.00	4.13	-0.53	-0.74	-0.69	-0.58	-0.69	-0.61	-0.54	-0.39	-0.28	-0.21	-0.24
	STD	4.72	3.85	0.81	1.02	0.97	0.86	0.97	0.88	0.82	0.67	0.56	0.48	0.52
	RMS	2.03	2.69	4.75	12.84	12.01	10.33	17.67	15.70	17.93	13.62	9.67	7.23	10.54
Proposed Method	ε(P)	9.27	9.75	0.05	-0.35	-0.14	0.11	-0.10	0.00	-0.09	0.01	0.07	0.10	-0.04
	STD	7.84	8.31	1.38	1.78	1.57	1.33	1.53	1.44	1.52	1.42	1.37	1.34	1.48
	RMS	3.77	6.35	0.44	6.00	2.40	1.88	2.62	0.12	2.99	0.26	2.33	3.40	1.89

Table 3. Percentage error obtained after testing over the interval [0.001% to 1%] for vertical polarization

Methods (For Vertical Polarization)	Parameters	Time Percentage (%p)												
		1	0.5	0.3	0.2	0.1	0.05	0.03	0.02	0.01	0.005	0.003	0.002	0.001
ITU-R P. 530-16	ε(P)	1.96	2.18	-0.60	-0.73	-0.64	-0.51	-0.52	-0.50	-0.49	-0.39	-0.37	-0.44	-0.42
	STD	2.07	2.29	0.48	0.61	0.52	0.39	0.41	0.39	0.38	0.28	0.25	0.33	0.31
	RMS	0.80	1.24	3.55	7.95	7.36	6.00	7.91	8.55	10.70	9.06	9.57	14.69	16.28
Da Silva Mello Model	ε(P)	-0.27	0.30	-0.79	-0.84	-0.75	-0.61	-0.60	-0.57	-0.55	-0.46	-0.46	-0.54	-0.55
	STD	0.25	0.81	0.28	0.33	0.24	0.10	0.09	0.05	0.03	0.06	0.06	0.03	0.04
	RMS	0.11	0.17	4.73	9.22	8.74	7.26	9.12	9.73	11.98	10.57	11.90	18.07	21.28
Moupfouma Model	ε(P)	3.89	3.55	-0.46	-0.64	-0.65	-0.44	-0.49	-0.44	-0.43	-0.30	-0.24	-0.35	-0.35
	STD	3.69	3.34	0.66	0.84	0.86	0.64	0.70	0.64	0.63	0.51	0.44	0.56	0.56
	RMS	1.58	2.02	2.72	7.00	7.58	5.16	7.47	7.52	9.33	7.06	6.14	11.78	13.53
Proposed Method	ε(P)	2.97	4.62	-0.21	-0.45	-0.24	0.07	0.03	0.06	0.03	0.17	0.13	-0.06	-0.11
	STD	2.43	4.08	0.75	0.99	0.78	0.47	0.51	0.48	0.51	0.37	0.40	0.60	0.65
	RMS	1.21	2.63	1.27	4.90	2.73	0.81	0.45	1.03	0.72	3.92	3.52	2.11	4.31

from decreased STD and RMS values. For instance, the proposed method shows relative error percentage of 14%, 9%, 4% at 0.1%, 0.01% and 0.001% of the time, respectively.

A similar trend of statistical results is obtained in the case of vertical polarization, as indicated in Table 3. ITU-R P.530-16, Moupfouma Model, Proposed Method result in higher relative error when $0.5\% \leq p \leq 1\%$ which is justified from increased STD and RMS values whereas for lower time percentage when $0.001\% \leq p \leq 0.3\%$, there is lower values of relative error probabilities which are supported by the decreasing STD and RMS values.

In order hand, Da Silva Mello Model shows lower relative error when $0.5\% \leq p \leq 1\%$, which is justified from decreased STD and RMS values. Thus, for higher time percentage Da Silva Mello Model can be used. In addition, for lower time percentage, ITU-R P.530-16, Da Silva Mello Model and Moupfouma Model give higher relative error values which underestimate the measured cumulative rain attenuation statistics. ITU-R P.530-16 shows the relative error percentage of 64%, 49%, 42% while it is 75%, 55%, 55%; 65%, 43%, 35% for Da Silva Mello Model and Moupfouma Model at 0.1%, 0.01% and 0.001% of the time, respectively. Thus, these models seem to be less effective at lower time percentage. Additionally, the proposed method shows relatively lower error percentage values which are justified from decreased STD and RMS values. For instance, proposed method results in relative error percentage of 24%, 3%, 11% at 0.1%, 0.01% and 0.001% of the time respectively.

V. CONCLUSIONS

The rain induced attenuation was recorded for experimental microwave links operating in 18 GHz, at Icheon, South Korea. Full rainfall rate distribution measured over three year periods from 2013 to 2015 were used for prediction of rain attenuation over terrestrial microwave links. The experimental results are observed to be underestimated by ITU-R P.530-16, Da Silva Mello and Moupfouma models. Interestingly, Da Silva Mello Model can be used for higher time percentage when $0.5\% \leq p \leq 1\%$ of the time under horizontal and vertical polarization.

Similarly, proposed method seems to be more appropriate for prediction of rain attenuation for lower time percentage when $0.001\% \leq p \leq 0.3\%$ of the time whose performance criteria are judged from lower values of relative error, STD and RMS error. Further research works are going on to exploit the possibilities of applying proposed method for higher operating frequencies particularly at 38 GHz and 75 GHz. It is observed that horizontal polarization is more prone to rain fades because as raindrops increase in size, they get more extended in the horizontal direction. In overall, the paper emphasizes that ITU-R P.530-16 did not significantly reflect the South Korea's local rain attenuation characteristics for microwave link operating at 18 GHz. It is expected that the results will help for the design of broadband wireless link which will ensure link availability and reliable communication during rain events and quality of service for the end user.

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