IMPROVEMENT ON ALPHA-BETA BEHAVIOUR ANALYSIS FOR RAIN PREDICTION OF RADIO PROPAGATION SYSTEMS

[1] AFOLAYAN A. OLUMIDE and [2] OYELEKE OLAOSEBIKAN
[1]*Physics with Electronics Unit, Department of Science Laboratory Technology, Federal Polytechnic Ilaro, Ogun State, Nigeria*
[2] *Department of Science Laboratory Technology, Federal Polytechnic Offa, Kwara State, Nigeria*

E-mails: flyn_olumide@hotmail.com

Abstract
A good knowledge of the effect of rain in the design of satellite and terrestrial microwave radio links is of interest to engineers and scientists. In equal importance is the role plays by tropical rainfall in agricultural practices and in ensuring the constant availability of atmospheric wind circulation as a result of latent heat energy produced by tropical rainfall. A good prediction often required for guaranteeing high level of accuracy of the rain rate distribution from the lowest rain rate value to the highest. The present work proposes an improved model that expresses rain rate as a function of alpha and beta obtained at 0.01% of the time when tested. Observational data from tropical regions especially along equatorial region were used, with two locations in Nigeria. The results obtained are shown to be reliable for discussing the performance of the rain intensities of between 5mm/h to 200mm/h.

Keywords: *Rain, Radio, Program, Alpha, Beta, Behaviour, Rate*

Introduction
The effect of rain on electromagnetic wave is enormous and there is a noticeable effect of rain on the propagation of radio wave. Rain is a natural phenomenon that reduces the propagating signal at microwave and millimeter-wave frequencies. Other contributing factors that reduce signals in the atmosphere are as a result of fog and signals scattering due to atmospheric particles and precipitation. Low level of interference at higher frequencies, provision for frequency reuse, huge bandwidth availability and deployment are some of the positive opportunities available when higher frequencies are used. Degree of rainfall in the tropical zone calls for concern due to high level of attenuation caused to signal strength. This has affected the ease of signal transmission in Ku and Ka band that are used for satellite communication (Ajayi and Ofonche, 1984). There is a proportionality that exists between the level of rainfall and disruption caused due to signal attenuation; a phenomenon referred to as rain fade occurs. The disruption to signal transmission is mostly observed in the tropospheric and ionospheric layers of the atmosphere with tropospheric precipitation taking prominence when it comes to signal absorption of atmospheric signal meant for transmission. This is prominent with frequency transmission higher than 10 GHz especially in satellite communication which many nations of the world depend upon for their activities. Many researchers have concentrated on better modeling that will aid improved prediction of rainfall by studying the physical and statistical characteristics of rainfall through analysis of observational data (Adimula et al. 1991; Meneghini and Jones, 1993; Kummerow and Coauthors, 2000; Iguchi and Kwiatkowski,2001; Aro, 1982). This is required for the understanding of the large-scale space, temporal variations and other constraints needed to be satisfied for the spatial and temporal interpretations. A lot of models have been proposed, among them are the log-normal and gamma which are extensively used and give approximation for low and high rainfall rate distribution for intensities above 2mm/h for both high and low rainfall rates and which is useful for radio system engineers. In this work an attempt has been made to express rainfall distribution as a function of alpha and beta during % of time 0.01(Adimula et al. 1991; Meneghini and Jones, 1993; Kummerow and Coauthors, 2000; Iguchi and Kwiatkowski,2001; Aro, 1982).This percentage was chosen because it is the rain fall intensity recommended by the ITU-R for evaluating the availability of terrestrial and satellite radio wave systems (Das et al. 210; Iguchi and Kwiatkowski, 2001).

Background Study
One major causes of reduction in signal strength that bedeviled transmission at high frequency is absorption and interference of signal by raindrops. Other sources of signal disruptions are absorption from dissolved atmospheric gases, vegetation of foliage blockage. Past studies of weather as its relates to the fields of climatology, meteorology, hydrology and signal transmission place emphasis on the spatial and temporal dynamics of rainfall as it affects signal transmission across the spectrum of frequencies (Berne et al 2005). Ajayi and Ofonche (1984) proposed a model for approximation for low and high rainfall rates respectively based on long-normal and gamma models Oyeleke (2003) proposed an empirical model for rainfall distribution using observational

data from Ilorin; an equatorial region. According to the same source, for measurements made in Ilorin; an equatorial climate, empirical model for rainfall distribution was proposed as R_{p}=16.626 r-0.2691. Works on rain attenuation and distribution obtained using ITU model was reported by Union (2005 and 2013). Rainfall rates rain attenuation at 0.001 to 0.1% was researched on and reported. Absorption of electromagnetic signal is certain at higher frequencies because the size of raindrops is comparable to the wave lengths at higher frequencies (Das et al, 2010).In all of these, the empirical approach to measurement and prediction is always preferred by using equations with appropriate variables like rain height, rain rate, earth-station latitude and longitude (Adimula et al. 1991; Meneghini and Jones, 1993; Kummerow and Coauthors, 2000; Iguchi and Kwiatkowski, 2001; Aro, 1982).. Although many models have been proposed, the log-normal and gamma models are extensively used and give a good approximation for low and high rainfall rates respectively (Ajayia nd Ofonche, 1984)). Rain rate is a parameter that should be determined when considering satellite meant for space communication (Adimula et al. 1991; Meneghini and Jones, 1993; Kummerow and Coauthors, 2000; Iguchi and Kwiatkowski,2001; Aro, 1982)..The equatorial region is where there is tropical rainfall of interest because of its role in supporting agriculture and for the fact that about three-fourths of the total energy available for atmospheric wind circulation is gotten from the latent heat injected by tropical rainfall (Kummerow and Coauthors, 2000). Absorption and scattering of electromagnetic wave due to attenuation at varying frequencies is prevalent in signal communication (Islam et al 1999). Operators prefer transmission within higher frequency zone in an attempt to utilize greater bandwidth for greater data rates and the fact that lower frequencies are already congested (Senso et al., 2012).

Methodology

A good prediction often required for guaranteeing high level of accuracy of the rain rate distribution from the lowest rain rate value to the highest. The present work proposes an improved model that expresses rain rate as a function of alpha and beta obtained at 0.01% of the time when tested. Observational data from tropical regions especially along equatorial region were used, with two locations in Nigeria. The results obtained are shown to be reliable for discussing the performance of the rain intensities of between 5mm/h to 200mm/h.

Results and Discussion

Rain rate distribution measurement

Rain rate distribution measurement obtained from various locations in the tropical climate is indicated in Table I with their corresponding latitudes.

Table 1: Tropical stations considered and their latitudes

Location	Latitude
Brazilia	23.32^0S
Nairobi	1.170S
Dar-es-salamn	6.15^0S
Ile -Ife	7.49^0 N
Ilorin	8.30^0 N

Parameters 'α' that represent alpha and ' β ' that represent beta were obtained by the use of regression analysis and the results are shown in Table 2.

Table 2 The variability of parameters 'α' and ' β ' with geographical locations.

Parameters				Measurement Table
Location	Latitudes	α	B	No of Years
Brazilia	23.32^0 S	5.255	-0.365	1
Nairobi	1 17^0 S	6.3396	-0.435	1
Dar es Salaam	6.15^0S	8.1138	-0.406	1
Ife	7.49^0N	13.4246	-0.3738	1
Ilorin	8.30^0N	16.626	-0.3691	2

Clearly, there are variations in the values of 'α' and 'β ' which shows that the effect of Convective rain is much felt in some area than other areas. Those effects include wind, strong updraft, temperature changes and other location phenomenon associated with thunderstorm rain produce significant variability in the values of 'α'. Average values of these parameters are taken for the viabilities in thunderstorm and other effect like topography, mountains and large body of water. Rain data was taken over a period of two years at Ilorin and others were taken over a period of one year.

Determination of alpha and beta behaviour at $R_{o.01}$ (mm/h)

Rainfall intensity $R_{o.01}$ (mm/h) exceeded for 0.01% of the time in different tropical stations were studied. The 'α' and 'ß' parameters at that percentage of time are very important because they are recommended and used for radio wave attenuation predictions both on line-of- sight and Earth-space links. Table 3 below show the values of parameters 'α' and ' β' computed by the use of Regression programme. The rain rate obtained for the different locations at $R_{0.01}$ are as provided.

Table 3: Values of parameters and root for different locations

Location	Values of Parameters		Root (mm/h)
	'α'	' β '	
Brazilia	5.255	-0.365	50
Nairobi	6.359	-0.435	58
Dar es Salaam	8.110	-0.406	72
Ile-lfe	13.446	-.03738	80
Ilorin	16.625	-0.3691	90

In Figure l, the parameters ' β 'plotted against the values of rainfall intensity during the 0.01% of the time for each location in Table 3.The corresponding point can be fitted by the relation:

$$\beta_p = 0.0025R_{0.01} - 0.5826 \qquad \text{Eq. 1}$$

For all the stations considered, there is a good agreement between the values obtained from the predicted equations and the values obtained from the measurement. Prediction is indicated by subscript 'p' and measurement by subscript 'm'. Table 4 below shows the values of both predicted and measurement.

Table 4: Values of both predicted and measurement

Parameters			
$R_{o.01}$ (mm/h)	β_m	β_p	% error
90	-0.3691	-0.3576	3.1-2.4
80	-0.3728	-0.3826	0.8
72	-0.4060	-0.4026	-0.6
58	-0.4350	-0.4376	0.2
50	-0.40650	-0.4876	

β_m is measurement and ßp is predicted.

Parameters 'α' plotted against corresponding $R_{o.01}$ (mm/h) has resulted into a linear equation and the empirical equation is now written as:

$$\alpha_p = 0.288\, R_{0.01} - 10.199 \qquad \text{Eq. 2}$$

Using this expression to generate predicted values 'α' results into Table 5

Table 5: Predicted values 'α'

Parameters			
$R_{0.01}$(mm/h)	α_m	α_p	% error
90	16.625	15.721	-5.5
80	13.446	12.841	-4.5
72	8.110	10.537	30.0
58	6.359	6.0505	2.3
52	5.255	4.201	20.1

α_m is measurement and α_p is predicted.

Tables 4 and 5 reveal the consistency of the empirical equation obtained from the graphs of Parameter 'β' versus $R_{0.01}$ (mm/h) and Parameter 'α' versus $R_{0.01}$ (mm/h). Figures 3 and 4 are graphs that compare the values of parameters 'α' and 'β ' obtained by measurement and the ones obtained by prediction. Since these parameters are very important in the prediction of rain-rate from the previous model,

$$\mathbf{R_p = \alpha^{r-\beta}} \qquad \textbf{Eq. 3}$$

Substituting these values of 'α' and 'β' and varying the percentage of time, the following Tables 6 (a, b, c, d and e) were obtained with:

$$\alpha_p = 0.288R_{0.01} - 10.199 \qquad \text{Eq. 4}$$

$\beta_p = 0.0025\ R_{0.01} - 0.5826$ for the stations considered and compared with Nairobi and Dar es Salaam in Tables 6 d and e. Comparing Rain-rate obtained by the use of predicted equation for 'α' and ' β ' in Table: 6 (a)

Table 6 (a): $R_{0.01}$for Ilorin: $R_{0.01}$= 90mm/hα = 15.72, β= -0.3691

% of time	R_m (mm/h)	R_p (mm/h)	% error
0.001	198	201.3	-1.7
0.003	152	134.2	-1 1.7
0.01	90	86.0	-4.4
0.03	60	57.4	-4.3
0.1	45	36.8	18.2
0.3	23	24.5	6.5

Table 6 (b) Ile-Ife R_{001} – 80 mm/h, α = 12.841, β= -0.3826

% of time	R_m (mm/h)	R_p (mm/h)	% error
0.001	140	180.5	29
0.003	125	118.5	-5.2
0.01	80	74.8	-6.5
0.03	65	49.1	-24.5
0.1	38	31.9	-16.8
0.3	15	20.4	36

Table 6 (c): Brazilia$R_{0.01}$=50mm/h, α=4.201, β= -04876

% of time	R_m (mm/h)	R_p (mm/h)	% error
0.001	95	121.9	28.3
0.003	64	71,4	-1 16
0.01	50	39.7	20,6
0.03	32	23.2	-27,5
0.1	16	12	25 0
0.3	06	7.6	26.7

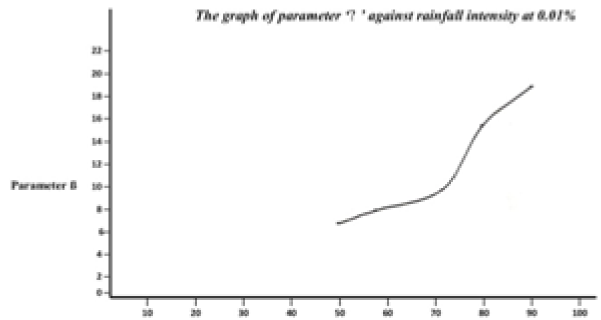
Table 6 (d): Nairobi$R_{0.01}$=58mm/h, α= 6.3391, ß = -0,435

% of time	R_m (mm/h)	R_p (mm/h)	% error
0.001	95	12	34.6
0.003	76	7.9	4.3
0.01	58	79.4	19 -
0.03	40	47 29	27,5
0.1	20	12	15
0.3	08	10.8	26.7

Table 6 (e): Dar es Salaam, $R_{o.01}$=72mm/h,α =10 537, β = 0.350

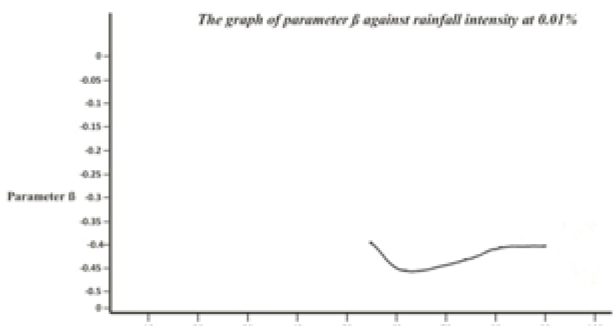
% of time	Rm (mm/h)	Rp (mm/ll)	^{0}/0 error
0. 001	96	118.2	-23.1
0.003	86	80.5	-27
0.01	72	52.5	-21.7
0.03	46	36	21.1
0.1	19	23	23.5
0.3	13	16	

Figures 1 to 9 are graphs that reveal the performance of the prediction of parameters 'α' and 'β' at $R_{0.01}$ for different locations. The figures highlight that the prediction is in close agreement with the measurement when parameters are used.



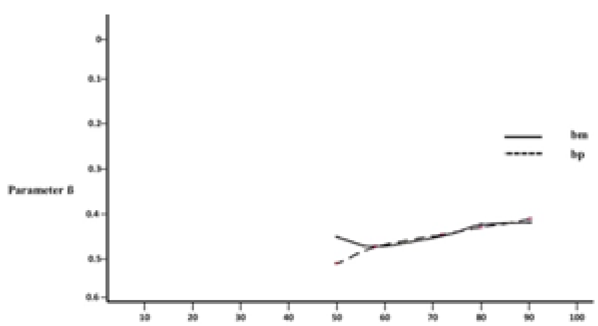
$R_{0.01}$ (mm/h)

Figure 1: The graph of parameter '∝' against rainfall intensity at 0.01%



$R_{0.01}$ (mm/h)

Figure 2: Comparison between parameter ‘β’ obtained by measurement and prediction of rain intensity of 0.01%



$R_{0.01}$ (mm/h)

Figure 3: Comparison between parameter ‘β’ obtained by measurement and prediction of rain intensity of 0.01%

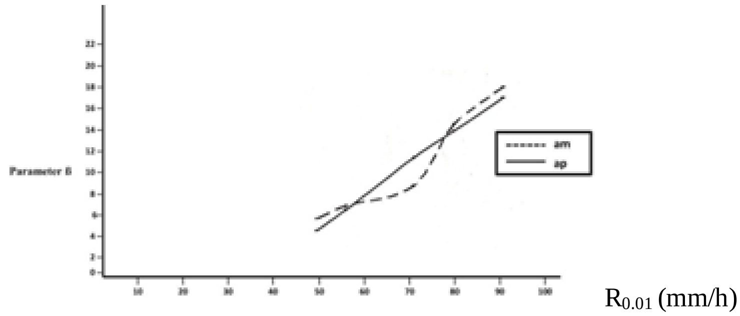


Figure 4: Comparison between parameter '∝' obtained by measurement and prediction of Rain Intensity of 0.01%

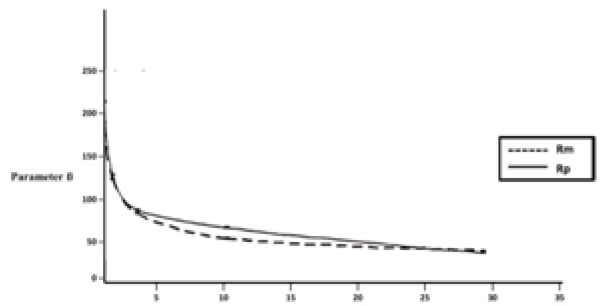


Figure 5: The graph of rain intensity measurement compared with the prediction from Predicted equations for ∝ and β at $R_{0.01}$for Ilorin

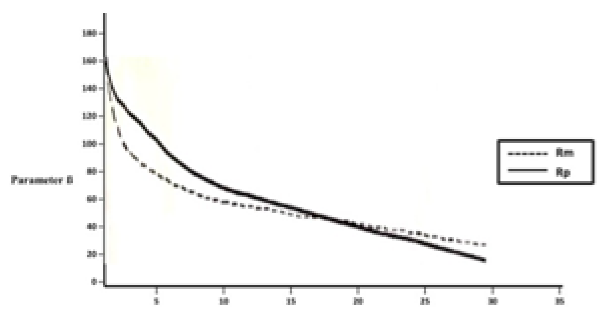


Figure 6: The graph of rain intensity measurement compared with the prediction from Predicted equations for ∝ and β at $R_{0.01}$ for Ile-Ife

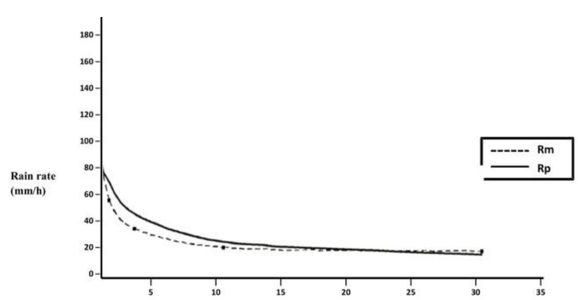


Figure 7: The graph of rain intensity measurement compared with the prediction from Predicted equations for ∝ and β at $R_{0.01}$ for Brazilla.

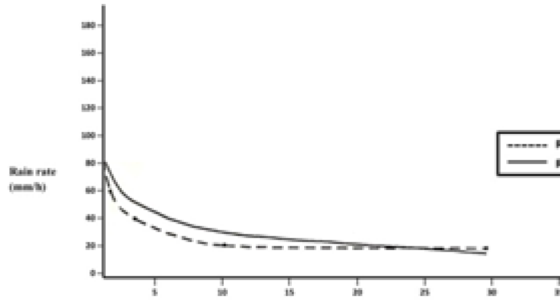


Figure 8: The graph of rain intensity measurement compared with predict equations for ∝ and β at $R_{0.01}$ for Nairobi

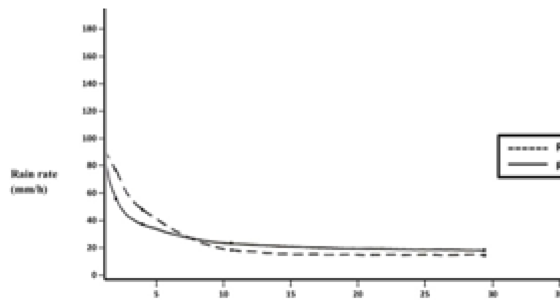


Figure 9: The graph of rain intensity measurement compared with the prediction from Predicted equations for ∝ and β at $R_{0.01}$ for Dar es Salaam

The proposed model for the rainfall rate distribution makes it possible that, in the absence of appropriate rain-fall intensity data for a particular location, one can determine the average cumulative distribution using the ITU-R contour map of rainfall intensity exceeded for 0.01% of the time. Hence, the ITU-R maps, giving $R_{0.01}$(mm/h) are more convenient for use in the present model than the ITU-R rainfall climatic zone representation. The initially proposed power law model of the form $\alpha\ ^{r-\beta}$ gives a very good prediction for the rain-rate up to 200mm/h. The new parameters later proposed at rain-rate 0.01% of time gives a very good representation of the parameters for the stations considered. The linear relationship that revealed for parameters 'U' and ' p 'at the rain rate 0.01% of time makes the prediction for cumulative rain rate distribution a very good fit for the medium and high rain rate locations, especially in the tropical regions. The linear models for 'α' and 'β'

$\alpha_p = M_\alpha R_{0.01} - C_\alpha$ and

$$\beta_p = M_\beta\ R_{0.01} - C_\beta$$

where M_α and M_β are the slopes of the graph plotted for 'α' versus and 'β' versus $R_{0.01}$ respectively C_α and C_β are the intercepts obtained on their vertical axis respectively. For all the stations considered in this work, the consistency test conducted holds well for the measurement of about 5mm/h to about 200mm/h. High rain rates and the consequent high alternation in tropics is arguably the greatest constraint to the usability of the Ku and Ka bands in the tropics. Despite the enormous work carried out on this subject in the temperate regions of the world, lack of reliable rain measurement makes it less applicable here in the tropics. Generally, rain rate prediction depends on certain parameters. Parameters 'α' and ' β' have been taken to be functions of rain intensity. Their values are greatly affected by local climatology and geographical locations.

Conclusion

There is, therefore, the need for more data from high rain rate locations in other to provide reliable values of the parameters. If attenuation is to be predicted from rain rate, it would be better to use a single observable parameter if observable that remains substantially the same in most environments. There may also be need to re-examine the ITU-R climate map to take account of environmental factors including all weather elements such as pressure, temperature, humidity, winds and phenomenon such as clouds, storms and other forms of precipitations. These elements have to be measured in regular intervals because of the increasing use of radio systems. The proposed empirical model for parameters for the rain-rate prediction could be a useful tool for the radio design engineers at high rain rate areas (Adimula et al. 1991; Meneghini and Jones, 1993; Kummerow and Coauthors, 2000; Iguchi and Kwiatkowski, 2001; Aro, 1982).

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