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Dry Hot and Cool Tropical Climate Attenuation models at VHF

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***Abstract* – This paper presents the experimental investigation of VHF (92.1MHz) radio wave attenuation due to the effects of dry hot and dry cool weather conditions plus the effects of ground and tree-canopy reflections (GCREFS) in the tropical region. Using the method of least square fit to the measured data, new attenuation models characterizing the VHF radio wave propagation loss during the dry hot and dry cool atmospheric conditions in the region of consideration were obtained. It was shown that the signals suffer more loss during dry cool weather than during dry hot weather. When some existing models were compared with the measured data, it was found that measured data are fairly favorably in agreement with the ground and tree-canopy reflections (GCREFS) plus dry air weather ITU-R model prediction (the normalized root-mean-square deviation~ +0.32%).**

***Keywords* – VHF Radio Attenuation, Dry Hot and Cool Weather, Tropical Region.**

I. Introduction

In recent time, there are great interests in the radio communications to provide fast, clear and genuine information and news around the globe. More HF, VHF, UHF and microwave radio transmitting stations have emerged to meet these demands. The planning, budgeting and design of the communication systems depend on the existing attenuation models of the radio wave propagation [1]. It is simply because attenuation has remained the major impairment of radio wave propagation.

Attenuation (*A*) is defined as the reduction in magnitude of a radio frequency signal from the transmitting station on passing along any transmission path [2] – [5]. It is directly proportional to the frequency and distance of transmission as shown by the free space Line of Sight (LOS) radio wave attenuation formula given as (1) by [3].

$$A_{FSLOS} = 147.5571 - 20\log_{10} \mathrm{f} - 20\log_{10}\mathrm{d}\text{ , dB} \quad (1)$$

Where, *f* is resonant frequency in Hz and *d* is distance covered by the radio waves in meters.

Generally, attenuation can be determined using the expression given by [4], [5], [6]:

$$A = 10\log_{10}\left(\frac{P_R}{P_T}\right),\ \text{dB} \quad (2)$$

Where P_R is the signal power received, and P_T is the signal power transmitted, all in Watts.

In addition to distance and frequency that affect propagation of radio waves, other factors that can cause attenuation of radio waves are buildings, vegetations and terrain, and weather conditions [5] – [11]. Consequently, there is emphasis on the research on radio wave propagation loss (attenuation and path loss) especially in complex tropical forest climatic region [8] – [15]. The major adverse effect of radio wave propagation loss when not checked is the complete breakdown of communication systems performance. Therefore, the propagation characteristics of radio signals at a given frequency must be understood before communication links using that frequency can be designed. Once understood, further research is necessary particularly if a new (additional) service is to be introduced that makes unusual demands on radio channels. It is even a policy by European Space Agency: ESA that research on the radio wave propagation should be carried out on the new and existing radio transmitting stations in particular to gain further insight into the nature of the effects of atmospheric conditions on LOS (Line of Sight) and non-LOS propagations [1], [4]. Several research works have been reported in the literatures on the radio propagation loss due to the effects of the forest (trees canopy, trees trunk), air and ground layers, and atmospheric conditions at VHF in the tropical region [9] – [15]. According to [11], the VHF radio wave propagation loss due to the ground and trees canopy reflections, based on ray tracing technique, can be expressed as:

$$L_{GCREFS} = A_{FSLOS} \pm 10\log_{10}(1 + 2\Delta\phi_1\Delta\phi_2),\ \text{dB} \quad (3)$$

Where, $\Delta\phi$ is the phase different between the direct and reflected rays, and it is given by:

$$\Delta\phi = \frac{4\pi h_T h_R}{\lambda d_f}, \quad (4)$$

h_T and h_R are the transmitting and receiving antenna heights over the ground in meters respectively. $\Delta\phi_1$ and $\Delta\phi_2$ are the phase differences between the direct and ground-reflected rays and the direct and tree-canopy reflected rays respectively. While, the ITU-R Recommendations formula for dry air atmospheric attenuation is given as [13], [14]:

$$A_{dry\,\mathrm{air}} = \gamma_a d\ ,\quad \text{dB} \quad (5)$$

Where *d* is distance covered by the radio waves in kilometers, and γ_a is the specific attenuation of the atmosphere in dB/km, which can be extrapolated from the plot of specific attenuation of dry air in [15].

To the best of my knowledge, there is very scarce report in the open literatures on the experimental investigation of VHF radio propagation loss due to the effects of dry hot and dry cool climatic conditions plus the effects of the attenuation due to free space line-of-sight, ground and three canopy reflections in the tropical region. Therefore,

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in this paper, the effects of dry hot and dry cool atmospheric conditions, in addition to effects of the free space line-of-sight attenuation, ground and three canopy reflections, on the VHF radio wave propagation in the tropical region are investigated experimentally. The experimental measured results obtained are compared with the existing ground and tree canopy reflections model (GCREFS) plus dry air attenuation model based on ITU-R P.530-9 and ITU-R P.676-5. Using the method of least square fit to the experimental measured data, the VHF attenuation models in the tropical forest region during dry hot and dry cool weather conditions are presented.

II. Experimental Measurements

The tropical forest region where the experiment took place is between (LAT 8° 29'N, LONG 4° 29'E) and (LAT 7° 50'N, LONG 3° 56'E). In this study, Oyo State Broadcasting Cooperation, 92.1MHz Ajilete FM Transmitting Station, Gambari, Ogbomoso, Nigeria is employed, as a case study, as the transmitting station. The transmitting station consists of the 92.1MHz, 3.5kW transmitter, and transmitting antenna of 130m high. The actual power radiated from the antenna after transmitter and cable losses are deducted is 2.5kW. The experimental measurement set up is as shown in the figure 1a, b. GSP810-Spectrum Analyser (figure 1b) is the receiver system employed and the power supply system. The receiving units were moved in a vehicle to measure the power received in dBm at every 1km along the possible Line of Sight (LOS) through the forest region to cover the distance of 64km from the transmitting station during dry hot and cool weather conditions for the period covering the months of November 2011 to February 2012. In this study, when the air temperature is less than 28°C, the climate is regarded as dry cool during the period under consideration. When the air temperature is greater than or equal to 28°C, the climate is regarded as dry hot. The attenuation of the radio waves was determined based on (2).

III. Results and Discussion

In this study, the experimental investigation of the effects of dry hot and dry cool atmospheric conditions, on the attenuation of VHF radio wave propagation in the tropical forest region is carried out. The measurements were carried out during the months of November 2011 to February 2012 under no wind, and no rain weather conditions when daily average air temperatures were between 22°C and 34°C. The power received in dBm was measured during dry hot and dry cool climatic conditions for distance up to 64km through the forest region from the transmitting station.

The attenuation of the radio waves propagation at VHF (92.1MHz) was determined using Equation (2) for the weather conditions considered. Matlab2007software was employed for the analysis of the results. Figure 2 shows the plots of the attenuation versus distance for the dry hot and dry cool climatic conditions. The variation between the two conditions shows that the VHF signal suffers more loss during dry cool weather condition than during dry hot weather condition. Using the method of least square fit to the measured data, the attenuation models characterizing the VHF (92.1MHz) radio wave propagation loss during the dry hot and dry cool atmospheric conditions in the region of consideration were obtained and shown in (6) and (7) respectively. The summary of the statistical analysis of new models is shown in Table 1.

$$A_{hot} = -11.2\ln(d) - 80.45\text{, dB} \qquad (6)$$

$$A_{cool} = -12.1\ln(d) - 87.14\text{, dB} \qquad (7)$$

The normalized root-mean-square deviation calculated shows that the variation between the two conditions is about 0.19%.

Also, the experimental measured results are compared with the existing ground and tree canopy reflections model (GCREFS) plus dry air attenuation model based on ITU-R P.530-9 and ITU-R P.676-5 [11], [13] – [15]. The statistical analysis comparing the measured attenuation due to the dry hot weather with some existing attenuation models is summarized in the Table 2. The normalized root-mean-square deviation between the measured attenuation due to the dry hot weather and the dry air weather ITU-R model is -1.9%. While, the normalized root-mean-square deviation between the measured attenuation due to the dry hot weather and the GCREFS plus dry air weather ITU-R model is +0.32%. The experimental measured data are fairly favorably in agreement with the GCREFS plus dry air weather ITU-R model prediction.

(a)

(b)

Fig.1. Showing the experimental measurement set-up: (a) the transmitter antenna and (b) the receiver system

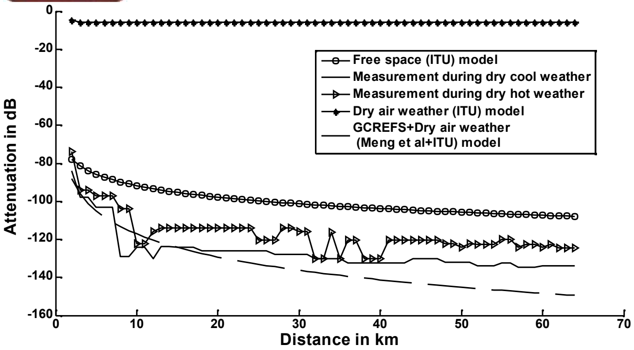

Fig.2. Showing the plots of Attenuation versus distance for measurements during dry hot and cool weather conditions, and compare of measurements with some existing attenuation models.

Table 1: Comparing the measured attenuation with the least square fit attenuation models.

Fitted Attenuations	R^2-Value	Chi Square Test Value
Polynomial (dry cool climate)	0.942	0
Logarithmic (dry cool climate)	0.828	1
Polynomial (dry hot climate)	0.870	0
Logarithmic (dry hot climate)	0.8	1

Table 2: Comparing the measured attenuation during dry hot weather with the measured attenuation during dry cool weather and some other existing models.

MODELS	NRMSD(%)
FSA (ITU) model	-0.32
Dry cool air weather measurements	-0.19
Dry air weather (ITU) model	-1.9
GCREFS + Dry air weather (Meng et al + ITU model)	+0.32

IV. Conclusion

Due to the reported anomalous behavior of radio waves propagation at VHF in the dry season period, this paper investigated the effects of dry hot and dry cool atmospheric conditions on the attenuation of VHF radio wave propagation through the tropical forest region. Using the method of least square fit to the measured data, new attenuation models characterizing the VHF radio wave propagation loss during the dry hot and dry cool atmospheric conditions in the tropical forest region of consideration were obtained. It has been shown that the signals suffer more loss during dry cool weather condition than during dry hot weather condition. When some existing models: free space attenuation model, dry air atmosphere (ITU-R) attenuation model and the ground and tree-canopy reflections (GCREFS) plus dry air atmosphere (ITU-R) model were compared with the measured data, it was found that the measured data are fairly favorably in agreement with the GCREFS plus dry air atmosphere ITU-R model prediction (the normalized root-mean-square deviation is about +0.32%).

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