Effect of Temperature and Ground Water on VHF Radio Wave Propagation in Tropical Climate.

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Abstract: Radio-wave propagationis the study of how radio waves travel through a medium from one point to another. Ultra-high Frequency (UHF) and Very High Frequency (VHF) signals are easily reflected by substances and can also be absorbed by some environmental factors such as relative humidity, wind, air and ground temperature, and vegetation. In this paper we present the results of the experimental investigation of the effect of Ground Temperature and Ground Moisture content ratio on the Very High Frequency (VHF) radio wave propagation in wet tropical climate. The data obtained by the experimental method were analysed by 2D-line plotting using originLab software. The results indicate that with the increase in ground temperature, there is a relative increases in the path loss of the radio wave propagation. The inconsistency in the path loss values is due to effect of other climate and environmental factors that can cause distortion of the radio wave. An inverse relationship between the path loss and the relative humidity was obtained from the plot. That is, a decrease in relative humidity brings about a slight increase in path loss. A lower ground moisture ratio brings about a lower path loss because ground moisture increases the conductivity of the soil which allows for better propagation of the surface wave and the results also show that ground moisture has minimal effect on the value of the signal path loss.

Keywords: Ground, Moisture, Attenuation, signal path loss, relative humidity, VHF

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Introduction

Radio-wave propagation is a term used to explain how radio waves behave when they are transmitted, or are propagated from one point on the earth (or in space) to another. It is the study of how radio waves travel through a medium from one point to another. Ultra-High Frequency (UHF) and Very High Frequency (VHF) signals are easily reflected by substances and can also be absorbed by some environmental factors such as relative humidity, wind, air and ground temperature, and vegetation. This can cause the signal to be weak before reaching the receiver. VHF signals are generally less degraded by moisture than higher bands, such as UHF signals (Springer, 2003).Tropical climate plays a major role in the propagation of radio-waves at various frequencies ranging from VHF (30-300MHz) to UHF (300-3000MHz).

In recent times, particular interest in wireless communication in tropical climatic environments at UHF bands has risen due to increasing global demand for high quality communication systems. The telecommunication sector heavily relies on bands such as UHF (as it is within this frequency range that its mobile telecommunication systems operate) and VHF (for television and radio signals). In order to predict, simulate, and design high performance communication systems, accurate propagation characteristics ofradio waves in various environments have to be known. As radio waves travel through vegetation, there is always some signal loss caused by attenuation which is the reduction in the strength of a signal. For any particular path through a region, the signal loss increases as the distance increases.

The importance and significance of weather on radio wave propagation at different frequency bands has been an important topic since the 1960s and a lot of effort has been put into its research especially through wet tropical regions. Josephson (1958) shows that the influence on field strength from ground moisture and temperature, snow, topography, and vegetation, and also field strength variations along mixed land-water paths have been studied. The moisture in the ground is found to play a principal role and a method is shown for calculation of changes in the path attenuation caused by known or predicted changes in the water content of ground. The influence of temperature is found to be small even when the ground freezes, but a covering of snow may be of greater consequence. The measurements however refer to a terrain typical for middle Sweden which makes it inapplicable to geographic areas within tropical climate.

Scott and Smith (1992) showed by experimental investigation, the effects of increased water content of the soil. The relative permittivity and conductivity will both increase with increasing water content. The relative permittivity is fairly independent of frequency except at the lowest frequencies measured (< 250MHz, that is, at VHF) where it increases with decreasing frequency.

US Army Signal Center and Fort Gordon (2005) assert that as a surface wave passes over the ground, it induces voltage into Earth. The induced voltage takes energy away from the surface wave, thereby weakening (attenuating) the wave as it moves away from the transmitting antenna.

To a considerable extent, the amount of attenuation that a surface wave undergoes due to the induced voltage in the Earth depends on the electrical properties of the terrain over which the wave travels. Any surface that has good electrical conductivity is the best type of surface which enhances better conductivity, less attenuation and better propagation of the signal. The study area has different degrees of conductivity, which determine the rate of radio wave propagation. However, since salt enhances conductivity, salt water can be used in the field when grounding a communications assemblage or generator because of its high degree of conductivity. Moist land surfaces provide fair conductivity, while a dry terrain provides poor conductivity and thus, impedes wave propagation. It can therefore be said that increased ground water content allows for improved radio wave propagation along the Earth.

Aboaba (2006), after statistical and experimental analyses carried out in the south-western (tropical) region of Nigeria, recorded high values of signal strength between the dry months of November and March and concluded as a result of this, that there could be serious consequences for planning of VHF radio broadcasting services because the incidence of interfering signals associated with small time percentages (10% to 0.1%) would be high.

Gunashekar*et al*. (2006) discussed the enhanced signal strengths of UHF radio-wave signals caused by super refraction and tropospheric ducting which depend on micrometeorological conditions in the troposphere particularly the spatial and temporal distributions of water vapour and temperature. While this research is undoubtedly beneficial to the study and design of good propagation techniques and equipment, it still leaves room for much more to be done; especially since they carried out their work based mainly on the UHF band.

In 2009, Liao observed that the moisture content effect of the total field was demonstrated for any earth surface. The clay loam of San Antonio has a dry density of about 1.4g/cm^3, and the corresponding value of relative humidity for each moisture level was obtained from the measurement done Hip (1974). The Author reported that the strength of the field can be obviously affected due to the relative permittivity of the ground surface. In-situ, it was noted that as the field strength, Snow layer and moisture content increases with the signal strength of the vegetation layer decreases. Carol (2001) further explained that the effect of temperature inversion can cause increased range of radio wave propagation by extending wave signals through a means of multi hop refraction.

Alade (2013a; 2013b and, 2013c) reported that ground surface temperature and air (space) temperature have additional propagation loss effect on Very High Frequency radio wave propagation. With high relative humidity, the water vapor content in the air, can affect the refraction, diffraction and scattering of the radio wave. He also studied several other factors that can affect its propagation such as terrain, building, vegetation, weather parameters (such as rain, snow, haze and dust).

The effects of air temperature variation, ground temperature, and groundwater content are undeniable limitations of the radio waves that propagating at VHF signal. The attenuation of VHF signal is noticed, for example, when watching local television stations which propagate over the VHF band. There is a noticeable deterioration of signal strength/quality

With the world showing increased preference for wireless communication over wired communication, it is quite apparent that VHF and UHF will continue to be major options for signal propagation. Hence, it is necessary to study the effects of tropical weather on these signals.

Materials and Methods

This experimental investigation was performed using CR-1000 logger mounted vertically on a casted concrete within the department of Pure and Applied physics, LAUTECH (plate1). Measurement of the receiving signal was performed using GSP-810 analyser, connected to the receiving antenna to measure the radio signal strength from the transmitting station. The received signal generated by the GSP-810 analyser was monitored and recorded throughout the period of experiment. The transmitting and the receiving stations lie within latitude 8^0 08'01'' N and longitude 4^0 14' 48 E. The air temperature variation, ground temperature, ground moisture ratio, and relative humidity were measured alongside with the receiving signal. Also the receiving power was calculated as well as path loss for each reading of signal strength received. The initial readings of the received signal strength were recorded in decibel metres, results were converted to milliwatts used in calculations by the formula: $X = 10log_{10}\left(\frac{P_t}{P_r}\right)$, where X= value in dBm, P_t = transmitting power in mW and P_r = received power in mW. The measurements were carried out between the months of August and September, 2015.

Results and Discussion

In this work, the result of temperature variation and ground water content effects on VHF Radio wave propagation during wet tropical climate is presented. The measured data obtained were compared critically. The data were analysed by 2D-line plotting using originLab software. Figure 1 s a graph of path loss and ground temperature against the period of the experiment, the results shows that with the increases in ground temperature, there is a relative increases in the path loss of the radio wave propagation. The inconsistency in the path loss values is due to effect of the other climate and environmental factors that can cause attenuation of the radio wave. Figure 2 shows the graph of the path loss and relative humidity against the period of experiment. The results show an inverse relationship between path loss and relative humidity, that is, a decrease in relative humidity brings about a slight increase in the path loss. Figure 3 shows the graph of path loss and ground moisture ratio against the period of the experiment.

The implication herein is that a lower ground moisture ratio brings about a lower path loss. The reason for this could be traced to the fact that ground moisture increases the conductivity of the soil which allows for better propagation of the surface waves. We therefore report that ground moisture ratio has minimal effect on the value of the path loss.

Conclusion

We have presented a detailed result of temperature inversion and its importance to the propagation of radio wave in this paper. The frequently changing weather conditions of the tropical climate implies that environments that lie within the tropics are prone to such usual events that facilitate radio waves to have higher signal strength and travel over longer distances than normally expected. It is important to note that other environmental factors also influence the propagation of radio waves in the tropics. Researches in larger scale are encouraged to further affirm the result of this work.

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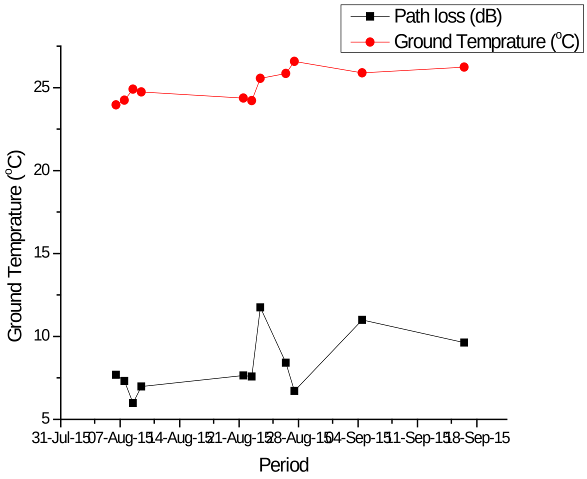

Figure 1: Graph of Path Loss and ground temperature against period

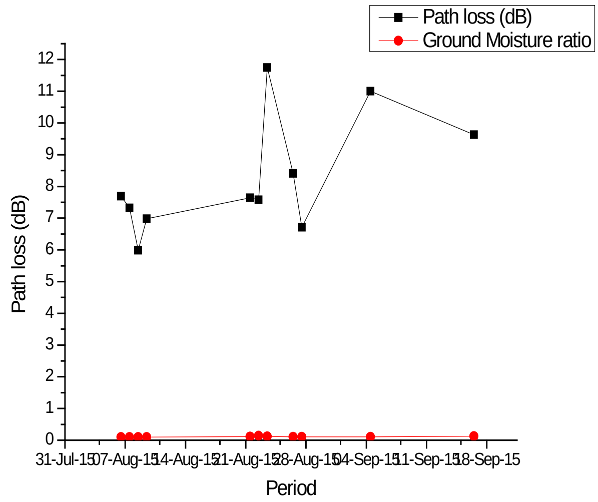

Figure 3: Graph of Path Loss and Ground Moisture against Period

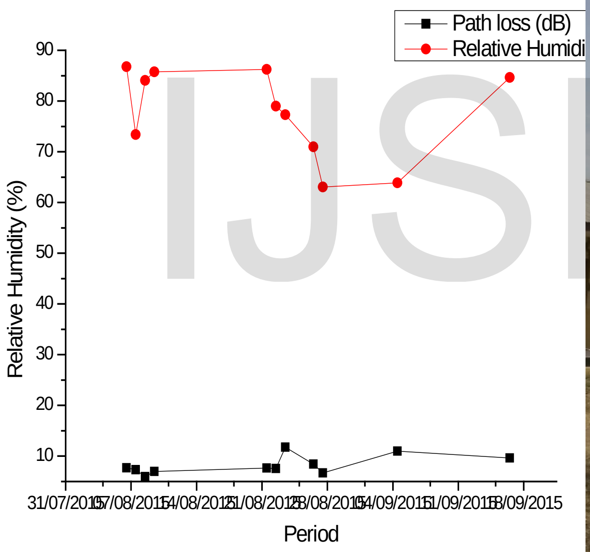

Figure 2: Graph of Path Loss and Relative Humidity against Period

Plate 1: CR-1000 logger

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