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Research Article

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Influence of Tropospheric Variables on Signal Strengths of Mobile Networks in Calabar, Nigeria

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AbstractThis work investigates how mobile network signals are affected by tropospheric variables. A TEMS investigation software installed in a laptop was used in obtaining log files of signal strength for the four networks while a digital thermometer/hygrometer was used to measure temperature and relative humidity, simultaneously. Collected data was averaged on a weekly basis. Graphs of signal strengths against the tropospheric variables were plotted for each network and in each case, the tropospheric variables were the independent variable while signal strength was the dependent variable. Also, correlation and regression analysis were made for a better description and understanding of how tropospheric variables affect signal strengths of mobile networks operating in Calabar. Results show that only signals from MTN network was affected by temperature and relative humidity. A weak relationship between tropospheric variables and signal strength was obtained for Glo, Airtel and 9mobile. This shows that signals transmitted from the base stations of the four networks were affected by terrain, transmitter power and the frequency band which the signals are transmitted.

Keywords Signal strength, Tropospheric variables, Mobile networks, Base stations, Signal transmission

Introduction

Signal transmission occurs in the lower layer of the atmosphere called the troposphere, where all weather events occur [1]. The troposphere is the portion of the earth's atmosphere that spans from the surface of the earth to a height of about eighteen kilometers at the equator and about six kilometers at the poles. Here, temperature decreases with altitude. Hence, clouds form and turbulence occur due to variations in relative density, temperature and pressure [2]. In this region, signals, usually transmitted as radio waves, are affected by unfavourable weather conditions during propagation such that signal quality reduces giving rise to signal losses [3-6].

When radio waves are transmitted, they are affected by weather parameters such as rain [7-8], wind [9], relative humidity [10], temperature [11], sand and dust storms [12]. As a result, the transmitted signal undergo absorption and interference [13], refraction [14-15], scattering [16], reflection [17], fading and attenuation [18]. This introduces distortions to terrestrial communication systems [19], causing transmission error and affecting signal quality [20].

In Nigeria, network operators rely on transmitting signals through the troposphere without pre-evaluation and characterization of the troposphere and this is the reason for poor QoS. To describe the reliability of networks, one needs to know which weather parameters affect the propagation of signal and the changing weather conditions, which may cause severe degradation in system performance [21]. Unfortunately, this is highly unstable, in terms of both spatial and temporal variability [22]. Clouds, which result from the effect of evaporation and increased humidity are the most unpredictable of all meteorological parameters [23], hence causing signal path losses and consequential distortions in signal transmission.

Several researches have in different regions investigated the effect of tropospheric variables on received signal strength. [24] investigated the impact of atmospheric temperature on Ultra High Frequency (UHF) signal. Signal strength from Cross River State Broadcasting Co-operation Television (CRBC-TV), transmitted at 35mdB and 519.25 MHz were measured using a Cable TV analyzer in a residence along Etta-Agbor, Calabar, simultaneously with weather parameters. The weather components along with signal strength were measured every 30 minutes from the residence for over 24 hours to obtain reasonable data set for analysis. Radio signal strength varied inversely with atmospheric temperature, provided, other measured meteorological components were observed constant. The correlation of the signal strength and atmospheric temperature was 0.93 and the equation S = K/T was postulated, where S, T and k are signal strength, atmospheric temperature and constant respectively.

[25] studied the impact of the force of atmospheric humidity on Ultra High Frequency (UHF) radio signal where it was shown that radio signal strength varied inversely with atmospheric humidity. The correlation of the signal strength and atmospheric humidity was found to be -0.94 and the equation SP = K was postulated, where S, P and k are signal strength, atmospheric pressure and constant respectively.

The influence of atmospheric temperature and relative humidity on FM radio signal strength was investigated by [26]. The We FM radio station which operates in Abuja at a frequency of 106.3 MHz was studied. The measurement location was done in a residence in Karshi, Abuja. A S-110 Community Access Signal Meter (CATV) was used to measure the signal strength, while the digital hygrometer/thermometer was used in measuring the relative humidity and temperature respectively. The research was carried out during cloudy and uncloudy days. The calculated correlation coefficients of temperature and signal strength for the two days were -0.42369 and -0.51878. The calculated correlation coefficients of relative humidity and signal strength are 0.29 and 0.39. This result shows that as signal strength reduces, temperature increases but signal strength increases with increase in relative humidity.

[27] studied the effects of atmospheric temperature and wind speed on UHF radio signal. The experiment was carried out in the Automated Weather Station Signal Strength Meter (AWSSSM) in the Department of Industrial Physics, Enugu State University of Technology (ESUT), from a signal receiving system which was set up by connecting a high gain UHF antenna and spectrum analyzer coupled to a laptop system. The high gain UHF antenna transmitted at 519 MHz and Ku band signal of 11.7-12.7 GHz with a Global Positioning System (GPS) of longitude 7.5, latitude 6.3. Measurement was taken for a period of five months starting from the month of April to August 2017. The signal strength in the KU band spectrum was obtained every two seconds daily and simultaneously the meteorological components were observed. The curves for signal strength on temperature and wind speed were obtained. It was observed that temperature inversion in the tropospheric layer causes a ducting effect which affects radio signals. Consequently, the speed of wind was found to have an effect on the bending capability of the wave.

The received signal strength and path loss of a GSM (Globacom) Network operating at a frequency of 900MHz in Umuahia, Nigeria using drive test was evaluated by [28]. During the period of investigation, low signal quality was discovered. Results from simulation of the acquired data using Matlab reviewed a considerable decline in the Received Signal Strength Level (RSSL), mainly due to increase in vegetation, population and building heights. An increase in the frequency band was recommended to remedy the effect of path loss within this study area.

[29] examined five experimental broadcast models- Egli's model, free space model, ECC model, COST 231 Hata model and ERICSSON Model for path loss performance in Owerri, Imo State, Nigeria. A drive test was carried out to obtain the real-time field data on the Long Term Evolution (LTE) operating at a frequency of 700MHz. A TEMS Investigation tool was used to obtain log files while a TEMS Discovery software was used in the analysis of the log files. Results obtained shows that Ericsson model was found to best predict the environment with a minimum deviation of 10.11dB being closest to the measured path loss with 2.01dB compared to the other models.

The research by [30] was aimed at assessing and comparing the performance of four cellular networks (MTN, Airtel, 9mobile and Globacom) operating in Calabar, using their Received signal Strengths (RSS). An extensive measurement of RSS was conducted and collected over base stations in Calabar, through a benchmarking drive test. This was possible with the aid of a TEMS investigation software running on a Windows 10 operating system laptop. A total of 8,640 RSS measurements were taken for 3 months (April to June, 2021). Graphs and bar charts were plotted and statistical analyses (calculations of standard deviations and standard errors of mean) made for a better visualization and understanding of RSS data trends. Average signal levels for the three months was obtained as 65dBm for MTN, -70dBm for 9Mobile, -72dBm for Airtel and -68dBm for Globacom, while the most obtained signal level was -68dBm for MTN, -70dBm for 9Mobile, -72dBm for Airtel and -67dBm for Globacom. Results obtained shows good signal coverage for the four mobile networks. However, the four networks experienced signal fluctuations which could be attributed to meteorological factors and terrain. This result is useful to the network operators and RF planners for the assessment of their network performance, planning and optimization.

[31] presented and compared the degree of propagation loss as radio signals travels through foliage. The propagation loss due to foliage of CRBC signals transmitted on 519.25MHz was measured and compared with the Weissberger modified exponential decay model and the Early ITU model. The result shows a high correlation between the measured propagation loss and the model’s predictions. The plots of the data obtained from the measurement against the predictions of the models shows a higher correlation between the measured data and the Weissberger predictions.

This work addresses the effects of temperature and relative humidity on signal strength of the four cellular networks in Calabar. It is hoped the results , will be found useful to NCC, network operators and designers, policy makers in Calabar – Nigeria as those help determining the right QoS for efficient network planning and optimization.

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Materials and Methods

The central idea of this research is to investigate the relationship between signal strengths of the major mobile networks and some meteorological parameters such as temperature and relative humidity. The study location of this research is Calabar and the cellular networks investigated are MTN, Airtel, Globacom and 9Mobile. A Garmin Global Positioning System (GPS), four W995 TEMS mobile phones, four SIM cards, one for each network, TEMS 15.1 investigation software, a laptop, a USB hub, a car inverter and a car, a digital thermometer and hygrometer are the materials used for this research.

The SIM cards were slotted into the TEMS phones while the TEMS investigation software was installed in the laptop. The TEMS phones were powered by connecting them to the USB hub which is plugged to the laptop. The GPS, which is also powered by the laptop, gives the location for the drive test. An extensive drive test measurement was conducted and signal strength data were collected over base stations in Calabar, using TEMS investigation software running on a Windows 10 operating system laptop. While taking readings of the signal strengths, readings of temperature and relative humidity was simultaneously collected hourly with the aid of the digital thermometer and hygrometer for 12 weeks.

Collected data was averaged on a weekly basis. Graphs of signal strengths against the tropospheric variables were plotted for each network and in each case, the tropospheric variables were the independent variable while signal strength was the dependent variable. Also, correlation and regression analysis were made for a better description and understanding of how tropospheric variables affect signal strengths of mobile networks.

Results & Discussion

The relationship between temperature and relative humidity was investigated for the four major mobile networks in Calabar. Obtained data were averaged on a weekly basis. Graphs were plotted, correlation and regression analysis between the tropospheric variable and signal strength of mobile networks was made for a better visualization of the relationship between the variables. This is shown and discussed in figures 1 to 8.

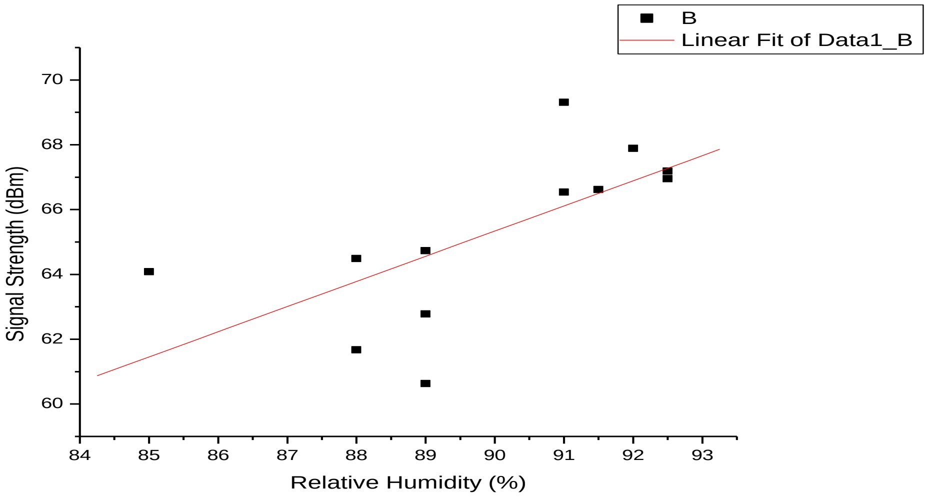

Figure 1: Graph of signal strength against relative humidity for MTN network

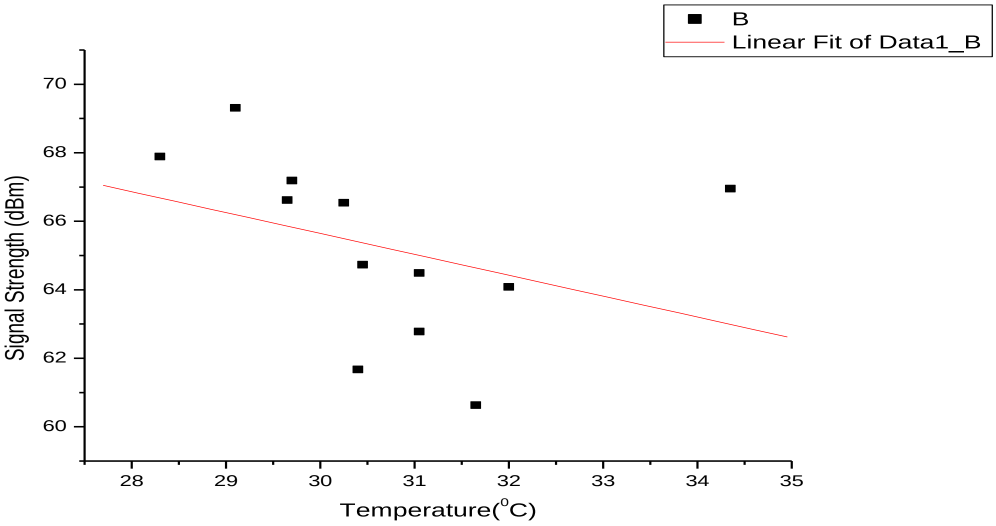

Figure 2: Graph of signal strength against temperature for MTN network

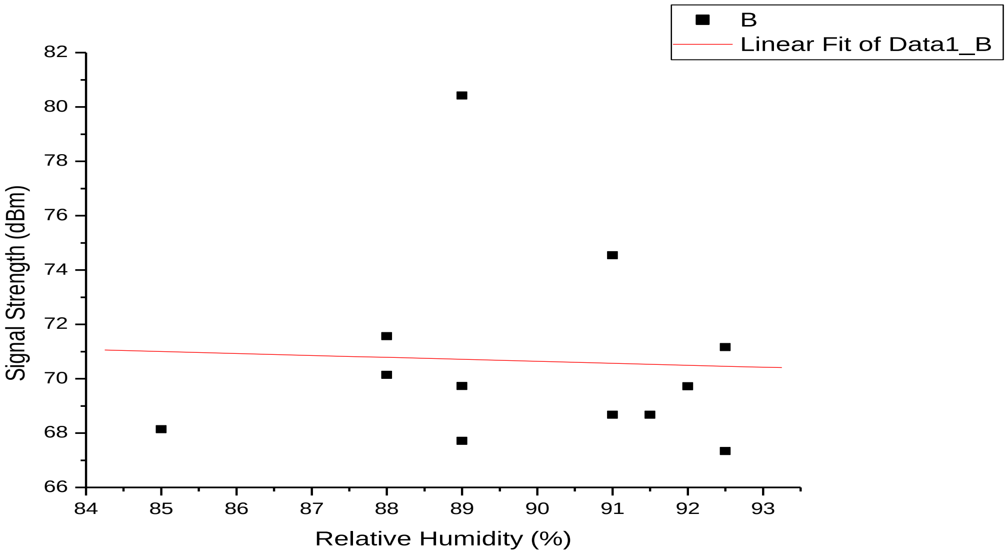

Figure 3: Graph of signal strength against relative humidity for Airtel network

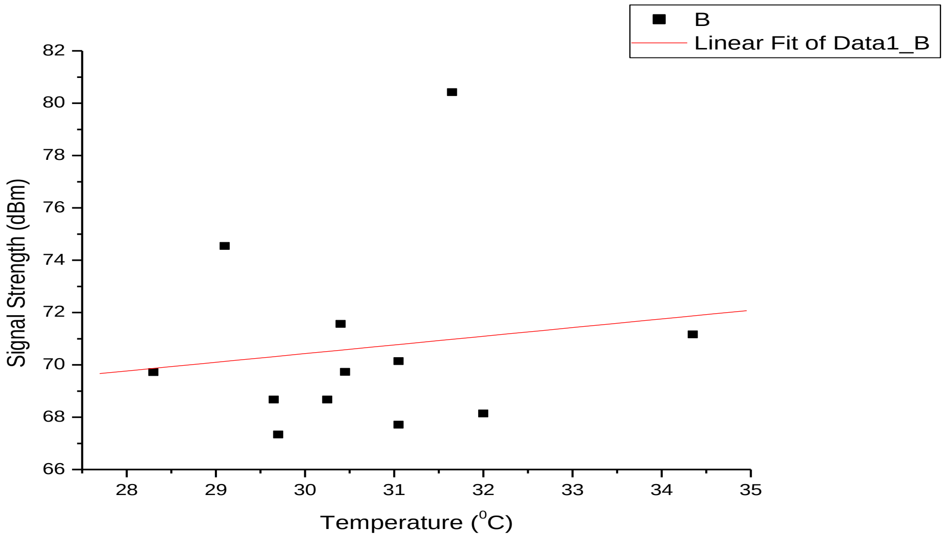

Figure 4: Graph of signal strength against temperature for Airtel network

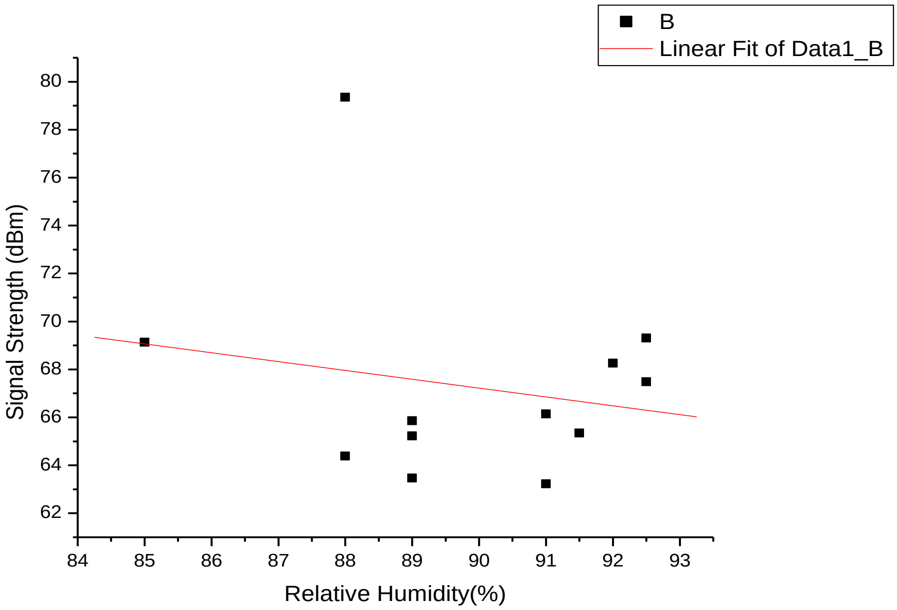

Figure 5: Graph of signal strength against relative humidity for Glo network

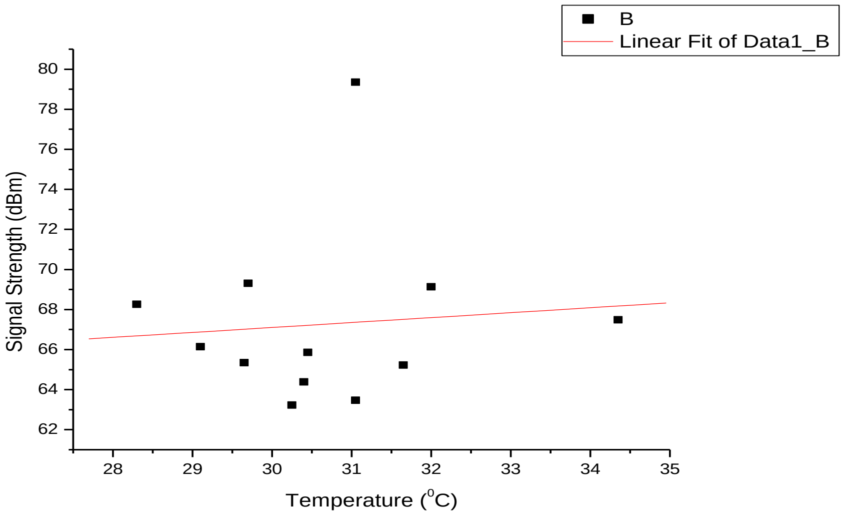

Figure 6: Graph of signal strength against temperature for Glo network

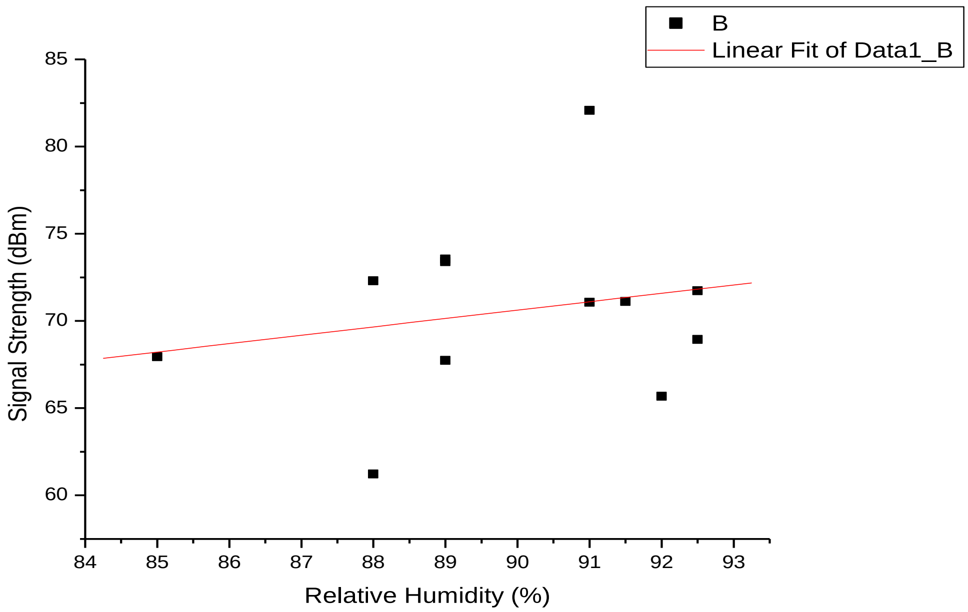

Figure 7: Graph of signal strength against relative humidity for 9mobile network

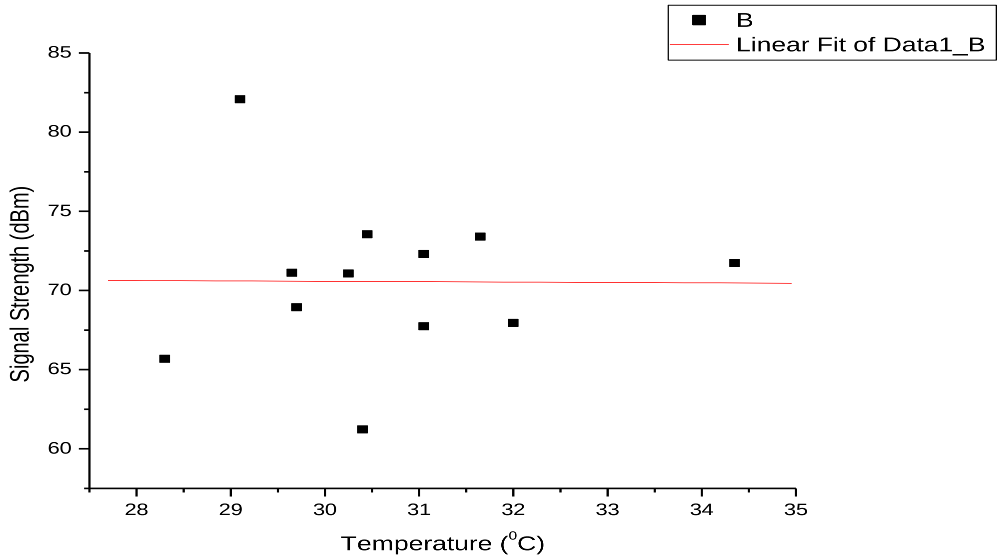

Figure 8: Graph of signal strength against temperature for 9mobile network

Figure 1 and Figure 2 are graphs of signal strength against relative humidity and signal strength against temperature respectively, for MTN network. For signal strength against relative humidity, a correlation coefficient of 0.81 was obtained with a regression model $S = 0.78R - 4.53$. For signal strength against temperature, a correlation coefficient of -0.60 and a regression equation $S = -0.61T + 83.95$ was obtained. For MTN, increase in relative humidity led to an increase in signal strength while an increase in temperature led to a decrease in signal strength and vice versa.

Figure 3 is a graph of signal strength against relative humidity for Airtel network. A correlation coefficient of -0.20 with a regression equation of $S = -0.07R + 77.13$ was obtained. This shows that an increase in relative humidity slightly led to a decrease in signal strength. A relationship between temperature and signal strength for Airtel network was further investigated in Figure 4. A regression model $S = 1.29T + 57.14$ with correlation coefficient 0.38 was realized. This shows a slightly positive relationship between signal strength and temperature.

An analysis of Glo network is described in Figure 5 and Figure 6. A relationship between signal strength and relative humidity as shown in Figure 5 results in negative correlation coefficient of -0.44 with regression equation S = -0.37 + 100.43. Figure 6, a graph of signal strength against temperature results in a low correlation coefficient of 0.30 with regression equation S = 0.25 + 59.71.

Figure 7 and Figure 8 are graphs of signal strength against relative humidity and signal strength against temperature respectively, for 9mobile network. For signal strength against relative humidity, a fairly weak correlation coefficient of 0.46 was obtained with a regression model S = 0.48R + 27.35. For signal strength against temperature, a correlation coefficient of -0.09 and a regression equation S = -0.02T – 71.29 was obtained. This shows no relationship between signal strength and temperature for 9mobile network.

In all regression equations above, S, R, and T represents signal strength, relative humidity and temperature. The relationship between meteorological variables and signal strength for the four networks did not follow a regular pattern. This could be as a result of the terrain, transmitter power and frequency bands which the operators transmit signals.

Conclusion

An investigation of the effect of tropospheric variables on signal strengths transmitted from the base stations of four major networks was analyzed. Collected data was averaged on a weekly basis. Graphs of signal strengths against the tropospheric variables were plotted for each network and in each case, the tropospheric variables were the independent variable while signal strength was the dependent variable. Also, correlation and regression analysis were made for a better description and understanding of how tropospheric variables affect signal strengths of mobile networks. The relationship between tropospheric variables and signal strength for the four networks did not follow a regular pattern. This could be as a result of the terrain, transmitter power and frequency bands which the operators transmit signals.

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