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# Design and Construction of a Weather Instrument and Its Use in Measurements to Determine the Effects of Some Weather Parameters on GSM Signal Strength

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**Abstract:** The design and construction of a weather instrument and its application to study the effects of some weather parameters on GSM signal strength in Port Harcourt metropolis have been successfully carried out. The design was implemented using a DHT11 humidity and temperature sensor, and Sim900 GSM module/A6 GSM module; 20x4-character Liquid Crystal Display (LCD) and an ATMEGA 8 microcontroller. The constructed device was used to measure relative humidity, temperature and signal strength. The values obtained were in good agreement with those got using a standard weather station as the designed and constructed weather instrument which was calibrated against the standard weather station in Port Harcourt measured relative humidity and temperature, with accuracy of about 98.3% and 86%, respectively. Physical measurements were carried out using the constructed weather station from July to December, 2017 covering the wet and dry seasons/part of harmarttan period in the study area. The data were analyzed using Microsoft excels 2013 version and analogue plots were digitized/quantized for more effective study of the fluctuations during the seasons by considering the peaks, dips and peak-to-dip values. Results showed that changes in weather conditions affect GSM signal strength, significantly. Variation in signal strength can be best explained by the variation in temperature which appears to be the best explanatory variable for signal strength variation and has a negative linear effect on signal strength. Relative humidity also has effects on signal strength, particularly in the months of November and December. Generally, the correlation between GSM signal strength, and temperature and relative humidity is negative and low/poor. Signal strength fluctuations were least in August/September and highest in December when the atmosphere is least and most perturbed, respectively. Our findings will be useful in designing GSM algorithms and protocols which are adaptive against the effects of weather and in GSM transmission planning in this part of the world.

**Keywords:** Construction, Weather Instrument, Weather Parameter, Signal Strength, Port Harcourt

## 1. Introduction

### *1.1. GSM Signal Strength and Weather Instrument*

Global System for Mobile Communications (GSM) is a telecommunication network that is used globally for communication services such as voice communication, data connection for fax, short message service (SMS) and full dial-up connection to the internet for e-mail and web browsing [1]. It is known that weather can significantly affect GSM signal strength and GPS observations because they occur in the troposphere [2]. Studies have, however, shown that the transmitted radio signals may go through spatial and temporal changes due to variations in atmospheric conditions as well as other environmental factors and that fluctuations of the atmospheric parameters like temperature, pressure and humidity in the troposphere cause the refractive index of the air in this layer to vary from one point to another [3]. There can also be spatial variation in weather, which affects GSM signal strength. While changes in weather conditions are inevitable and may have significant effects on GSM signal strength, they are usually measurable and could be mitigated based on experimental measurements. Hence, it is essential to explore weather-related factors affecting GSM signal strength in order to mitigate their impact and to adapt to varying conditions. Such studies will be useful to GSM providers in planning so as to improve the quality of service (QoS) of their networks.

Several researchers have proposed, designed and built miniaturized low cost wireless weather station/instrument to measure accurate temperature, relative humidity, light intensity and atmospheric pressure [4-9].

Dalip and Vijay [10] investigated the effects of environmental parameters on Global System for Mobile Communication (GSM) and Global Positioning System (GPS). They assessed variation in GSM signal strength as a function of weather parameters. The results obtained in their measurements showed values for GSM signal strength in the range -41 to -89 dBm. The performance of the GSM signal strength was also studied and its fluctuations were recorded as its receiver changed its state of motion [10]. Onuu and Adeosin [11] investigated propagation characteristics of UHF waves in Akwa-Ibom State and were able to characterize cities.

This work, which involves design and construction of weather instrument, is undertaken because of dearth of equipment for the measurement of weather elements in order to study their effects on GSM signals towards improving QoS, is path of our ongoing programme in investigating characteristics of radio waves and the factors affecting them as they propagate through cities. Port-Harcourt is chosen for this investigation because of its nature – having a wide-range of urban conditions resulting in observed rapidly varying changes in the troposphere.

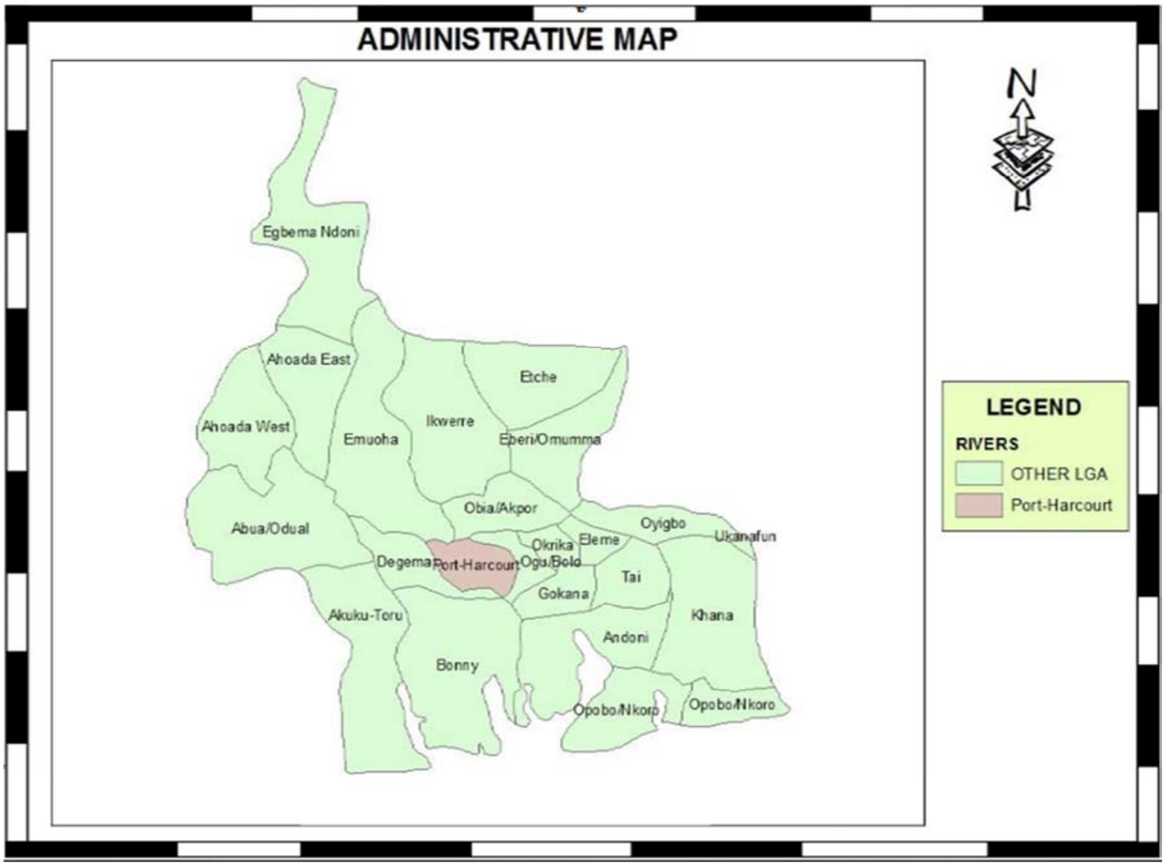



***Figure 1.*** *Administrative map of Rivers State showing Port Harcourt, the study area.*

### *1.2. About Port-Harcourt city*

Port-Harcourt is a metropolitan city [12] and the capital of Rivers State in the Federal republic of Nigeria (Figure 1). It occupies approximately 1811.6 km$^2$ area [13] and has a population of about 1.5 million [14]. It is Rivers State's main city and has one of the largest seaports in the Niger Delta region; thus being a centre of administration, commerce, and industrial activities. Port Harcourt is located between Latitudes 4°450 N and 4°550 N, and Longitudes 6°550 E and 7°050 E and is situated at the entrance of the Bonny River. The city is bounded in the north by Abia and Imo States, east by Akwa-Ibom State, west by Bayelsa State, and south by the Atlantic Ocean. Its estimated mean altitude is 12 km above average sea level, lying between the Dockyard Creek/Bonny River and the Amadi Creek [13]. Port-Harcourt, like every other city in Nigeria, has two distinct seasons, namely, dry season and rainy reason. Nonetheless, the atmosphere sustains adequate moisture throughout the year. The city's proximity to the South Atlantic explains the increased annual relative precipitation resulting in heavy and persistent rainfall owing to the strong south-west wind. Wind force reduces as it approaches inland. Mean minimum and maximum temperatures are approximately 21°C and 34°C, respectively, with the months of April through October, which constitute major path of the rainy season having the highest temperatures. Like other Nigerian cities, the interaction between two major pressures and wind systems drives the entire weather system in Port-Harcourt, River State. They include the two actively produced sub-tropical high-pressure cells (anticyclones) that are centered over Azores Archipelago (off the west coast of North Africa) and St. Hellena Islands (off the coast of Namibia). These permanent high-pressure centres create and run the North-East trade winds and the South-West winds, respectively, which are the northward extension of the re-curved South-East trade winds of the South Atlantic Ocean.

# 2. Materials and Method

## 2.1. Materials

The materials used in the design and construction of the weather instrument, together with their features and some technical details, are highlighted below.

i. DHT11 humidity and temperature sensor. The DHT11 humidity and temperature sensor has digital outputs and reacts to relative humidity and air temperature of the atmosphere (Figure 2). It has three pins, relative humidity range (20 – 90%), relative humidity accuracy (±5%), temperature range (0 – 50°C), temperature accuracy (±2°C), operating voltage (3-5.5V), very low power consumption and a calibrated digital signal output.

ii. SIM900 GSM GPRS and SIM A6 GSM modules. The SIM900 GSM GPRS and SIM A6 GSM modules were used in the measurement of GSM signal strength. The SIM900 is a complete Quad-band GSM/GPRS solution module. It delivers GSM/GPRS 850/900/1900 MHz performance for voice, SMS, data and fax in small factor with low power consumption. The SIM A6 GSM is a mini GSM/GPRS core development board based on GPRS A6 module that supports dual-band GSM/GPRS network, available for GPRS and SMS message data remote transmission. Both SIM900 GSM GPRS and SIM A6 GSM modules are compatible with any GSM network operator SIM card.

iii. Other components of the device are: Liquid Crystal Display (LCD). The Liquid Crystal Display (LCD) used is the 20 x 4, 4 line 20 characters-type. It is a flat panel electronic visual display device that uses the light modulating properties of liquid crystals for the display of data as output. Other features of the LCD are: built-in HD44780 Equivalent LCD Controller that works directly with AMTEGA, ARDUINO, PIC and many other microcontroller kits, 4- or 8-bit data I/O interface and low power consumption.

iv. ATMEGA8 microcontroller. The ATMEGA8 microcontroller is an 8-bit Automatic Voltage Regulator (AVR) microcontroller that is based on Reduced Instruction Set Computer (RISC) architecture, mainly used in the embedded system, to unite and control the activities of the device.

v. 74LS08 (Quad AND gates). The 74LS08 (Quad AND gates) is an IC and integrated circuit for AND gates (Figure 3). Its role was to establish effective communication between the GSM modules and the microcontroller. Some features of the 74LS08 (Quad AND gates) are four independent AND gates, standard pin configuration, fast switching times, operating temperature up to 70°C, and standard TTL switching voltages.

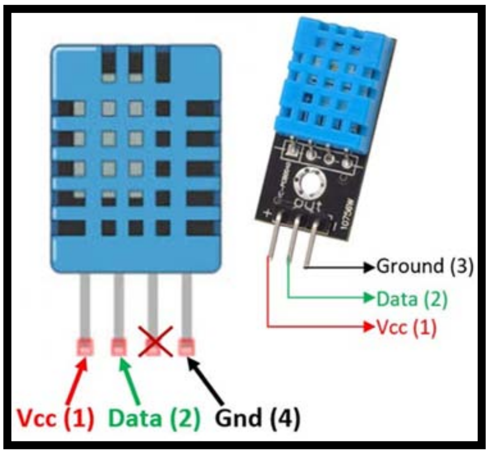



***Figure 2.*** *DHT11 Humidity and Temperature Sensor.*

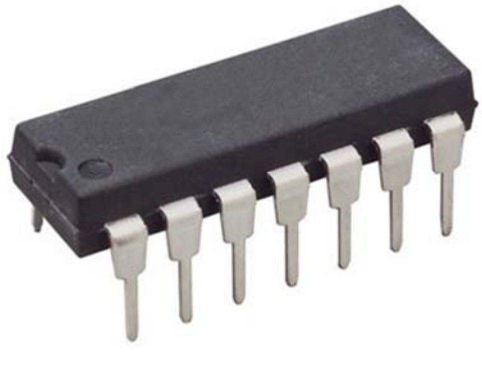


***Figure 3.*** *A 74LS08 (Quad AND gates) IC.*

vi. Power supply unit. Power supply unit was built and used in the construction of the weather instrument (Figure 4). It is a 5V, 700mA power supply unit module which was used to power the A6 GSM module and the transformer used to power the 7805, 5V regulator that in turn powered the microcontroller and the SIM900 module. It also comprised a IN4001 rectifying diodes used as a bridge rectifier to convert the ac from the transformer into a pulsating dc. In addition, the power supply unit was made up of a 1000µf, 25V capacitor which was used in filtering the pulsating dc fed-in from the bridge rectifier; a switch used as a power button to ON/OFF the device; resistors of 1kΩ and 10kΩ and a C1815 bipolar junction transistor and a 15V output transformer which was used to power the microcontroller module and the SIM900 module. A 12V dc fan was used for cooling the 5V regulator (7805) and buttons used to aid the human-machine interface.

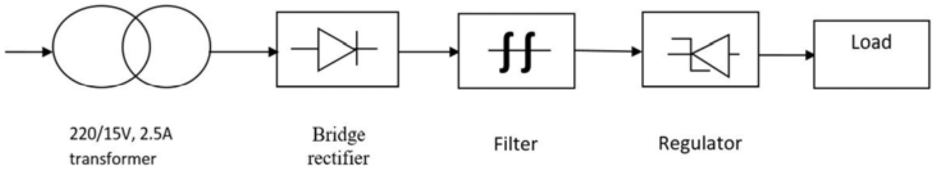



***Figure 4.*** *Block Diagram of the power supply unit.*

### *2.2. Method and Operation*

The components used in the construction were connected as shown in the block diagram in Figure 5. The weather instrument was calibrated using the application software, the Analog weather station version 2.8.7.1. Figure 6 shows the interfacing and circuit diagram of the device. When the system is powered, all the modules are initialized, that is, conditions and mode of operations are given out by the microcontroller. After an hour as it is programmed, the microcontroller receives information from the Relative Humidity and Temperature (RHT) sensor and the GSM modules. The information is then stored in the microcontroller. With the help of the buttons, the information is then displayed on the LCD.

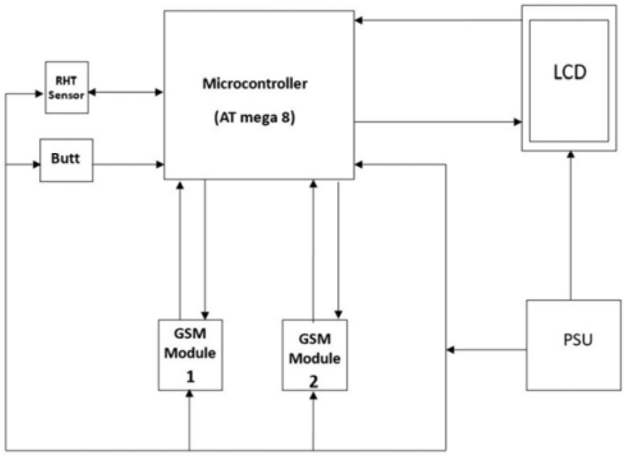



***Figure 5.*** *Block diagram of the weather station.*

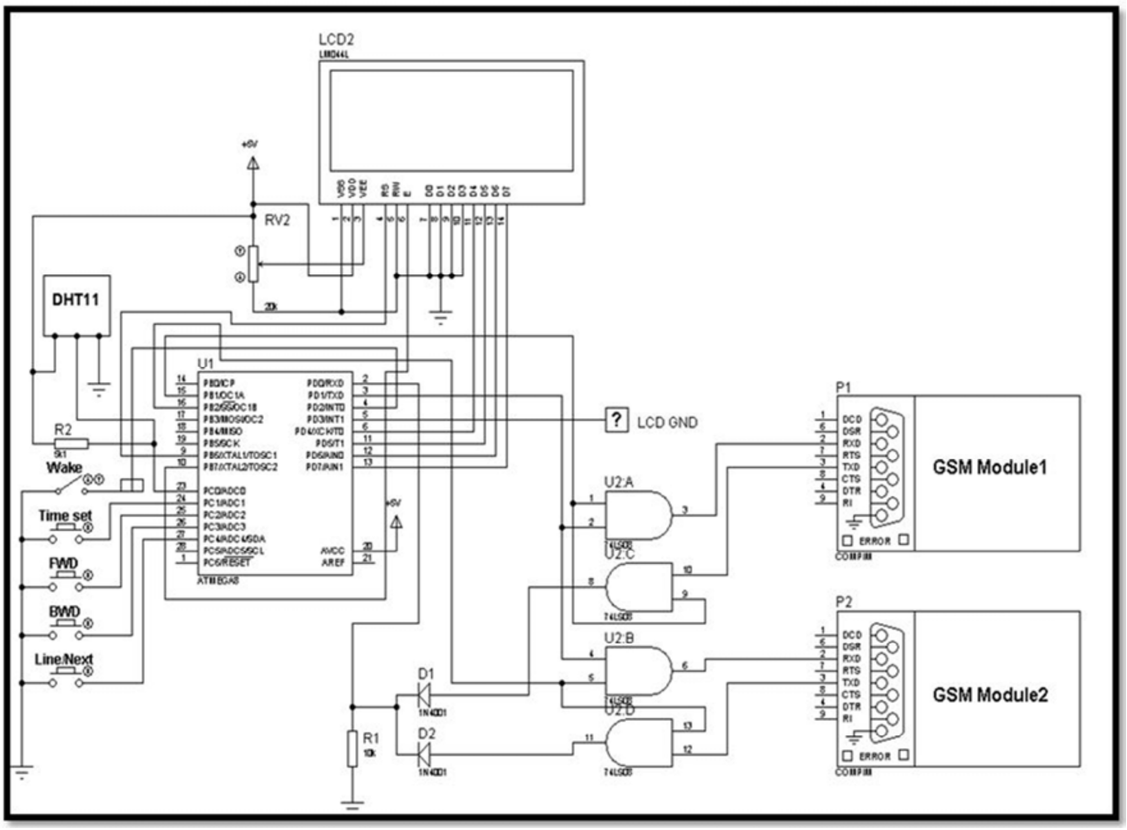



***Figure 6.*** *Interfacing and circuit diagram.*

### *2.3. Testing of the Weather Instrument, Measurements and Analysis*

The various materials were first coupled on breadboard and the device was then tested. After being powered, the device worked well and readings were randomly taken. The components were then transferred to a permanent board and soldered according to the proposed circuit plan, and the device was finally coupled on a case designed for it shown in the schematic diagram (Figure 7).

The display unit (Figure 8) showed time, date, temperature readings in their various units, relative humidity in percentage and signal strength in dB.

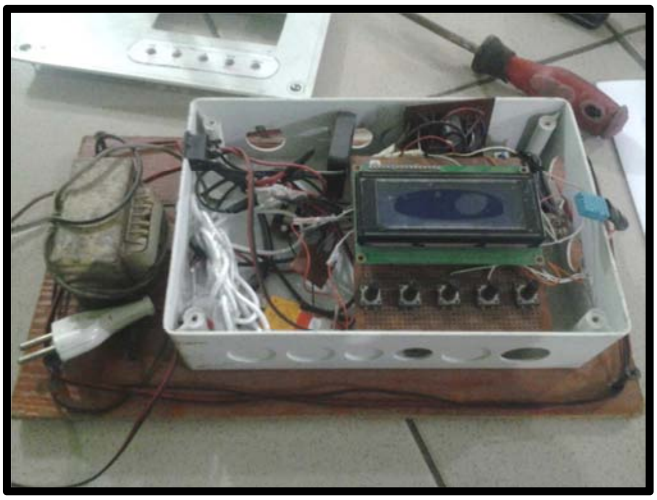


***Figure 7.*** *The developed weather instrument showing its display unit.*


***Figure 8.*** *The designed weather instrument.*

The device then was connected to an a.c. source and then the power button was switched on. When the system was put on, the microcontroller quickly sent instructions (conditions and mode of operation) to all the modules in the system for initialisation. At this point, the in-built clock began to tick and after an hour, as it was programmed, the device automatically measured and recorded at the same time, the relative humidity, atmospheric temperature and GSM signal strengths of both Airtel and Etisalat networks and stored them in its memory. The device continued to measure and store data at every interval of one hour for twenty-four hours of the day. The data stored were made visible and readable on the LCD with the help of the control buttons. A total of 24 readings each for relative humidity, atmospheric pressure and GSM signal strength for Airtel and Etisalat networks were obtained each day, on a continuous basis, and the average of each was computed using the eqn. (1) defined by Tuttuh *et al.* [15].

$$Average = \frac{Sum\ of\ each\ data}{Numbers\ of\ data} \quad (1)$$

From the data accumulated, graphs were plotted to illustrate the relationship between the variables. The graphs were plotted using EXCEL software.

## 3. Results and Discussion

### *3.1. The Weather Instrument*

The schematic diagram of the weather instrument that was successfully designed, constructed and used to measure relative humidity, temperature and GSM signal strength is shown in Figure 7. It was calibrated against a standard weather station and was found to agree very well with the latter. For example, the average values of the weather parameters measured with the designed and constructed instrument compared well with those measured with the standard weather station in Port Harcourt being in the respective ranges of 59-97% and 60-100% for relative humidity and 23-30°C and 25-30°C for temperature. This shows that the designed and constructed weather instrument has percentage accuracy of 98.3 and 86 as used to measure relative humidity and temperature, respectively. On the whole, the designed and constructed weather instrument compares very well with the standard weather station and other instrument designed by other investigators for the measurement of relative humidity and temperature as well as in low power consumption [4-9].

### *3.2. Weather Parameters and Signal Strength for July to December*

The daily averages of the variables were then analysed using microsoft excell 2013 version and displayed for the months for ease of comparison. Analyses of temperature and relative humidity with signal strength was carried out to determine possible relationships between GSM signal strength, and temperature and relative humidity. Further analysis was carried out to determine the extent of linear relationship between them. The plots of GSM signal strength versus daily values of temperature, relative humidity for the two networks, Etisalat and Airtel, for the months of July-December were recorded as shown in Figures 9 to 14 while Figures 15 and 16 show daily variation of signal strength for the two GSM networks.

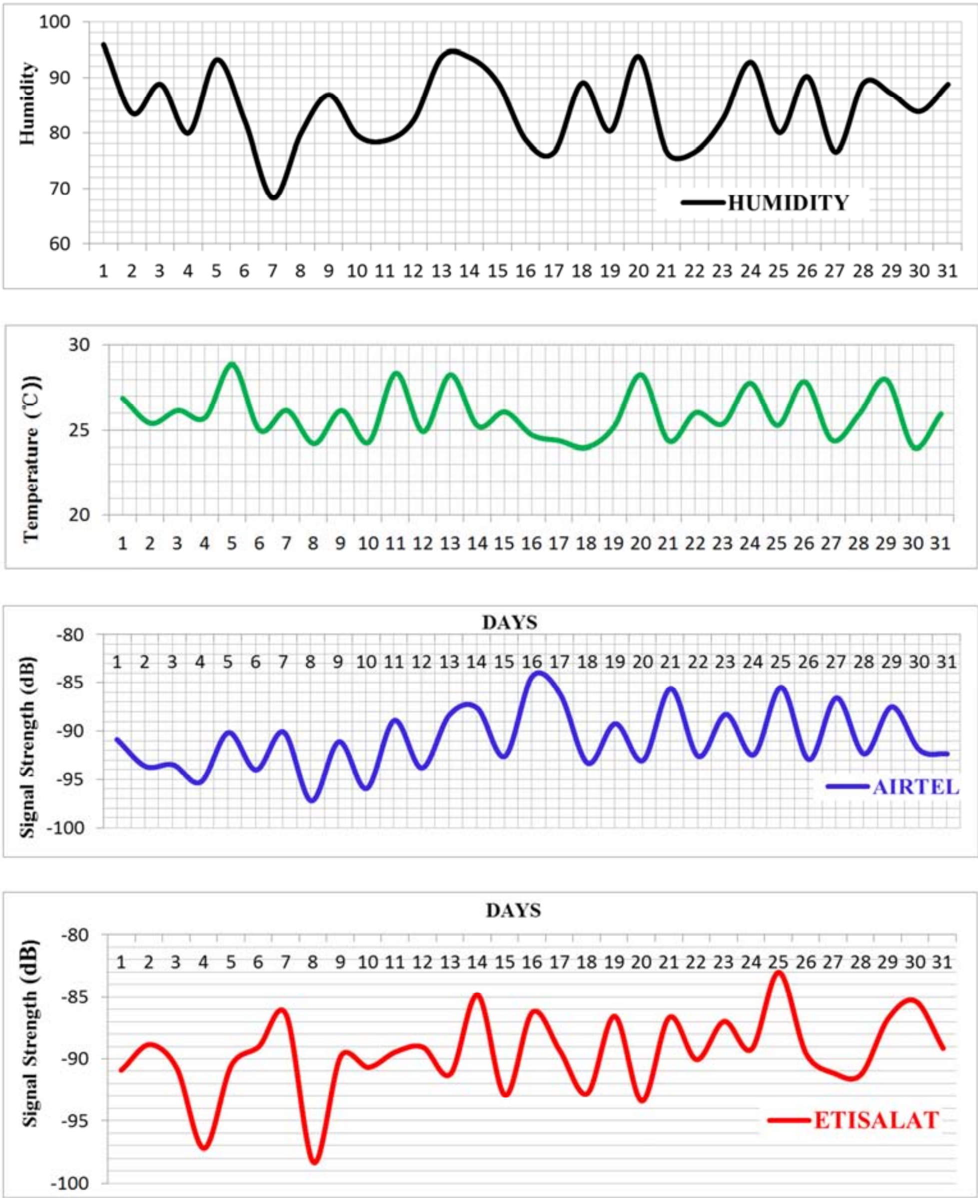
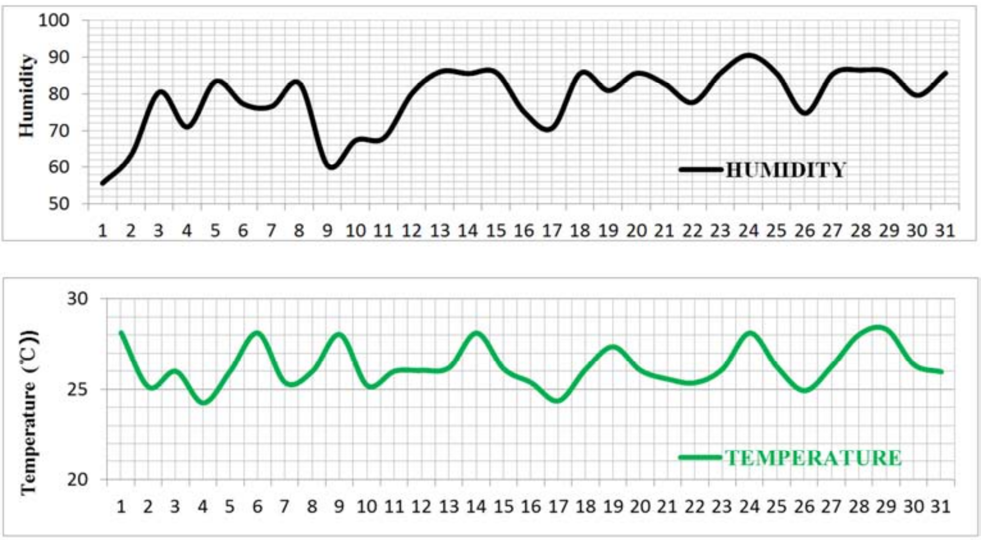



*__Figure 9.__ Daily variation in signal strength for Airtel and Etisalat networks (dB) with temperature (T) and relative humidity (RH) for the month of July, 2017.*



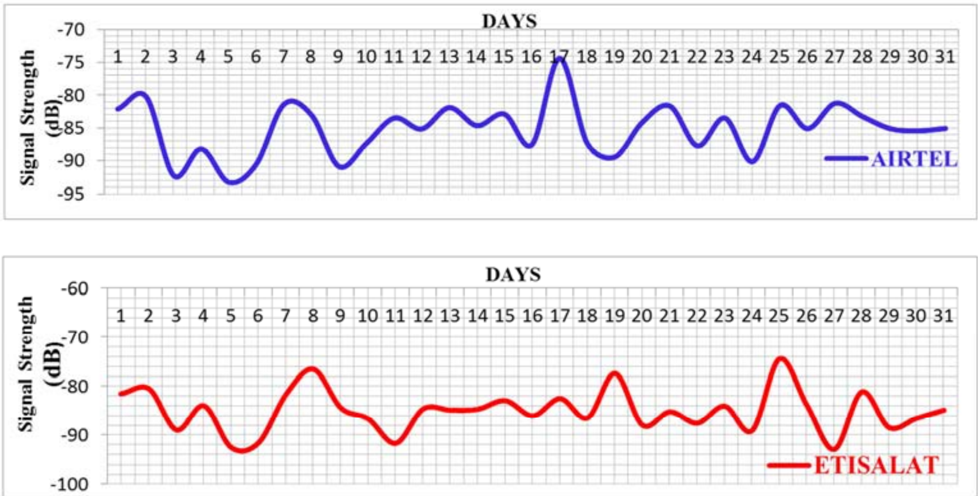



***Figure 10.*** *Daily variation in signal strength for Airtel and Etisalat networks (dB) with temperature (T) and relative humidity (RH) for the Month of August, 2017.*

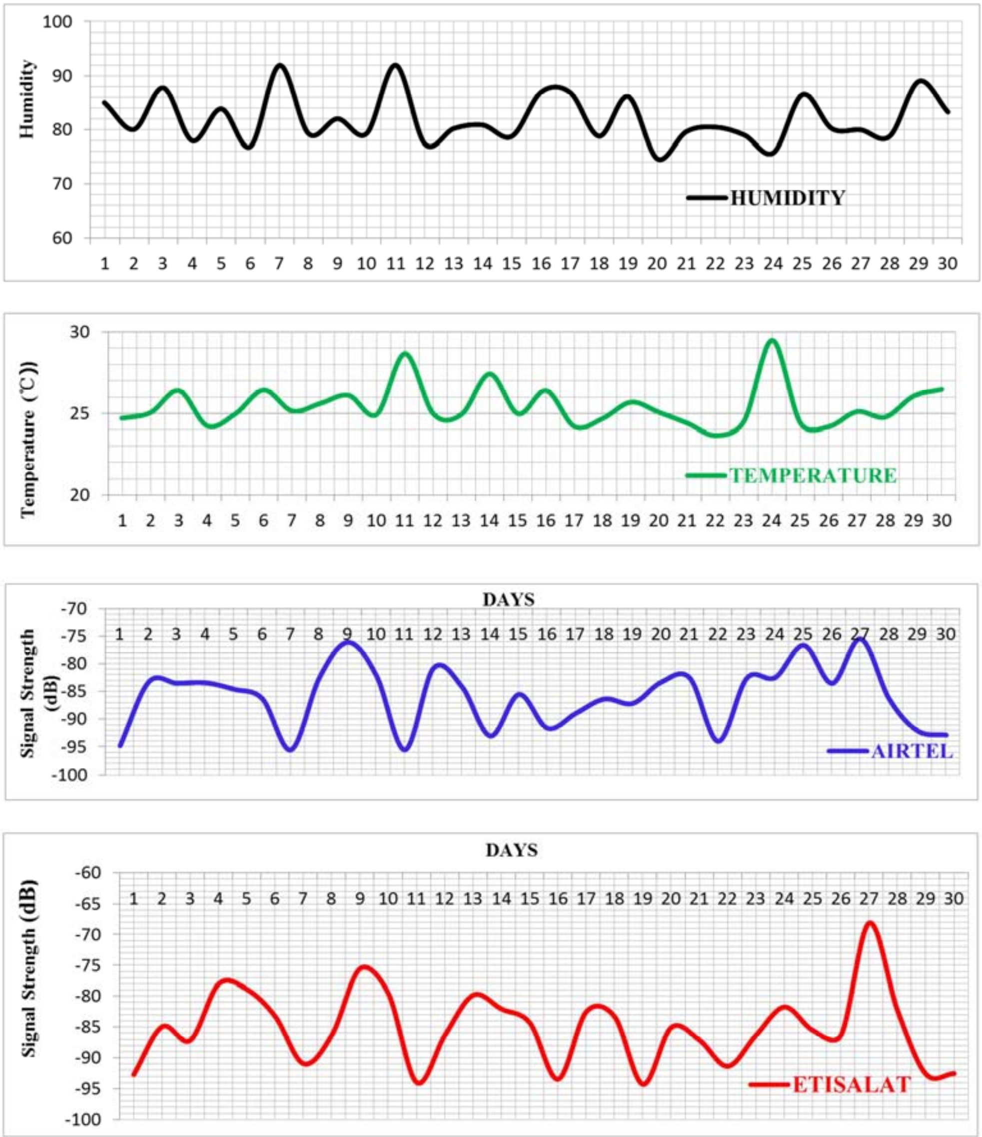



***Figure 11.*** *Daily variation in signal strength for Airtel and Etisalat networks (dB) with temperature (T) and relative humidity (RH) for the month of September, 2017.*

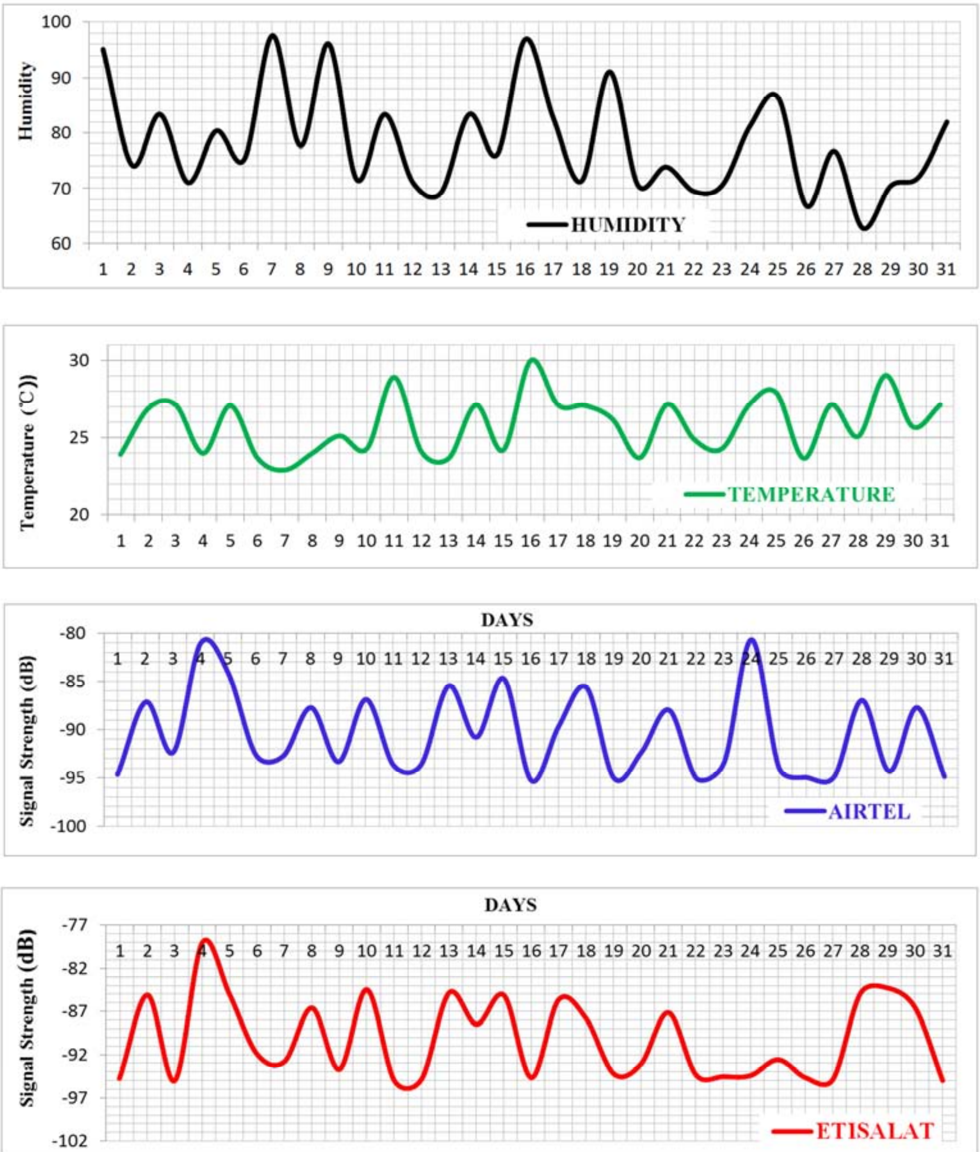
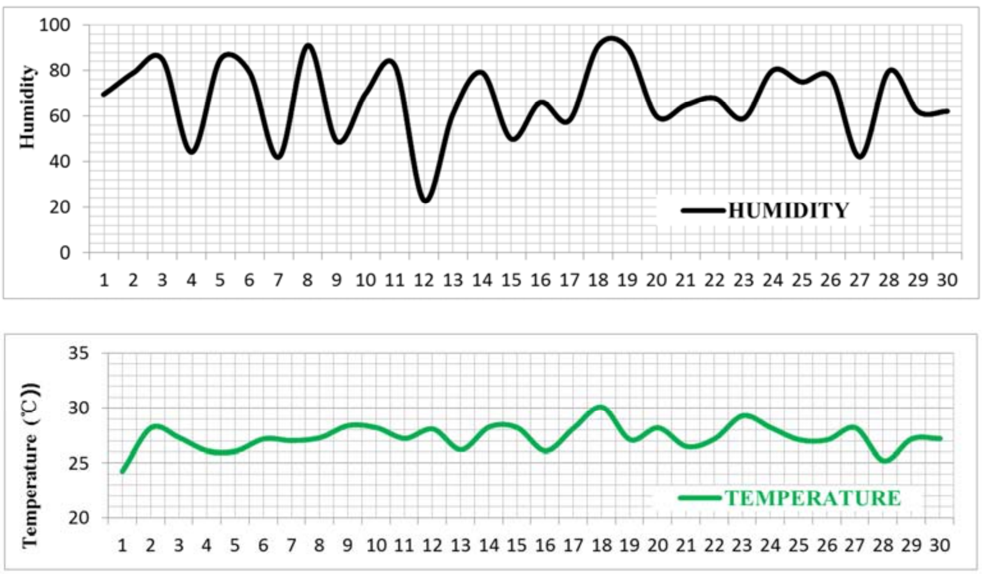



***Figure 12.*** *Daily variation in signal strength for Airtel and Etisalat networks (dB) with temperature (T) and relative humidity (RH) for the month of October, 2017.*



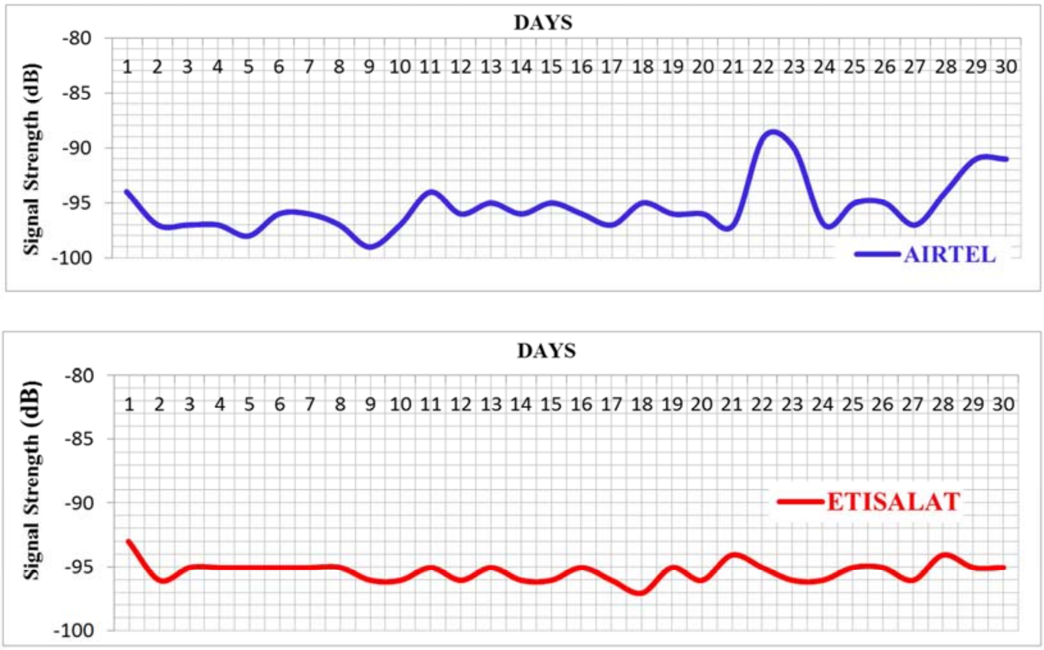
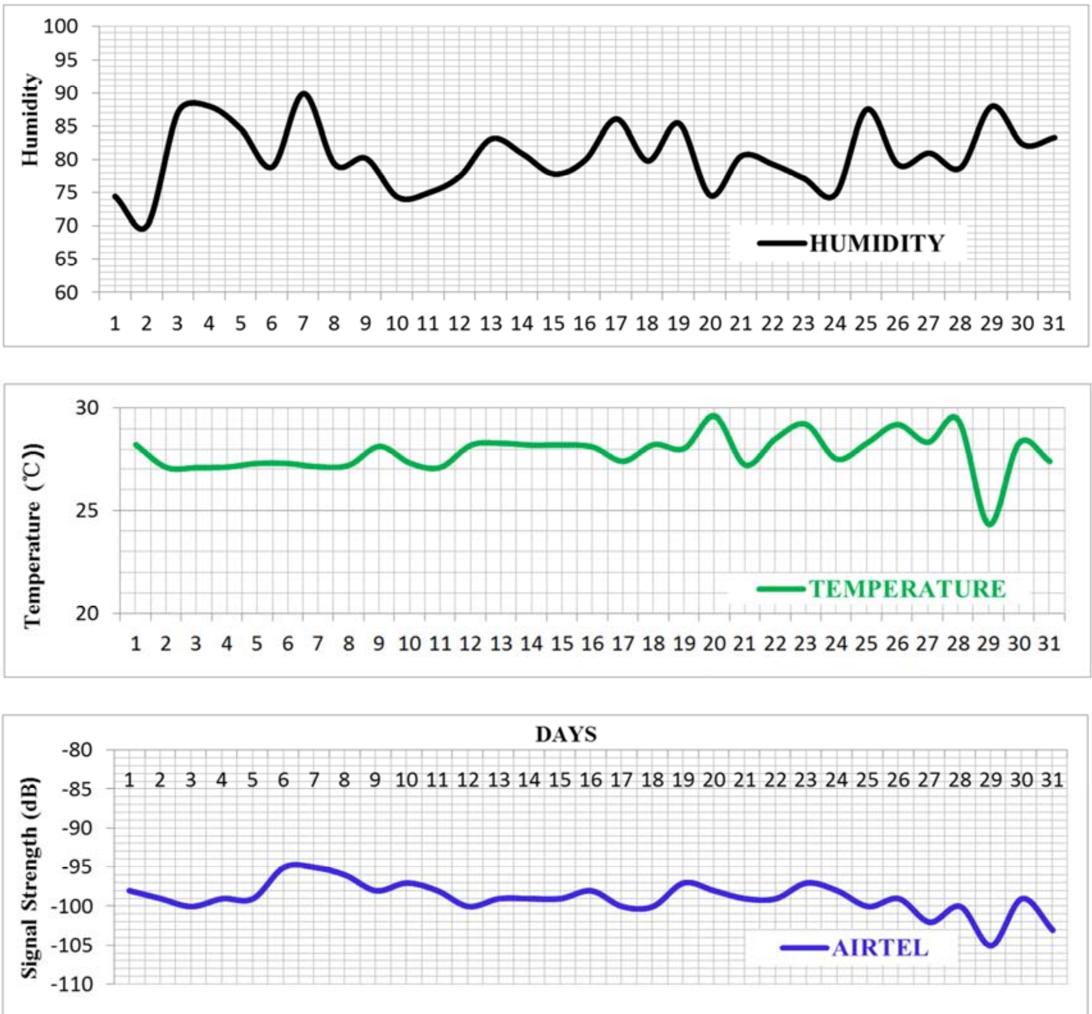



***Figure 13.*** *Daily variation in signal strength for Airtel and Etisalat networks (dB) with temperature (T) and relative humidity (RH) for the month of November, 2017.*



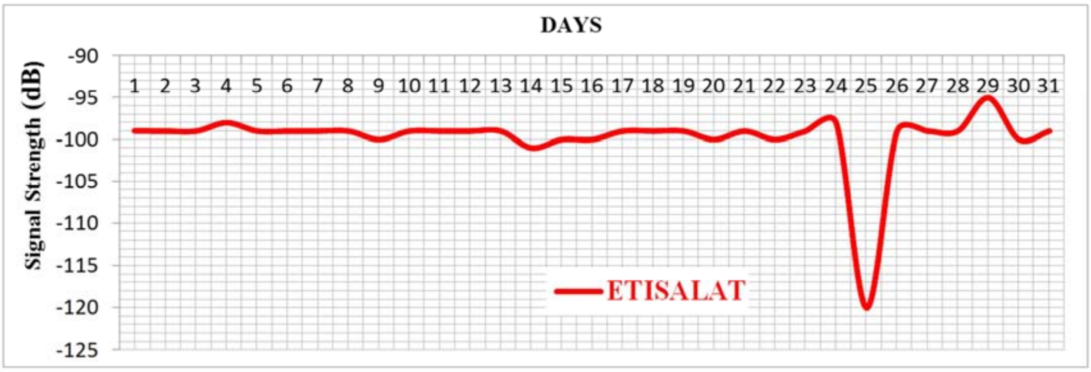



*Figure 14. Daily variation in signal strength for Airtel and Etisalat Networks (dB) with temperature (T) and relative humidity (RH) for the month of December, 2017.*

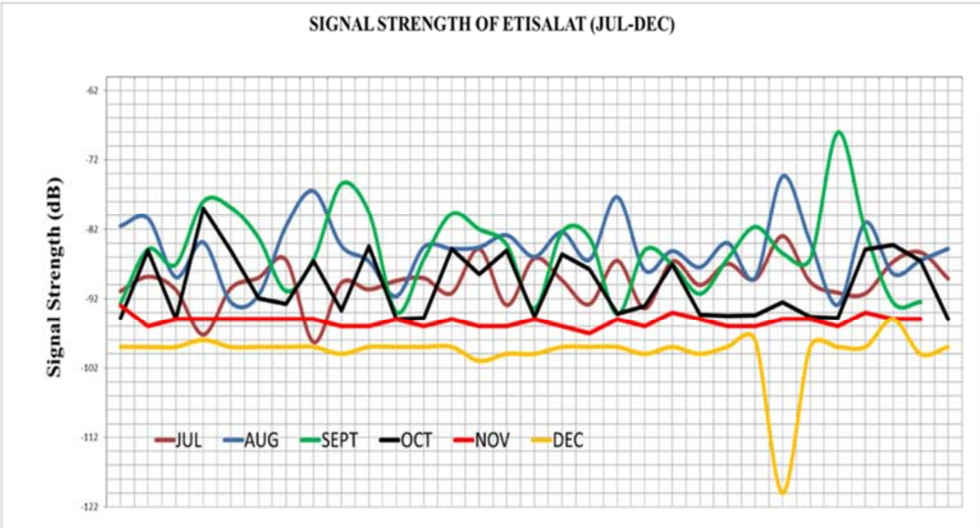



*Figure 15. Daily variation in signal strength for Etisalat network (dBm) for the months of July – December, 2017.*

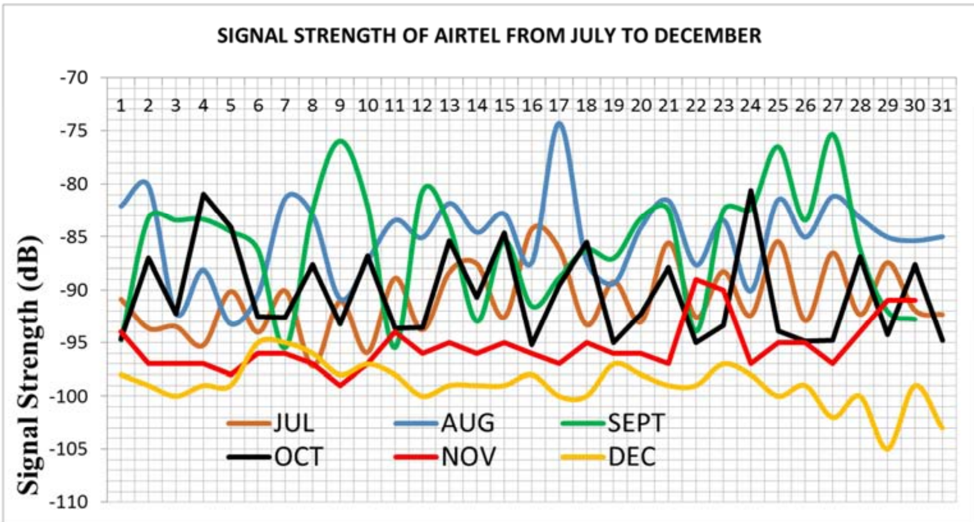



*Figure 16. Daily variation in signal strength for Airtel network (dBm) for the months of July – December, 2017.*

### *3.2.1. Effects of Temperature on Signal Strength*

As seen in Figures 9-14, it is observed that temperature has effect on GSM signal strength and that there could be a relationship between them. July, August, September and October are considered to be the wet season in Port Harcourt whereas November and December are considered as the dry season. To get a better understanding, Pearson correlation coefficient was computed to measure the degree of linear dependence of GSM signal strength temperature. Table 1 shows the Pearson correlation values for the months of July to December, 2017. Temperature has weak but considerable effect on signal strength. A linear, negative trend can be observed for all the links except for July (Etisalat and Airtel) and December (Etisalat) which are positive. Also, there are some variations regarding magnitude of the impact (regression coefficient). As can be seen from Table 1, the correlation between GSM signals and temperature is low and negative, although the correlation coefficient can have different values [16-18]; depending, perhaps, on location. Further, the GSM signal varies negatively with temperature in all months. An exception is observed in July and December which with positive and low correlation values for Airtel network.

#### 3.2.2. Effects of Relative Humidity on Signal Strength

From results, humidity is high in wet seasons but gradually decreases as season changes to dry (Figures 9-14). Humidity is lowest in late November and December. We also computed the Pearson correlation coefficients. The summary of the relationship between relative humidity and GSM signal strength is also presented in Table 1. Relative humidity has a weak and negative correlation with GSM signal strength from July to December. In November, signal strength for Etisalat network and relative humidity have a very low positive correlation. This is likely due to the humid nature of the season and shows that there may be other factors affecting it as it varies also [16, 17].

### 3.3. Variation of Network Signal Strength (July – December, 2017)

Figures 15 and 16 show daily variation of signal strength for Etisalat and Airtel networks for the months of July-December, 2017, respectively. It is seen that signal strength variation is least for the month of December and highest for the month of September for the Etisalat network (Figure 15). Signal strength is fairly flat for the month of November but varies month in September. Irrespective of the month, signal strength varies between -74 and -100 dB.

From Figure 16, it seen that signal strength is fairly flat for the month of November and is highest for the month of August when variations are least and highest, respectively, for the Airtel network. For this network, fluctuation in signal strength is in the range -75 to -108 dB.

Similar variations in signal strength with irregular peaks and dips were obtained by Sa'adu *et al.* who assessed variation in signal strength with MTN, Etisalat and Airtel networks Gusau, Zamfara State, Nigeria [19].

### 3.4. GSM Signal Strength and Weather Elements

#### 3.4.1. Empirical Relationships Between GSM Signal Strength, Temperature and Relative Humidity

Table 1 shows parameter estimates of the regression lines in the empirical relationships between GSM signal strength, temperature and relative humidity for the networks.

**Table 1.** *Parameter estimates of regression lines.**

| Month | Network | T and RH regressed on SS | $m_1$, $m_2$ | $c_1$, $c_2$ | Correlation coefficient, $r$ |
|---|---|---|---|---|---|
| Jul. | Etisalat | T | -0.0927 | -83.007 | -0.0908 |
| | | RH | -0.0843 | -82.444 | -0.1736 |
| | Airtel | T | 0.044 | -91.994 | 0.0193 |
| | | RH | -0.0927 | -83.007 | -0.1885 |
| Aug. | Etisalat | T | -0.0297 | -82.749 | -0.0842 |
| | | RH | -0.0507 | -80.978 | -0.0993 |
| | Airtel | T | -1.0062 | -58.624 | -0.2918 |
| | | RH | -0.0297 | -82.749 | -0.0641 |
| Sep. | Etisalat | T | -0.618 | -69.402 | -0.1339 |
| | | RH | -0.6661 | -30.525 | -0.5068 |
| | Airtel | T | -0.8998 | -62.894 | -0.2084 |
| | | RH | -0.621 | -34.897 | -0.5051 |
| Oct. | Etisalat | T | -0.1596 | -77.831 | -0.0772 |
| | | RH | -0.2164 | -73.154 | -0.4304 |
| | Airtel | T | -0.3033 | -82.514 | -0.1296 |
| | | RH | -0.1596 | -77.831 | -0.3391 |
| Nov. | Etisalat | T | -0.0018 | -95.209 | -0.9265 |
| | | RH | 0.0073 | -95.791 | 0.1531 |
| | Airtel | T | -0.0634 | -93.596 | -0.0306 |
| | | RH | -0.0018 | -95.209 | -0.0131 |
| Dec. | Etisalat | T | -0.1103 | -89.98 | -0.2570 |
| | | RH | -0.1485 | -87.772 | -0.1853 |
| | Airtel | T | 0.5739 | -114.85 | 0.2775 |
| | | RH | -0.1103 | -89.98 | -0.2620 |

* Equations estimated are $SS = m_1T + c_1$ and $SS = m_2RH + c_2$ where *SS* is signal strength in *dB*, *T*, temperature in °C and *RH,* relative humidity in%.

Regression analysis showed linear relationship between GSM signal strength, *SS*, and temperature, *T,* and relative humidity, *RH*. These linear relationships are:

$$SS = m_1T + c_1 \quad (2)$$

for signal strength in dBm and temperature in °C, and

$$SS = m_2 RH + c_2 \quad (3)$$

for signal strength and relative humidity in%.

Generally, negative and very low/poor correlation between signal strength and temperature, and relative humidity for almost all the months and both networks was obtained (Table 1). Several other investigators have studied the variation/relationship between signal strength and weather elements [20-22].

### *3.4.2. GSM Signal Strength Variation and Weather Elements*

Table 2 shows the peak, dip and peal-to-dip values of GSM signal strength for the two networks, temperature and relative humidity. These show the analogue values (Figures 9-16) that have been digitized or quantized. From Table 2, it is clear that signal strength varies in: peak from -74.3 (August) to -94.5 dB (December), dip from -93.2 (August) to -104.1 (December) and peak-dip from -167.5 (August) to -198.6 dB (December) for the Airtel network. For the Etisalat network, similar variations in signal strength are: peak, -68.0 (September) to -94.9 dB (December); dip, -93.9 (August) to -120.3 dB (December) and peak-dip, -162.3 (September) to -215.1 dB (December). From the analysis, it could be seen that least fluctuation in signal strength occurs in August and September while the highest occurs in December for both networks. This could be attributed to "August break", characterized by the absence of rain that now occurs in the month of August or September and lasts for a week or two. During this period, scattering radio waves is reduced and the signal is less perturbed. On the other hand, the month of December, the harmattan period, is characterized by haze and other aerosols in the atmosphere. These cause perturbation of atmosphere and the propagating radio wave. Earlier researcher had noticed obstruction of radio signal during harmattan and absence of radio line-of-sight [11, 23, 24].

***Table 2.*** *Summary of variation of GSM signal strength and weather parameters.*

| Month | Signal Strength (dB) | | | | | | Temperature (°C) | | | Relative Humidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Airtel | | | Etisalat | | | | | | | | |
| | Highest | | Peak-Dip | Highest | | Peak-Dip | Highest | | Peak-Dip | Highest | | Peak-Dip |
| | Peak | Dip | Value | Peak | Dip | Value | Peak | Dip | Value | Peak | Dip | Value |
| Jul. | -84.3 | -97.2 | -181.5 | -83.0 | -98.2 | -181.2 | 29.0 | 24.0 | 5.0 | 95.0 | 68.0 | 27.0 |
| Aug. | -74.3 | -93.2 | -167.5 | -74.4 | -93.9 | -168.3 | 28.5 | 24.1 | 4.4 | 90.7 | 60.5 | 30.2 |
| Sep. | -75.4 | -95.5 | -170.8 | -68.0 | -94.2 | -162.3 | 29.5 | 24.2 | 5.3 | 92.1 | 74.1 | 18.0 |
| Oct. | -80.6 | -95.2 | -175.8 | -79.0 | -96.0 | -175.0 | 30.1 | 24.0 | 6.1 | 98.0 | 62.9 | 35.2 |
| Nov. | -89.5 | -99.0 | -188.6 | -94.2 | -97.3 | -191.5 | 30.1 | 25.0 | 5.1 | 93.2 | 22.0 | 71.2 |
| Dec. | -94.5 | -104.1 | -198.6 | -94.9 | -120.3 | -215.1 | 29.6 | 24.4 | 5.3 | 90.5 | 69.0 | 21.5 |

Similarly, analogue temperature and relative humidity variations were digitized to obtained their corresponding varying values viz: peak, 28.5 (August) to 30.1°C (October and November); dip, 24.0 (July and October) to 25.0°C (November); peak-dip, 4.4 (August) to 6.1°C (October) for temperature and peak, 90.5 (December) to 98.0% (October); dip, 22.0 (November) to 69.0% (December) and peak-dip, 18.0 (September) to 71.2% (November) for relative humidity. Variations in temperature and relative humidity occur least in July/August and highest later in November/December for obvious reasons – the rainy season and dry season/harmattan periods, respectively.

## 4. Conclusion

Results showed that changes in temperature and relative humidity affect received GSM signal strength for the networks considered as shown in the regression equations that have been developed. Generally, the correlation between GSM signal strength, and temperature and relative humidity is negative and low/poor. Signal strength fluctuates least in August/September and highest in December when the atmosphere is least and most perturbed, respectively. Our results will be useful in designing GSM algorithms and protocols which are adaptive against the effects of weather and in GSM transmission planning in this part of the world.

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