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Atmospheric Humidity Impact on the Strength of Mobile Phone Communication Signal

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Abstract: *This study examines the influence of atmospheric humidity on mobile phone signal strength, focusing on two major Nigerian networks: 9Mobile and MTN. Signal strength measurements were taken across multiple frequency bands—2100 MHz, 800 MHz, 1800 MHz, and 2600 MHz—in selected cities in southern Nigeria. Data collection was conducted using a Cell Signal Monitor application installed on a dual-SIM Android device, with measurements restricted to specific cells to enhance data accuracy. Corresponding relative humidity data were obtained from hourly reports provided by the Nigerian Meteorological Agency (NiMet). Analysis revealed a slight positive correlation (r = 0.14) between relative humidity and signal strength, with a standard deviation of 0.23. However, results varied across different locations and network cells, suggesting the influence of additional environmental and technical factors, including local topography, base station antenna configurations, seasonal fluctuations, and the distance between mobile devices and transmitters. Some variability may also be attributed to the limitations of the data collection tool used. These findings provide valuable insights for radio scientists and network engineers in optimizing mobile communication infrastructure. Understanding the role of humidity in signal propagation can support more efficient radio resource management and contribute to reducing unnecessary radio frequency emissions.*

Keywords*: Impact, Atmospheric humidity, Signal strength, Mobil communications*

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1.0 Introduction

Weather refers to the immediate or short-term state of the atmosphere within the troposphere—the lowest layer of Earth's atmosphere (Amajama et al., 2023). It is characterized by key atmospheric parameters such as temperature, pressure, relative humidity, and wind speed and direction (Joseph, 2016b). These elements collectively determine the prevailing atmospheric conditions at any given location and time. Meteorologists rely on their understanding of atmospheric processes and the continuous monitoring of these parameters to observe patterns and predict weather developments (Iwuji et al., 2023a, 2023b, 2023c).

By analyzing data on temperature, humidity, air pressure, wind patterns, and cloud cover, meteorologists can identify temporal variations in atmospheric dynamics. These insights are vital for the development of complex computer models that simulate atmospheric behavior. Such models incorporate the intricate interactions among weather parameters—for instance, how temperature affects air pressure or how wind patterns contribute to cloud formation. Comparing real-time observations with model outputs allows meteorologists to forecast future weather conditions with increased precision.

The weather forecasting process involves tracking weather systems, identifying trends, and understanding how various atmospheric processes affect local and regional climates. Accurate forecasts enable the issuance of timely alerts and warnings, which are essential for public safety and for sectors that depend on weather conditions, including agriculture, aviation, and telecommunications (National Geographic Society, n.d.).

Among the various weather parameters, humidity plays a critical role in atmospheric processes and directly influences the formation of clouds and precipitation. It refers to the amount of water vapor present in the air and is commonly expressed as relative humidity—the percentage of water vapor in the air relative to the maximum amount the air can hold at a given temperature. Warmer air can contain more moisture than cooler air. When relative humidity reaches 100%, the air becomes saturated and condensation occurs, leading to the formation of clouds and precipitation as warm, humid air rises and cools (National Geographic Society, n.d.).

Humidity does not only affect weather phenomena—it also has a significant impact on telecommunications. Radio wave propagation, which underpins mobile and wireless communication, is influenced by the conditions of the medium through which the waves travel. As radio waves pass through the Earth's atmosphere, variations in humidity can cause signal attenuation due to energy loss through absorption and scattering (Luomala & Hakala, 2015; Amajama, 2016). Water vapor alters the permittivity and permeability of the atmosphere, impacting radio refractivity and, in turn, the integrity of transmitted signals (Joseph, 2016a).

Atmospheric variability is inevitable, and its effects on wireless communication are supported by both theoretical and empirical research. Despite several advances in wireless network optimization, the role of specific atmospheric parameters, particularly relative humidity, remains underexplored in certain geographic regions. As such, understanding and mitigating the influence of atmospheric components, particularly relative humidity, on communication signal quality is essential.

This study therefore, aims to empirically investigate the relationship between atmospheric humidity and mobile phone signal strength in selected southern Nigerian cities.

Several studies have explored this relationship in various geographic contexts. Ofure et al. (2017), for instance, conducted a 19-month study in Minna, Nigeria, assessing the effect of weather on GSM signals. Using data from a local weather station and signal strength measurements from the MTN network at a fixed distance of 300 meters from a Base Transceiver Station (BTS), they found a strong negative correlation between relative humidity and signal strength, ranging from -0.57 to -0.89.

Similarly, Osahenvemwen and Omatahunde (2018) studied mobile signal strength for the Glo network in Benin City, Nigeria. Data collected using frequency-signal tracker software revealed negative correlations of -0.50 and -0.44 for relative humidity and atmospheric pressure, respectively, indicating that higher humidity and pressure reduce signal strength.

In Haryana, India, Dalip and Kumar (2014) examined the effects of environmental parameters on GSM and GPS signals. Conducting tests along a 50 km route while excluding high-humidity zones near rivers, they noted that although rain could enhance signal clarity by washing away pollutants, high humidity generally absorbed radio waves and weakened signals.

In contrast, some studies have observed positive correlations between humidity and signal strength. For example, Felix et al. (2017) found that under cloudy conditions in Abuja, Nigeria, higher humidity was associated with stronger WE FM radio signals. Similarly, Ayantunji et al. (2018), studying UHF signal propagation in Gusau, Nigeria, reported a positive correlation between humidity and signal strength, with coefficients ranging from 0.418 to 0.728.

However, most studies support the conclusion that humidity generally attenuates radio signals. Ukhurebor and Umukoro (2018) found a strong negative correlation (-0.96) between relative humidity and UHF signal strength for EBS Television in Benin City. Amajama (2016) reported similar findings in Calabar, Nigeria, identifying a strong inverse relationship (-0.93) between humidity and UHF signal strength. Likewise, Segun et al. (2013) established that variations in relative humidity and atmospheric moisture significantly affect UHF radio signal propagation in Southwest Nigeria.

Guidara et al. (2018) also conducted a controlled laboratory study on the effects of temperature and humidity on Received Signal Strength Indicator (RSSI) in indoor wireless sensor networks. Although they reported a strong positive correlation between relative humidity and RSSI, the effect diminished at shorter transmission distances, suggesting that environmental influence is distance-dependent. In Kokkola, Finland, Luomala and Hakala (2015) further highlighted the importance of atmospheric variables on outdoor wireless sensor networks. Their study showed that both temperature and relative humidity had significant impacts on signal strength, confirming the broader relevance of meteorological conditions to wireless communication reliability.

Despite these valuable contributions, a noticeable gap exists in studies that isolate the effect of relative humidity on mobile phone signal strength within the coastal and humid regions of southern Nigeria. Most prior studies either consider multiple weather parameters or lack granularity in data collection across frequency bands. The specific objective of this study is to determine how relative humidity alone influences signal strength across multiple frequency bands (800 MHz, 1800 MHz, 2100 MHz, and 2600 MHz) for MTN and 9Mobile networks in cities such as Calabar, Uyo, Port Harcourt, Yenagoa, and Warri.

By restricting measurements to specific network cells and integrating real-time meteorological data, this study aims to produce localized and frequency-specific insights.

The significance of this research lies in its potential to inform telecommunication infrastructure design and optimisation strategies in regions with high humidity. Understanding the role of atmospheric moisture in signal propagation can help network engineers optimize antenna configurations, select robust frequency bands, and develop adaptive transmission protocols to enhance signal reliability and reduce energy waste due to retransmissions. Ultimately, this will contribute to improving the quality of service (QoS) and radio resource efficiency in mobile networks operating under variable atmospheric conditions.

2.0 Materials and Methods

This study examined the impact of atmospheric humidity on mobile phone signal strength in five cities across southern Nigeria: Calabar, Uyo, Port Harcourt, Yenagoa, and Warri. The objective was to evaluate how variations in relative humidity influence the downlink signal strength of selected mobile communication networks operating in 3G and 4G frequency bands.

Two major Nigerian mobile network providers—MTN and 9Mobile—were selected for analysis. MTN operates 3G services within the 2110.00–2120.00 MHz band and 4G services within two downlink bands: 791–821 MHz (800 MHz band) and 2620–2690 MHz (2600 MHz band). 9Mobile operates 3G in the 2130.00–2140.00 MHz band and 4G in the 1805–1880 MHz range (1800 MHz band) (Nigerian Communications Commission [NCC], 2020).

Signal strength measurements were collected using an Android smartphone (Nokia TA-1332), configured as a mobile station and fitted with dual SIM cards from MTN and 9Mobile. The Cell Signal Monitor app (Version 5.1.1) was used to monitor and log downlink signal strength data in real time. The application was configured to record signal strength at one-minute intervals, and hourly averages were computed for analysis. Data were collected at fixed measurement sites (referred to as "restricted cells") within each city to ensure localization and repeatability of measurements. Each measurement session was synchronized with hourly **meteorological reports** from the Nigerian Meteorological Agency (NIMET). Specifically, the **relative humidity data** corresponding to each hourly signal strength average were extracted from NIMET reports for the respective city. This enabled a point-to-point analysis between atmospheric humidity and mobile signal strength. Data were collected over a continuous period of **February 01, 2023 to July 30, 2023**, and all measurements were taken in open outdoor locations to minimize structural interference. Measurements were repeated across different times of the day to capture diurnal variations in humidity and signal behavior.

3.0 Results and Discussion

The linear graphs presented [Fig. 1 (a-p); Fig. 2 (a-p); Fig. 3 (a-p); Fig. 4 (a-p); and Fig. to 5(a-p)] illustrate the relationship between received signal strength and relative humidity for the eighty-eight (80) cells examined in this study. Among these, sixty-five (61) cells exhibited a positive correlation between received signal strength and relative humidity, while twenty-three (19) cells demonstrated a negative linear relationship. The correlation coefficients observed ranged from -0.61481 to 0.74409, indicating a significant correlation between these two variables, though the strength and direction of this relationship varied across the measurements taken from different transmitting cell identifiers (IDs) in the respective cities.

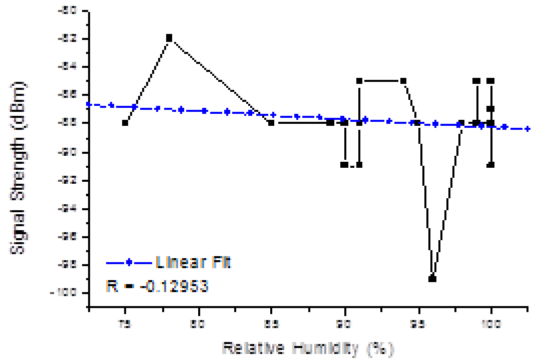
In Calabar, measurements were conducted from the following transmitting cell IDs: 14631, 14635, 1383, 1385, 29282, 29286, 23143, 23253, 25912, 25916, 23112, 2553, 14671, 14675, 25202, and 25209.

In Uyo, the transmitting cell IDs utilized for measurements included: 21013, 21017, 200313-1, 200225-2, 2034-1, 2034-3, 200222-13, 200085-83, 21041, 21045, 200085-82, 200222-13, 13743, 13747, 200584-13, and 200078-81.

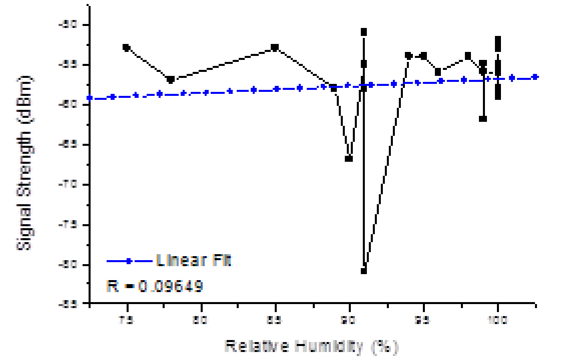
Measurements in Port Harcourt were taken from the following transmitting cell IDs: 20201, 20205, 230240-6, 230458-4, 19843, 19847, 230335-6, 230403-6, 48412, 48416, 22071, 22078, 20172, 20176, 902067-6, and 2303316.

In Warri, the transmitting cell IDs from which measurements were taken include: 42707, 42703, 510490-81, 510490-83, 4275, 45871, 902744-81, 510481-81, 42773, 42777, 510034-82, 510865-83, 42731, 42733, 510664-4, and 510512-83.

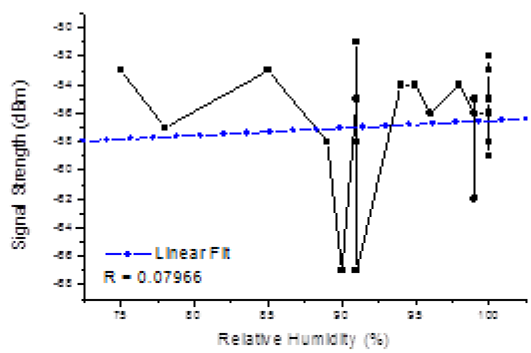
Finally, in Yenagoa, measurements were conducted using the following transmitting cell IDs: 20431, 20437, 24696, 24036, 13217, 13219, 24634, 24647, 20431, 20437, 1215, 24696, 13712, 3717, 24786, and 24787.


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.12953

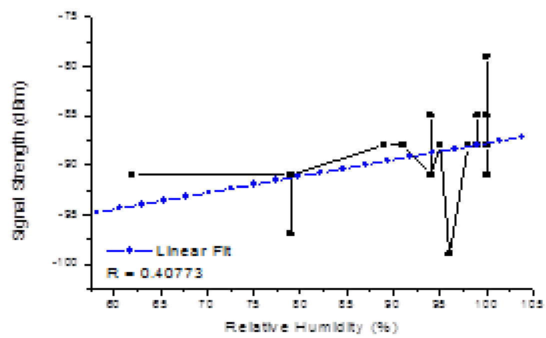
(a)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.09649

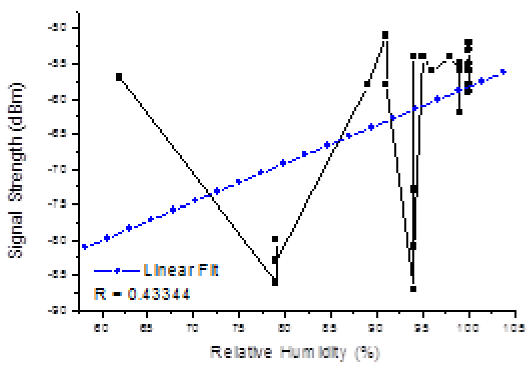
(b)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.07966

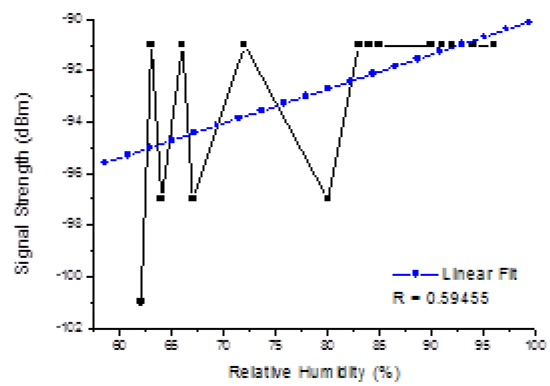
(c)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.40773

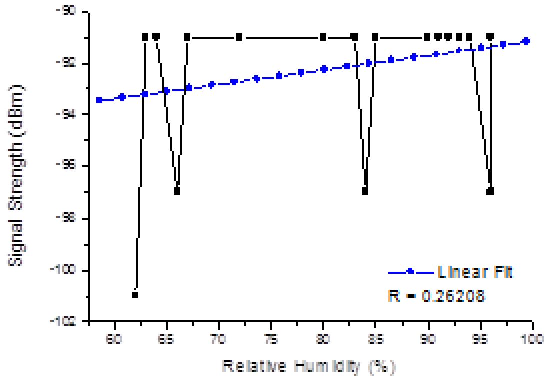
(d)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.43344

(e)

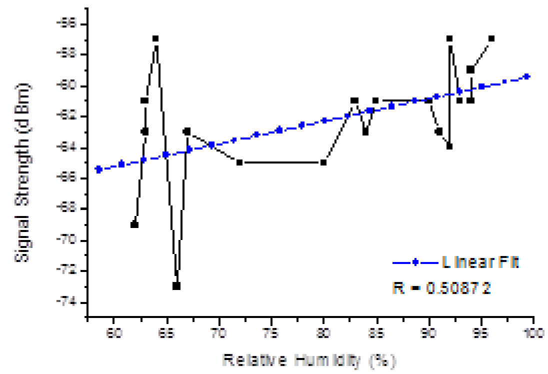

Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.59455

(f)



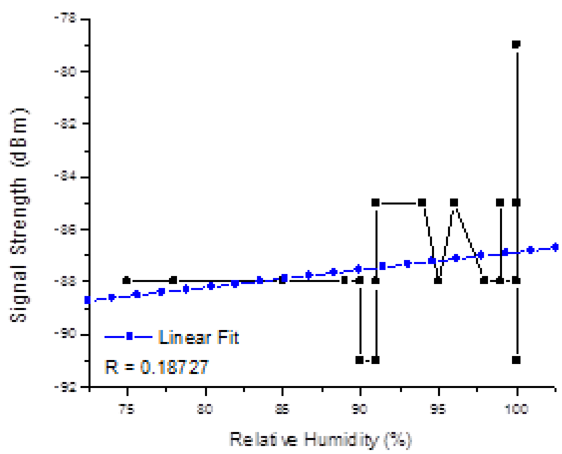
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.26208

(g)



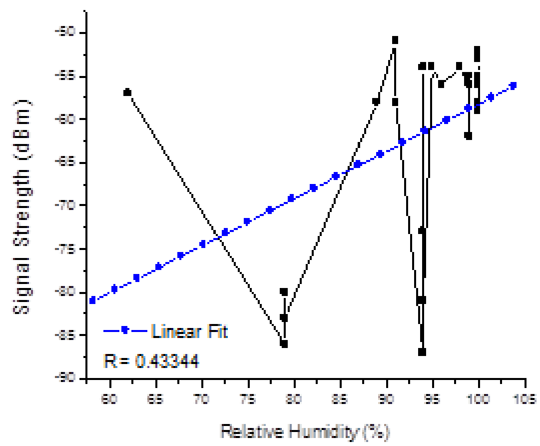
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.50872

(h)



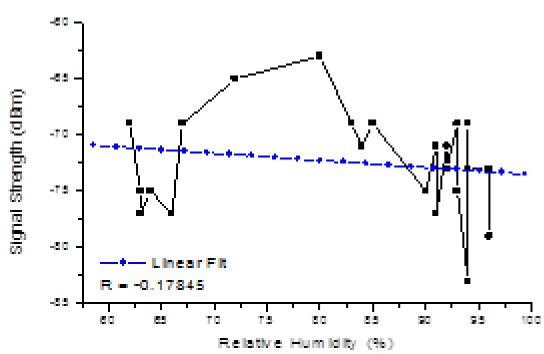
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.18727

(i)



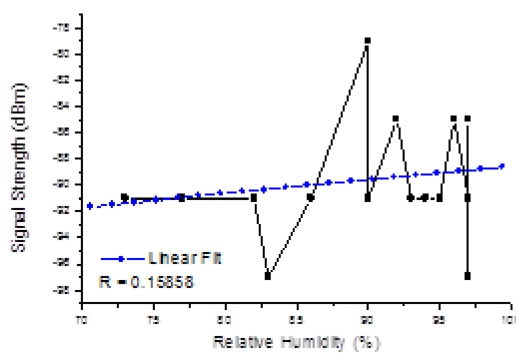
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R= 0.43344

(j)



Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.17845

(k)



Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.15858

(l)

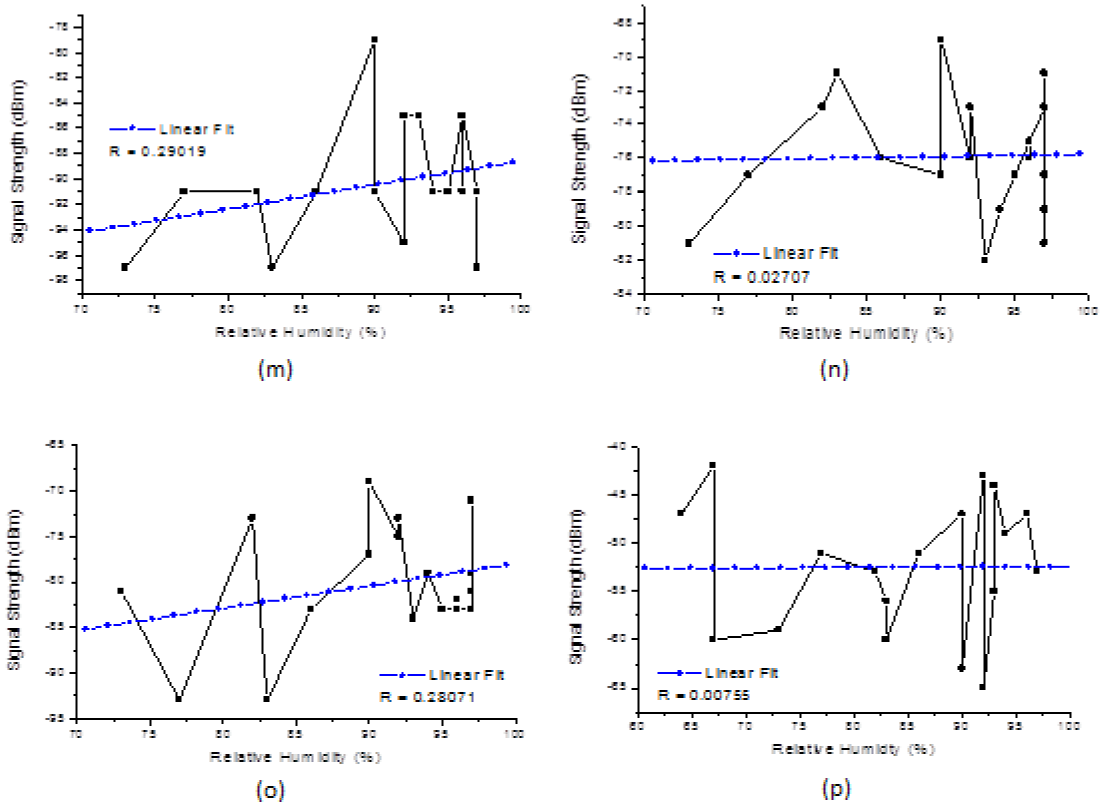
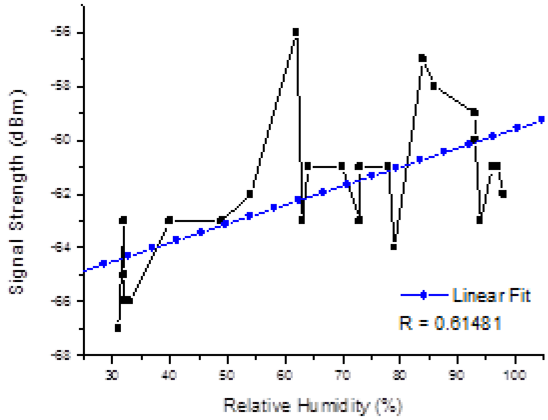
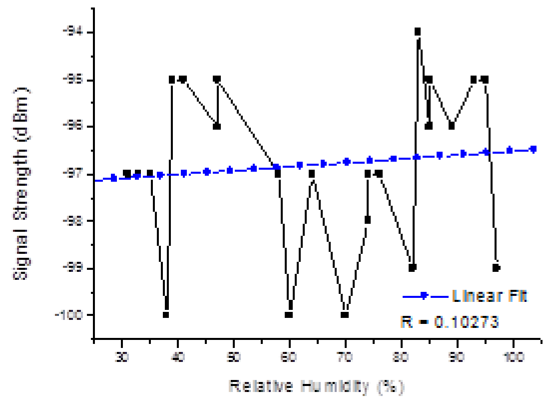


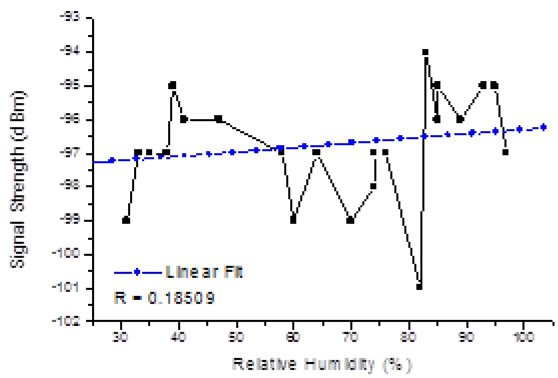
Fig.1 Signal strength VS Atmospheric Temperature in Some Cells in Calabar


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.61481

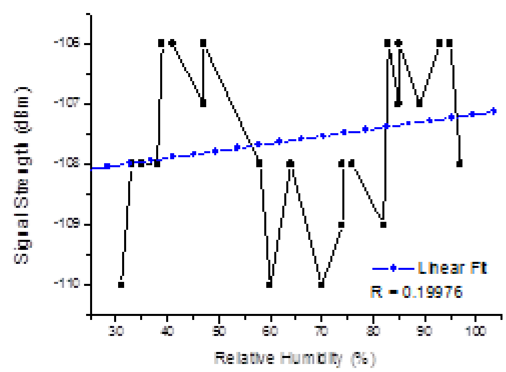
(a)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.10273

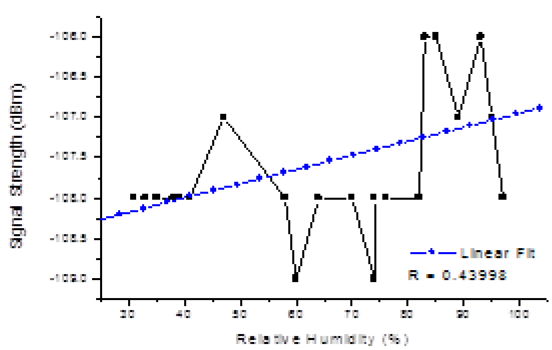
(b)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.18509

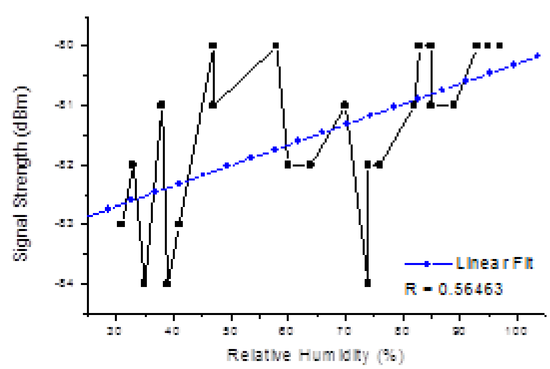
(c)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.19976

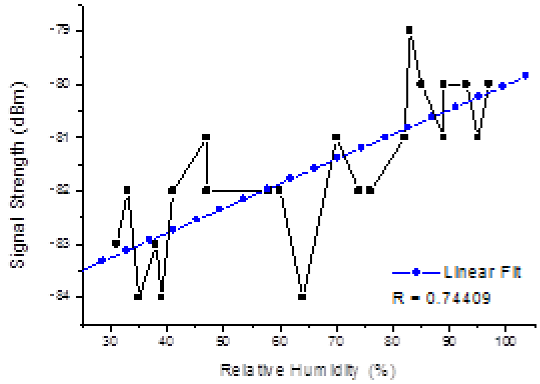
(d)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.43998

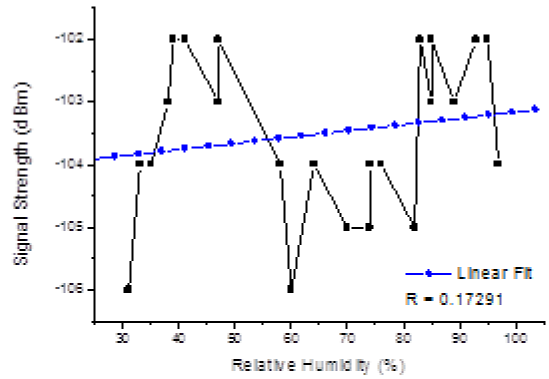
(e)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.56463

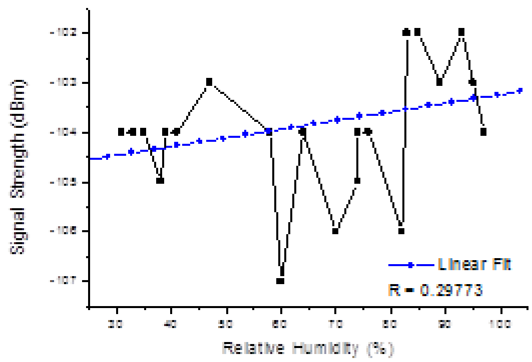
(f)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.74409

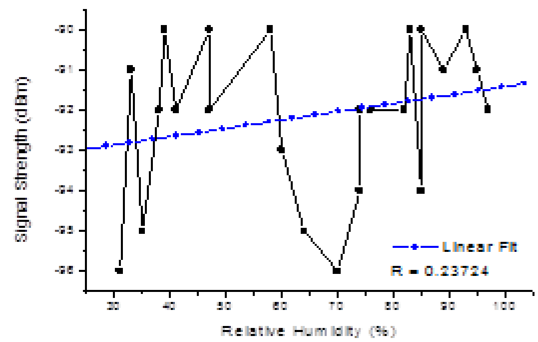
(g)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.17291

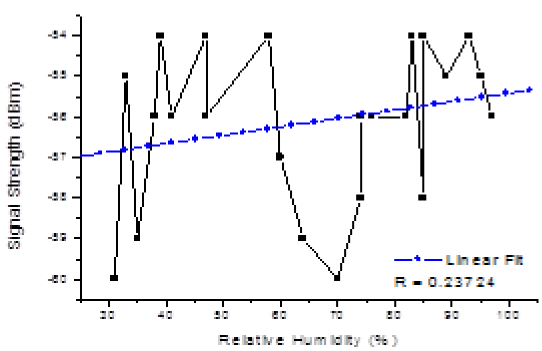
(h)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.29773

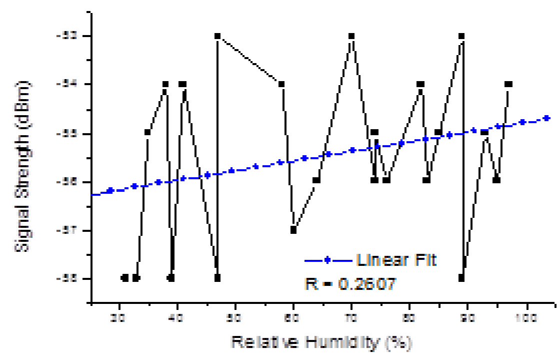
(i)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.23724

(j)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.23724

(k)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.2607

(l)

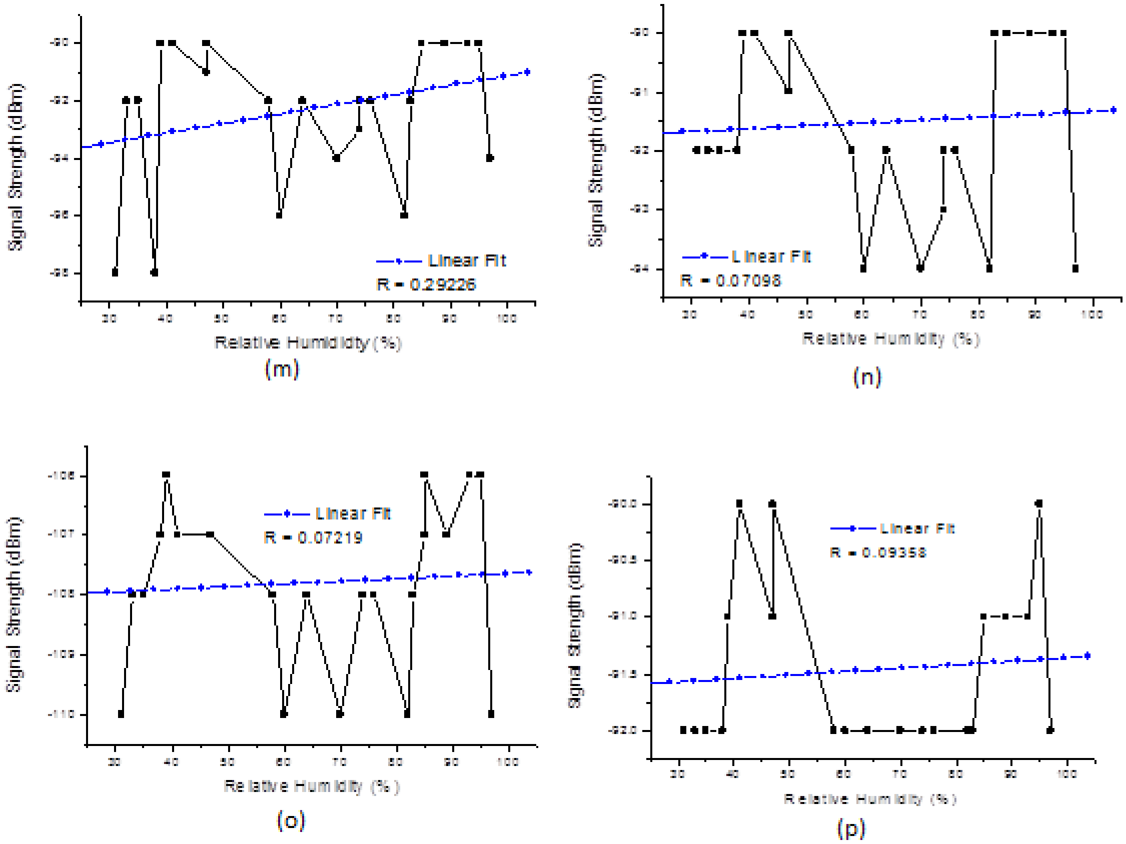
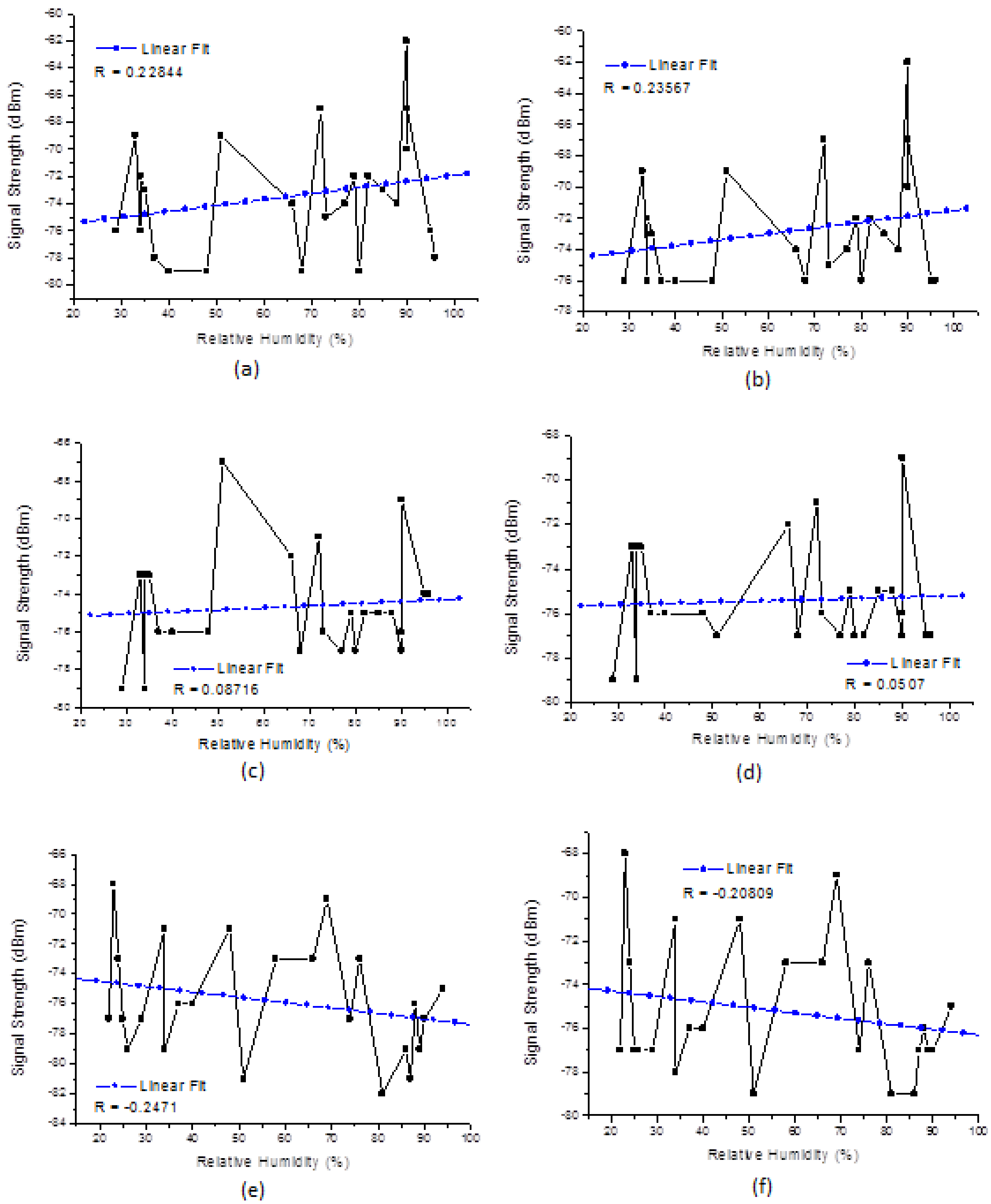
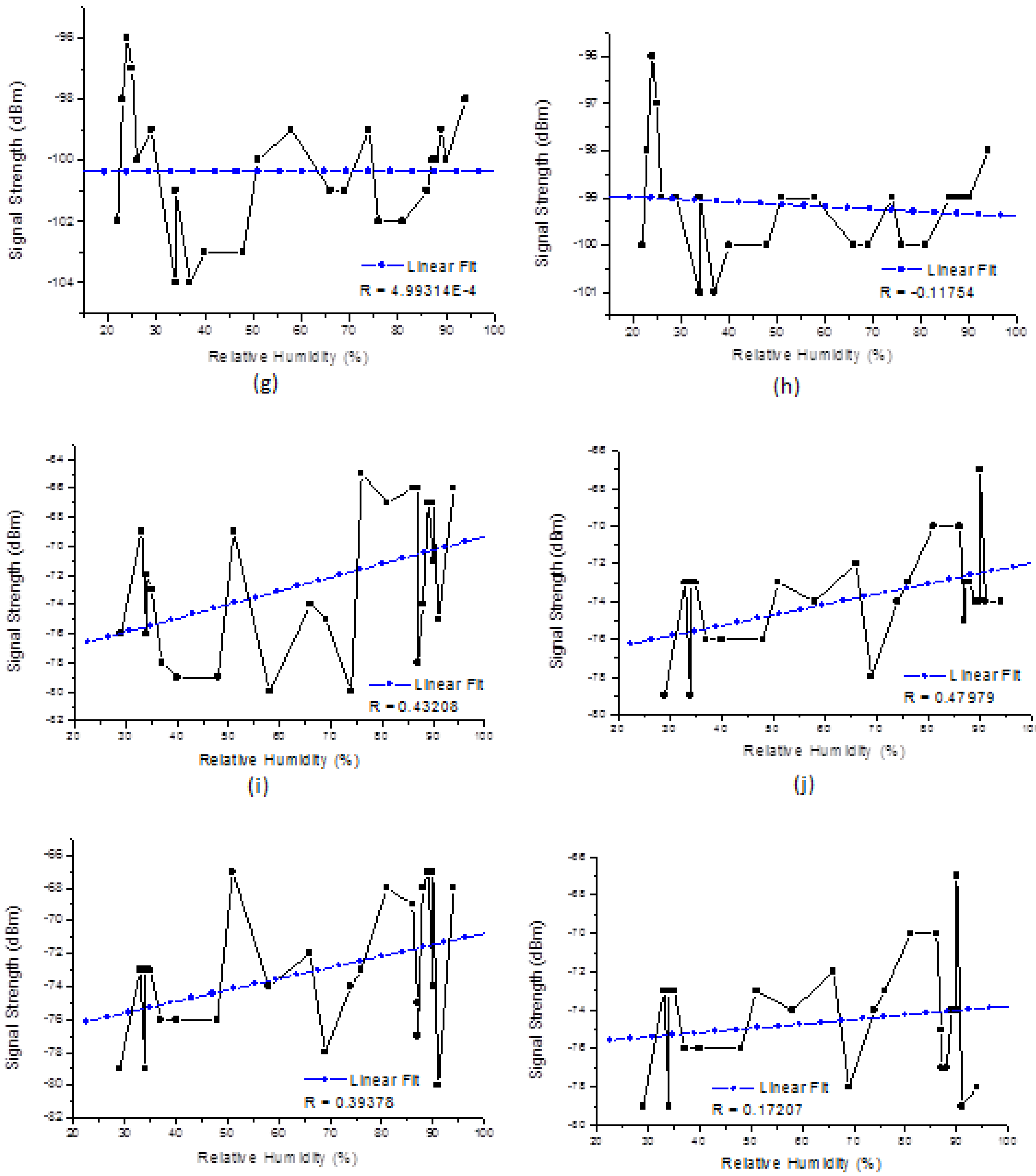


Fig.2 Signal strength VS Atmospheric Temperature in Some Cells in Uyo


Linear Fit
R = 0.22844
Signal Strength (dBm)
Relative Humidity (%)
(a)
Linear Fit
R = 0.23567
Signal Strength (dBm)
Relative Humidity (%)
(b)
Linear Fit
R = 0.08716
Signal Strength (dBm)
Relative Humidity (%)
(c)
Linear Fit
R = 0.0507
Signal Strength (dBm)
Relative Humidity (%)
(d)
Linear Fit
R = -0.2471
Signal Strength (dBm)
Relative Humidity (%)
(e)
Linear Fit
R = -0.20809
Signal Strength (dBm)
Relative Humidity (%)
(f)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 4.99314E-4
R = -0.11754
R = 0.43208
R = 0.47979
R = 0.39378
R = 0.17207

(g) (h)

(i) (j)

(k) (l)

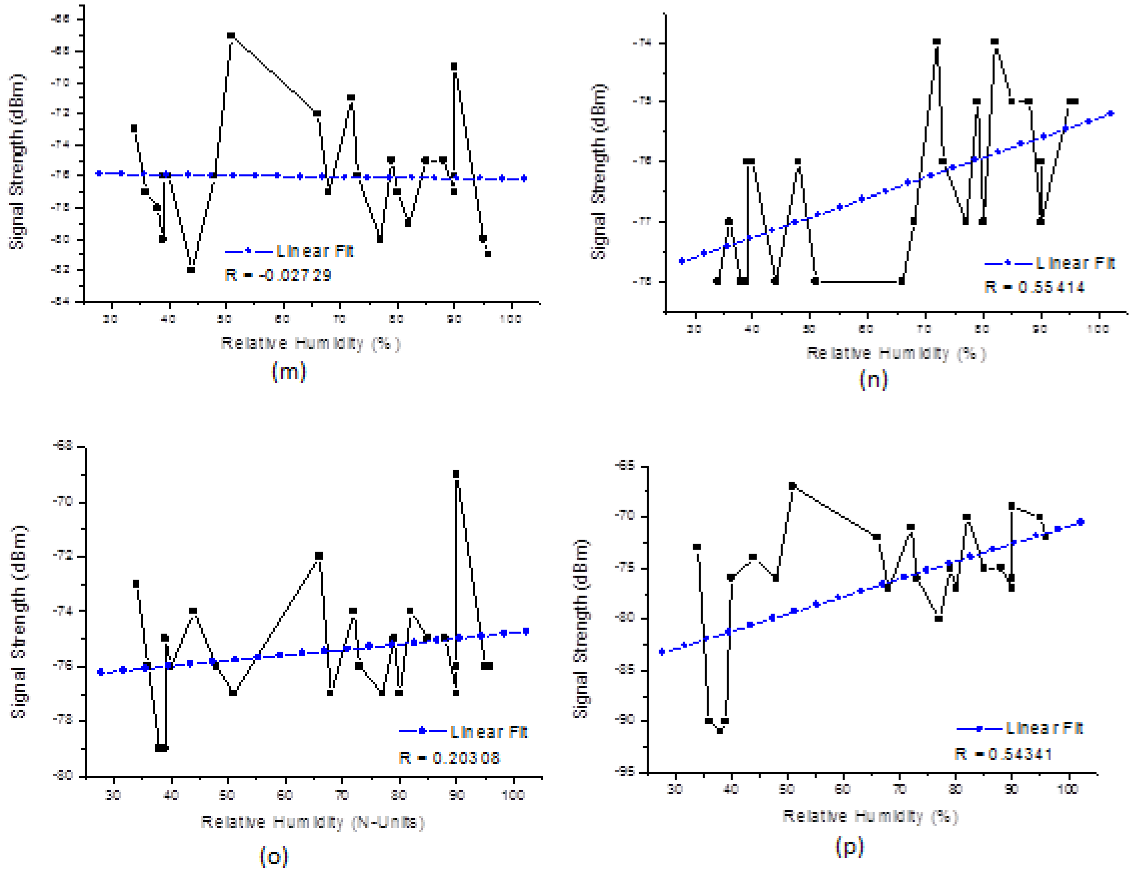
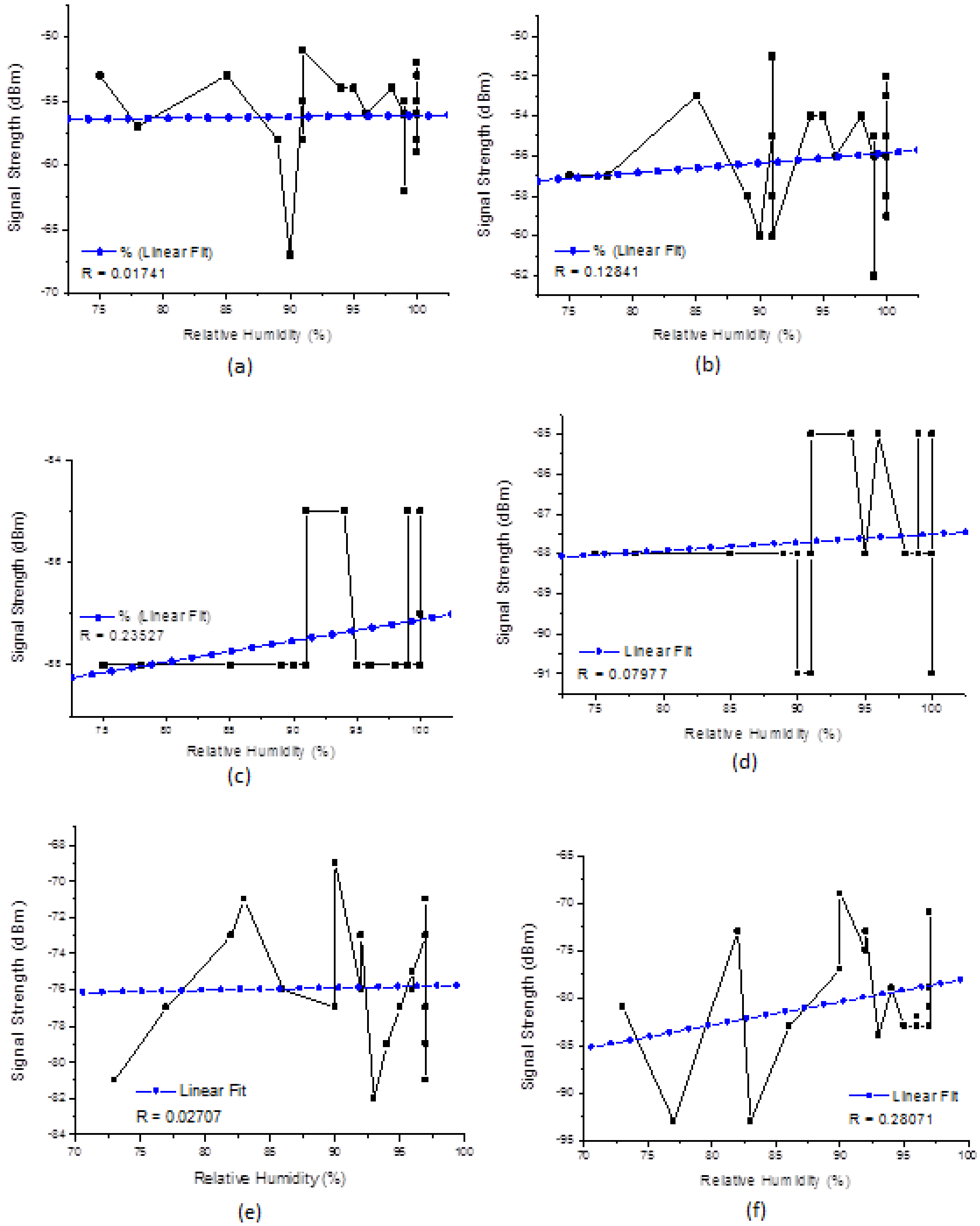
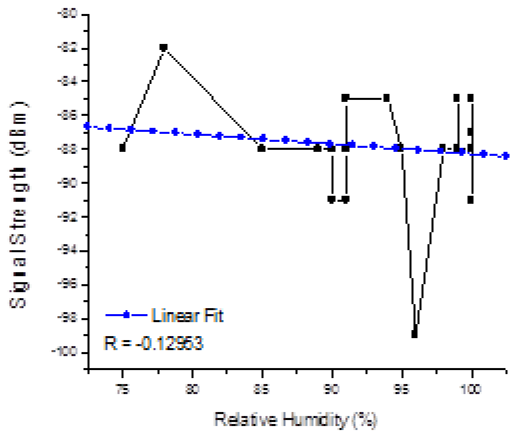
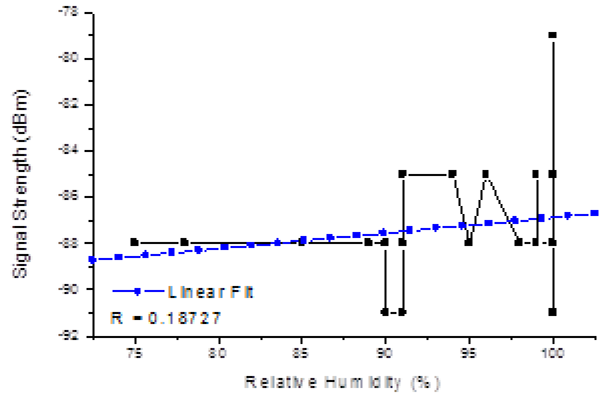
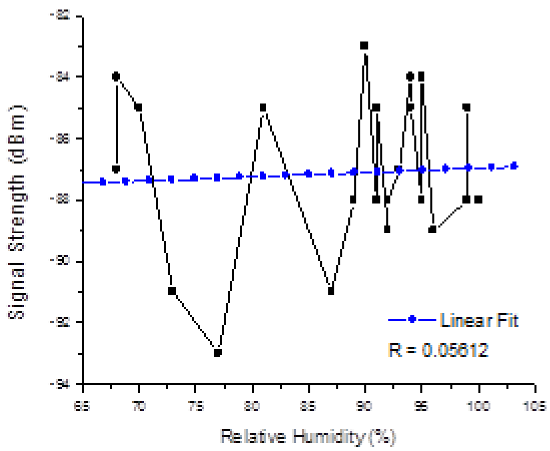


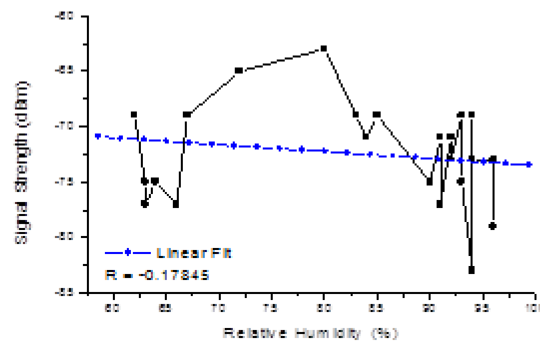
Fig.3 Signal strength VS Atmospheric Temperature in Some Cells in Port Harcourt

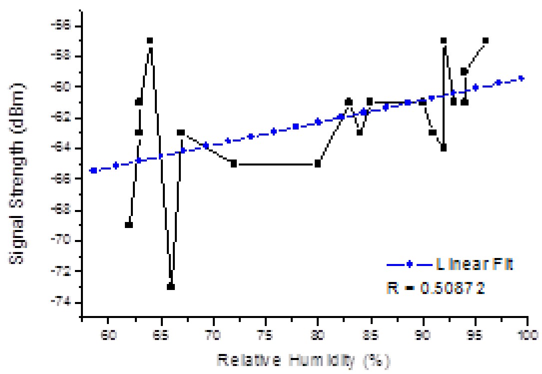

Signal Strength (dBm)
Relative Humidity (%)
% (Linear Fit)
R = 0.01741
(a)
% (Linear Fit)
R = 0.12841
(b)
% (Linear Fit)
R = 0.23527
(c)
Linear Fit
R = 0.07977
(d)
Linear Fit
R = 0.02707
(e)
Linear Fit
R = 0.28071
(f)

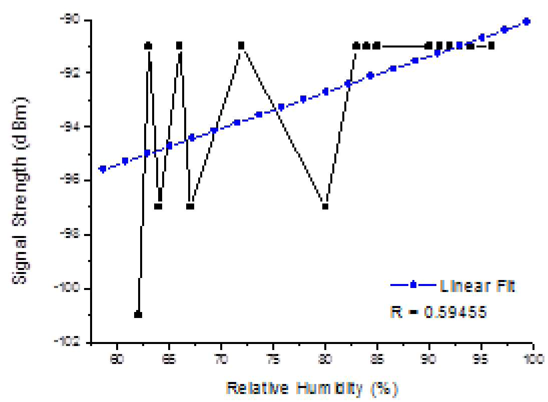

Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.12963
(g)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.18727
(h)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.05612
(i)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.17845
(j)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.50872
(k)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.59455
(l)

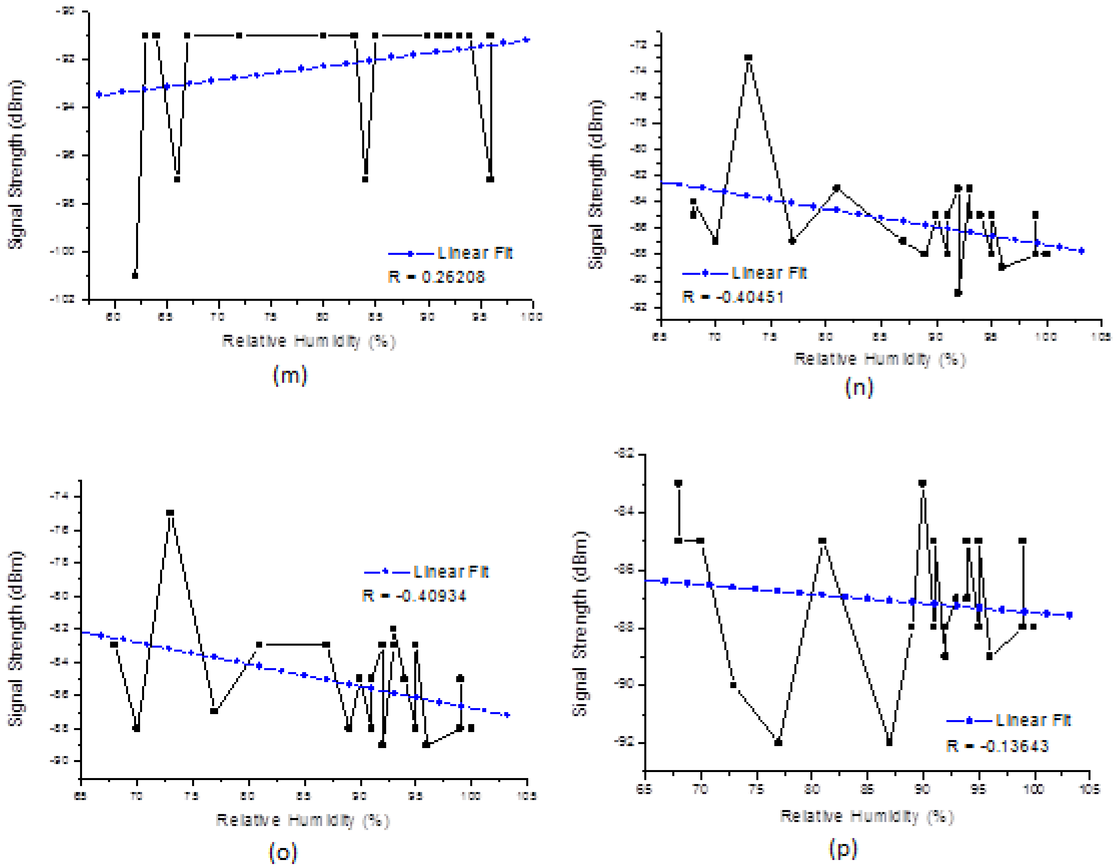
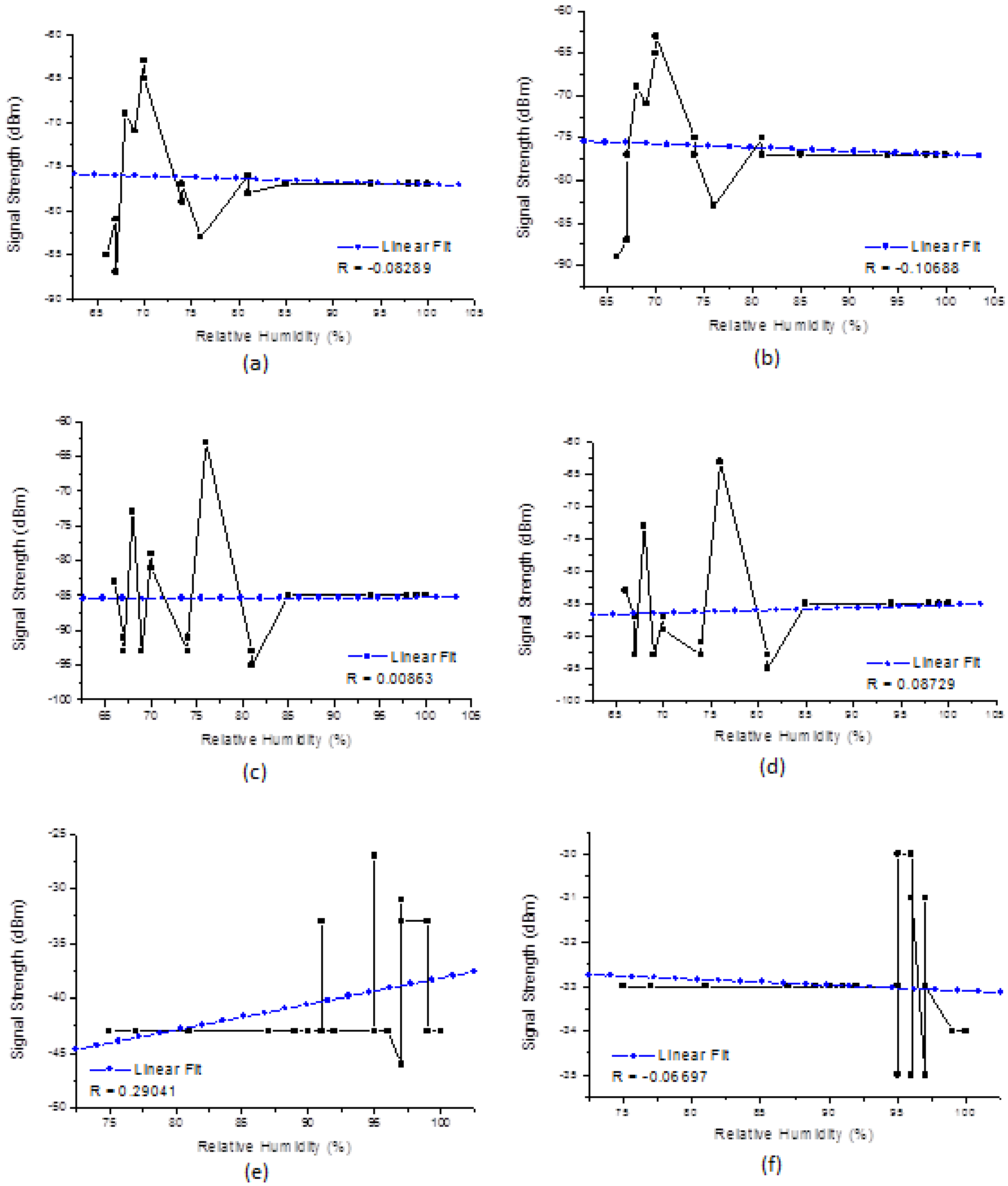
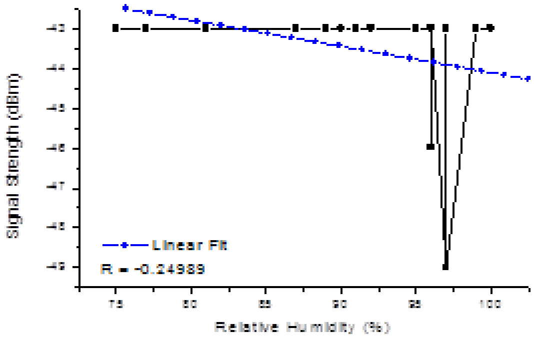
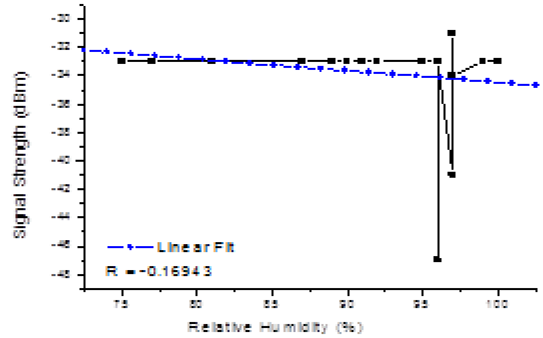


Fig.4 Signal strength VS Atmospheric Temperature in Some Cells in Warri

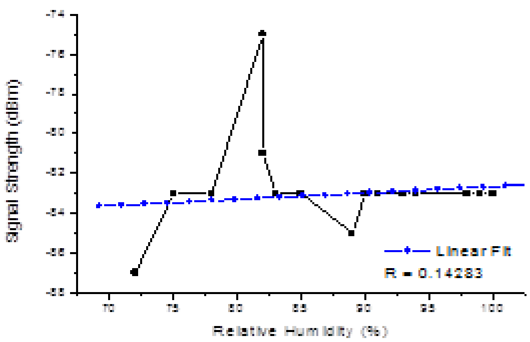

Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.08289
(a)
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.10688
(b)
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.00863
(c)
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.08729
(d)
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.29041
(e)
Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.06697
(f)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.24989

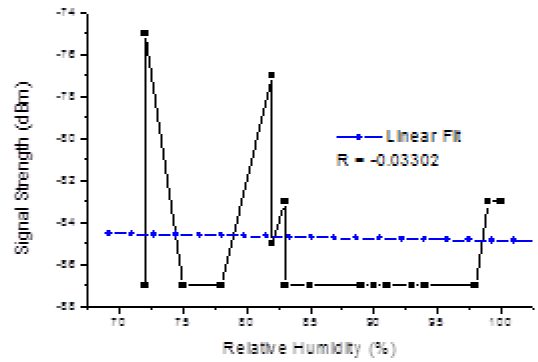
(g)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.16943

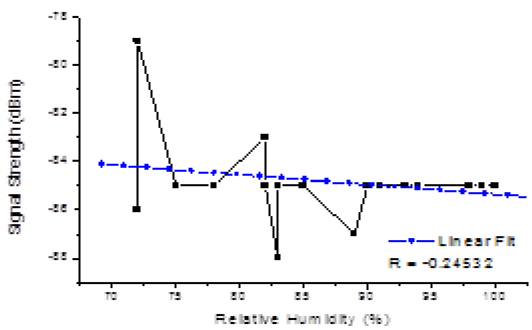
(h)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.14283

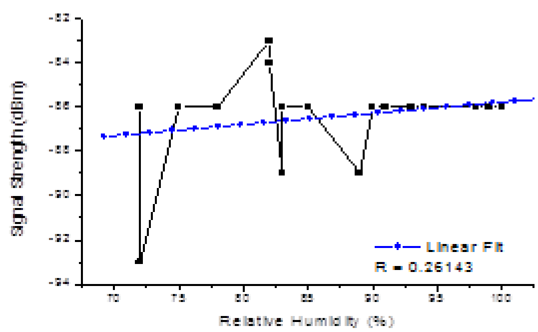
(i)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.03302

(j)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = -0.24532

(k)


Signal Strength (dBm)
Relative Humidity (%)
Linear Fit
R = 0.26143

(l)

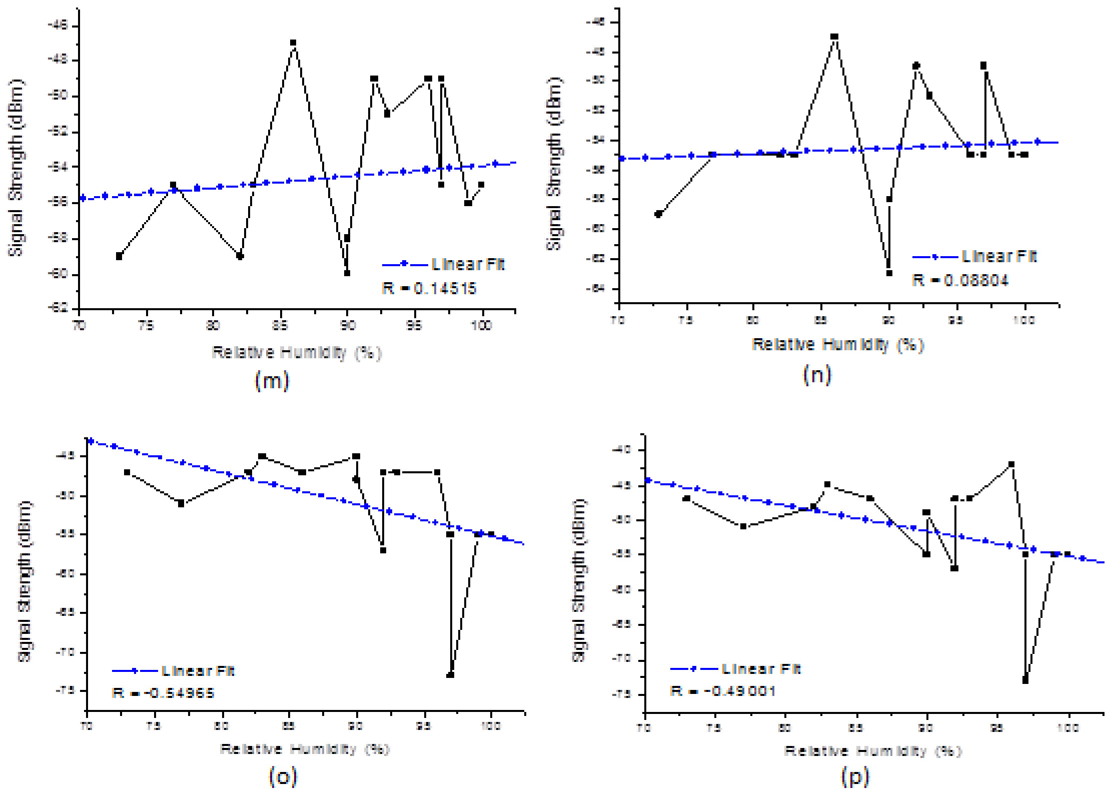


Fig.5 Signal strength VS Atmospheric Temperature in Some Cells in Yenagoa

Table 1 summarises the results of the analysis, presenting the average correlation coefficient (R-value) for each location, the average standard deviation of the R-values, the overall average R-value, and the overall average standard deviation of R-values.

The overall analysis indicates a slight positive linear relationship between signal strength and atmospheric humidity, as evidenced by an overall average R-value of 0.1386 and an overall average standard deviation of 0.2280.

The observed discrepancies among the results can be attributed to geographical and topographical differences between the locations of the base stations and the mobile stations where signal strength measurements were conducted. Mobile phone communication primarily operates on a point-to-point or line-of-sight basis, implying that variances in terrain and obstacles can introduce significant fluctuations in received signal strength. This aligns with the findings of Dalip & Kumar (2014) who noted that GSM receivers tend to exhibit improved signal strength at greater heights, thereby minimizing obstructions that could interfere with signal transmission. Conversely, lower heights increase the likelihood of encountering obstacles, which can weaken the signal and lead to variations in signal strength.

In lowland areas where the base station is situated at a higher elevation, an increase in radio refractivity generally correlates with enhanced signal strength. Conversely, in highland locations where the base station is located at a lower elevation, radio refractivity may impede signal strength.

Moreover, factors such as wind speed and direction, which were not considered in this research, could also contribute to the observed discrepancies in the results. Water vapor—the predominant atmospheric constituent—influences the density of vertical atmospheric layers, which can be concentrated or dispersed depending on various atmospheric conditions.

Table 1: Summary of results

Location	Average R-value	Average standard deviation of R-values	Overall average R-value	Overall average standard deviation of R-values
Calabar	0.202266875	0.171286972	0.138570601	0.228020572
Uyo	0.307398671	0.212507272		
Portharcourt	0.173799957	0.249834900		
Yenagoa	0.069973125	0.273578691		
Warri	-0.060585625	0.232895027		

The direction of wind, which affects radio wave propagation, can further complicate this dynamic, as radio waves behave both as particles and waves. Previous studies (Chima *et al.*, 2018; Meng *et al.*, 2009) have shown that adverse weather conditions, such as wind and rain, may introduce additional attenuation to signal propagation, significantly affecting signal strength and quality.

Zafar *et al.* (2019) indicated that high wind speeds and heavy rain could contribute to increased signal attenuation, particularly during the wet season. Their findings revealed a stronger negative correlation between received signal strength and wind speed during the wet season compared to the dry season. Additionally, they proposed that fresh breezes could elevate the concentration of moisture in the atmosphere, further affecting signal absorption and scattering.

Interestingly, the study also identified that wind speed, when not accompanied by rain, along with lowered humidity during the dry season, positively influenced received signal strength. The reduction of atmospheric moisture during dry conditions lessens absorption and scattering effects, allowing for improved signal propagation and enhanced received signal strength (Joseph & Oku, 2016; Rappaport, 1996; Wayne, 2001; Anyasi & Uzairue, 2014; Oku *et al.*, 2025).

Seasonal variations further complicate the analysis, as the study spanned the entire year of 2019. Regions such as Calabar and Bayelsa predominantly experienced wet season conditions, while Uyo, Port Harcourt, and Warri experienced both dry and wet seasons. The refractivity of the atmosphere tends to be higher in the rainy season and lower during the harmattan season. This finding is supported by prior research, including studies conducted by Oku *et al*. (2025), which demonstrated that average radio refractivity tends to be higher during the rainy season compared to the dry season. Similarly, Edet *et al.* (2017) observed little variation in seasonal radio refractivity patterns.

3.2 Effect of Relative Humidity on Received Signal Strength

The research indicated a positive correlation between signal strength and relative humidity. This correlation is closely associated with the inverse relationship between atmospheric temperature and relative humidity. Notably, four of the eighty-eight cells exhibited rare instances where atmospheric temperature and relative humidity did not align inexplicably. Nonetheless, eighty-four cells demonstrated that atmospheric temperature inversely correlates with both relative humidity and signal strength.

These findings resonate with previous studies (Ofure *et al.*, 2017; Felix *et al.*, 2017; Segun, 2013; Bawa *et al.*, 2017) that have identified correlations between atmospheric temperature and relative humidity affecting GSM received signal strength. Felix *et al.* (2017) concluded that radio signal strength is notably influenced by relative humidity, providing coefficients suggesting a direct proportionality between signal strength and humidity. Similarly, [12] established strong correlations between humidity and UHF signal strength across different months.

Contrarily, Michael (2013) reported an inverse relationship between signal strength and relative humidity, positing that lower humidity levels could degrade signal propagation. Likewise, Valerie (2020) noted negative correlations between relative humidity and GSM signal strength. This inverse relationship indicates that the degradation of GSM signal strength typically accompanies increased humidity levels.

Contrary to these findings, Dalip & Kumar (2014) suggested that relative humidity's influence on signal strength depends on seasonal factors, particularly during winter. They found that reduced foliage during winter improves signal reception, mitigating barriers caused by moisture-laden leaves. This variability highlights the complexity of atmospheric phenomena on signal propagation.

4.0 Conclusion

The findings of this study reveal a modest positive correlation between relative humidity and mobile signal strength—indicating that higher humidity levels generally correspond to stronger signals. However, this relationship is influenced by various factors, including atmospheric temperature, terrain, antenna characteristics, seasonal changes, and the distance between transmitter and receiver, which may account for observed inconsistencies.

This research offers valuable insights for radio scientists and engineers working to optimize mobile communication systems. By highlighting the role of humidity in signal propagation, it supports more efficient communication budgeting and helps minimize unnecessary radio frequency emissions—a concern linked to potential health risks (Dahal, 2013; Ahlbom et al., 2004; Erogul et al., 2006; Ishi, 2011; Pahal, 2013).

Additionally, these findings can improve frequency reuse planning by reducing interference and signal degradation caused by over-budgeting within limited communication bands (Scourias, 1997). Overall, this study enhances understanding of environmental impacts on mobile networks and aids in more effective link budgeting and system implementation.

5.0 References

Ahlbom, A., Green, A., Kheifets, L., Savitz, D. & Swerdlow, A. (2004). Epidemiology of health effects of radiofrequency exposure. *Environmental Health Perspectives*, 112, 17, pp. 1741-54. doi: 10.1289/ehp.7306.

Amajama, J. (2016). Harnessing molecular potential energy. *American Interanational Journal of Research in Formal, Applied & Natural Sciences*, 16(1), pp. 4-6.

Amajama, J., Asagha, N. E.,Ushie, J. O., Iwuji, C. P., Akwagiobe, U. J., Faithpraise, O. F., Ikeuba, I. A., & Bassey, E. D. (2023). Radio refractivity impact on signal strength of mobile communication. *Journal of Electrical and Computer Engineering*, 2023, pp.1-21.

Amajama, J., Ibrahim, A. T., & Akwagiobe, J. U. (2023). Influence of atmospheric temperature on the signal strength of mobile phone communication. *Communication in Physical Sciences*, 9, 4, pp. 717–737.

Amajama, J., Ibrahim, T. A. & Akwagiobe, U. J. (2023). Influence of atmospheric temperature on the signal strength of mobile phone communication. *Communication in Physical Sciences*, 9(4): pp 717-737.

Amajama, J. (2016). Impact of weather components on (UHF) radio signal. *International Journal of Engineering Research and General Science*, 4, 3, pp. 481-494.

Anyasi, F. I. & Uzairue, S. I. (2014). Determination of GSM signal strength level in some selected locations in Ekpoma. *Journal of Electronics and Communication Engineering*, 9, 2, pp. 8-15.

Ayantunji, B. G., Musa, B., Mai-unguwa, A., Adewumi, A. S. Saad, L. & Kado, A. (2018). Atmospheric humidity and its implication on UHF signal over Gusau, North West, Nigeria. *International Journal of Scientific and Engineering Research*, 9, 3, pp. 599-611.

Bawa, M., Galadanci, G. S. M., Ayantuji, B. G., Mai-ungwa, H., Mohammed, M. T. & Ibrahim, U. (2017). Variation of meteorological parameters and its effect on the refractive index of air over Lagos, Nigeria. *Bayero Journal of Pure and Applied Sciences*: 10, 2, pp. 222–225.

Chima, A. I., Onyia, A. I. & Udegbe, S. U. (2018). The effects of atmospheric temperature and wind speed on UHF radio signal: a case study of ESUT community and its environs in Enugu State. *IOSR Journal of Applied Physics*, 10, 2, pp. 83-90.

Dahal, P. K. (2013). Mobile communication and its adverse effects. *The Himalayan Physics*, 4, 4, pp. 51-59.

Dalip, K. & Kumar, V. (2014). Effect of environmental parameters on GSM and GPS. *Indian Journal of Science and Technology*, 7, 8, pp. 1183–1188.

Edet, C. O., Eno, E. E., Etta B. E., & Kamgba, A. F (2017). Seasonal variation of radio refractivity in Calabar, Nigeria. *International Journal of Scientific Research Engineering and Technology*. 6, 6, pp. 670-673.

Etim, I. P., Inyang, E. P., & Thompson, E. A. (2022). Digital Data Acquisition for Gamma-Ray Spectroscopy. *European Journal of Applied Physics*, *4*(, 1, pp. 29-34.

Erogul, O., Oztas, E., Yildirm, I., Kir, T. Aydur, E., Komesli, G., Irkilata, H. C., Irmak, M. K. & Peker, A. F. (2006). Effects of electromagnetic radiation from a cellular phone on human sperm motility: An in vitro study. *Archives of Medical Research*, 37, 7, pp. 840-843.

Felix, A., Olufemi, A. A., Ibrahim, D. H., Ayegba, A., Olu, J. J., Fonyuy, D. W. & Victor, A. (2017). Investigation of the influence of atmospheric temperature and relative humidity on FM radio signal strength: a case study of We FM Abuja. *International Journal of Scientific and Technology Research:* 6, 11, pp. 70-74.

Guidara, A., Fersi, G., Derbel, F. & Jemaa, B. M. (2018). Impact of temperature and humidity variations on RSSI in indoor and wireless sensor networks. *Procedia Computer Science*: 126, pp. 1072–1081.

Inyang, E. P., Inyang, E. P., William, E. S., Ushie, P. O., & Oteikwu, G. A. (2018). Measurement of Electric Field Radiation from 11KVA high tension power line and its environmental effects in Calabar Metropolis, Nigeria. *Physical Science International Journal*, 18, 2, pp. 2348-0130.

Inyang, E.P, Inyang, E.P, & Willaim, E. (2017). Assessment of the exposure of radio frequency radiation from Wi-Fi routers in Calabar Metropolis, Nigeria. *Nigerian Journal of Scientific Research*, *1*6(, 4, pp. 490-494.

Ishi K. (2011). Examining the adverse effect of mobile phone use among Japanese adolescents. *Keio Communication Review*, 33, pp. 69-83.

Iwuji, C. P., Okoro, C. R., Amajama, J., Idajor A. J. & Ibrahim, T. A. (2023a). Analysis and modeling of path loss for terrestrial television in Nigeria. *International Journal of Applied Science and Engineering*, 20, 4, pp. 1-10.

Iwuji, C. P., Okoro, C. R., Idajor A. J., Amajama, J., Ibrahim, T. A. & Echem, O. C. (2023b). Performance analysis and development path loss model for television signal in Imo State, Nigeria. Eurasian Physical Technical Journal, 2, 44, pp. 87-98.

Iwuji, C. P., Okoro, C. R., Bassey, E. D. & Amajama, J. (2023c). Development of a path loss model for radio wave signal for some selected routes in Enugu State, Nigeria. Jordan Journal of Physics, 16, 5, pp. 527-538.

Joseph, A & Oku, D. E. (2016). Wind versus UHF radio signal. *International Journal of Science, Engineering and Technology Research*, 5, 2, pp. 583-585.

Joseph, A. (2016a). The force of atmospheric humidity on (UHF) radio signal. *International Journal of Scientific Research Engineering and Technology*, 5, 2, pp. 56-59.

Joseph, A. (2016b). Impact of temperature on UHF radio signal. *International Journal of Engineering Research and General science*, 4, 2, pp. 619-622.

Lawal, K. M., Inyang, E. P., Ibanga, E. A., & Ayedun, F. (2023). Assessment of indoor radon gas concentration in National Open University of Nigeria: a case study of Calabar Study Centre. *East European Journal of Physics*, 4, pp. 371-375, https://doi.org/10.26565/2312-4334-2023-4-47.

Luomala, J. & Hakala, I. (2015). Effect of temperature and humidity on radio signal strength in outdoor Wireless Sensor Networks. *Federated Conference on Computer Science and Information Systems: pp.* 1–9.

Meng, S. Y., Lee, H. Y. & Ng C. B. (2009). The effects of tropical weather on radio wave propagation over foliage channel. *IEEE Transactions on Vehicular Technology*, 58(8), 4023-4030.

National Geographic Society (n.d.). *Weather*. Retrieved from www.nationalgeographic.org/encyclopedia/weather/.

Nigerian Communications Commission [NCC], 2020. *Spectrum Policy – (NCC)*. Abuja: Nigerian Communications Commission (NCC).

Ofure, I. E., David, O. O., Oludare, M. A., & Musa, A. A. (2017). Impact of some atmospheric parameters on GSM signal. *13th International Conference on Electronics, Computer, and Computation (ICECCO)*, pp. 1–7.

Oku, E. D., Amajama, J. & Obot, P. E (2015). Seasonal tropospheric radio refractivity variation in Calabar, Cross Rivers State, Nigeria. *American International Journal of Research in Formal, Applied and Natural Sciences*, 13, 1, pp. 14-17.

Osahenvemwen, O. A. & Omatahunde, B. E. (2018). Impacts of weather and environmental conditions on mobile communication signals. *Journal of Advances in Science and Engineering*, 1, 1, pp. 33–38.

Pahal, P. K. (2013). Mobile Communication and its Adverse Effects. *The Himalayan Physics*, 4, 4, pp. 51-59.

Rappaport, T. S. (1996). *Wireless communications*. New Jersey: Pearson Prentice Hall, 495 -502.

Scourias, J. (1997). *Overview of the Global System for Mobile Communications*. Waterloo: University of Waterloo press.

Segun, A. A., Olusope, M. A. & Kofoworola, H. A. (2013). Influence of air temperature, relative humidity and atmospheric moisture on UHF radio propagation in South Western Nigeria. *International Journal of Science and Research*, 4, 8, pp. 588–592.

Valerie, T. F. T. (2020). *Investigation of the effect of temperature and humidity on the transmission of radio waves.* Singapore: School of Science and Technology publication.

Wayne T. (2001). *Electronic communications systems, fundamentals through Advanced*. New Jersey: Prentice-Hall, pp. 39.

Zafar, S. A. N. S, Sabri, H. N., Umar, R. & Ibrahim, A. Z. (2019). Radio Frequency Interference on nearby radio astronomical lines: the relationship between wind speed and radio signal strength measured at the East coast of Peninsular Malaysia. *Sains Malaysiana*, 48, 1, pp. 183-189.

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Not applicable

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Data shall be made available on demand.

Competing interests

The authors declared no conflict of interest

Ethical Consideration

Not applicable

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Authors' contributions

Joseph Amajama conceptualized the study, designed the experimental methodology, and supervised the overall project. He led data collection and performed analysis related to atmospheric temperature variations. Ahmed Tunde Ibrahim conducted the literature review, developed data analysis models, and carried out statistical analyses. He also contributed to interpreting the results and drafting the manuscript. Julius Ushie Akwagiobe assisted with the experimental setup and data acquisition, contributed to the discussion of findings, and reviewed the manuscript for technical accuracy and clarity. All authors have read and approved the final manuscript.