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Analyzing the Relationship between Atmospheric Pressure and Mobile Network Signal Strength in Southern Nigeria

Joseph Amajama*, Julius Ushie Akwagiobe, Eyime Echeng Eyime and Efa Ubi Ikpi

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Abstract: *This study examines the influence of atmospheric pressure on mobile phone signal strength across five Nigerian cities: Calabar, Uyo, Port Harcourt, Yenagoa, and Warri. Signal strength data were collected from two major mobile networks—MTN and 9Mobile—operating on both 3G and 4G frequency bands. Measurements were taken using Android smartphones running the Cell Signal Monitor application (Version 5.1.1). Data were logged at one-minute intervals at selected cell sites, focusing on the first fifteen minutes of each hour to maintain consistency. Simultaneously, atmospheric pressure readings were obtained from the Nigerian Meteorological Agency (NIMET) for correlation analysis. The findings reveal a generally weak and statistically insignificant inverse relationship between atmospheric pressure and signal strength (average correlation coefficient R = -0.042771). However, variations across locations and cell sites point to additional influencing factors, including local topography, antenna characteristics, seasonal weather patterns, and the spatial configuration of transmitters and receivers.*

Keywords: *Atmospheric Pressure, Climatic Variables, Weather Patterns, Meteorological Analysis, Environmental Correlation*

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1.0 Introduction

Air pressure—also known as *atmospheric pressure* or *barometric pressure*—is a fundamental meteorological variable that represents the force exerted by the Earth's atmospheric gases on a given surface area (Dutton, 2014). It reflects the weight of the air column above a specific point and plays a pivotal role in shaping weather patterns and broader climate dynamics. Atmospheric pressure is measured in various units, including pounds per square inch (psi), millimeters or inches of mercury (mmHg or inHg), dynes per square centimeter, standard atmospheres (atm), millibars (mb), and kilopascals (kPa) (Joseph, 2016c).

At sea level, typical atmospheric pressure ranges from approximately 950 mb to 1050 mb, with 1013.25 mb considered the standard average. Although these fluctuations may appear minor, they significantly influence weather phenomena. For instance, the lowest recorded sea-level pressure is about 877.07 mb (in Siberia), while the highest is approximately 1083.98 mb (recorded during a typhoon in the South Pacific) (Dutton, 2014). Low-pressure systems are generally associated with storms and precipitation, while high-pressure systems correspond to fair, stable weather (Joseph, 2016c; Amajama, 2017; Ibrahim et al., 2024a; Ibrahim et al., 2024b).

Atmospheric pressure can be conceptualized as the weight of the air column above a unit area. The term *barometric pressure* arises from the use of mercury barometers, which measure the height of a mercury column that balances atmospheric weight. The height of this column correlates directly with atmospheric pressure. In contrast, aneroid barometers use a sealed, flexible metal chamber that deforms with pressure changes; this mechanical movement is then translated into pressure readings (Dutton, 2014).

It is well established that atmospheric pressure decreases with increasing altitude (Amajama et al., 2023a). Near the Earth's surface, the pressure typically drops by approximately 3.5 millibars for every 30 meters (or about 100 feet) of elevation gain. In colder regions, where air density is higher, this rate of decrease can be even more pronounced.

Beyond its meteorological significance, atmospheric pressure also has an important impact on *radio wave propagation*—a key factor in mobile communications (Yilmaz & Erogul, 2004; Akinbolade & Adeniji, 2018; Amajama, 2016). As radio signals travel through the atmosphere, they encounter various impairments including path loss, refraction, and attenuation, all of which are influenced by prevailing atmospheric conditions (Tiwari & Sharma, 2014; Joseph, 2016a, 2016b; Iwuji et al., 2023a, 2023b, 2023c; Amajama et al., 2023a; Amajama et al., 2023b; Amajama et al., 2023c). Meteorological variables such as temperature, humidity, wind, and pressure jointly determine the degree of these signal degradations (Joseph & Oku, 2016; Kamarudin & Abdullah, 2019). In particular, atmospheric pressure affects the refractivity of the atmosphere, thereby altering how signals bend and weaken as they propagate through the troposphere (Amajama et al., 2023a; Amajama et al., 2025).

This research specifically investigates the role of atmospheric pressure in influencing mobile phone communication signal strength. Using data collected from southern Nigerian cities, the study examines the impact of pressure fluctuations on the signal quality of two major mobile networks in the country—MTN and 9Mobile. Given the growing reliance on robust wireless communication systems, understanding the relationship between local atmospheric pressure variations and mobile signal strength is essential for optimizing network performance in this region (Bian et al., 2015; Erogul & Yilmaz, 2006; Ghorbani & Zakeri, 2017; Pahal, 2013).

2.0 Literature Review

Several empirical studies have explored the relationship between atmospheric parameters and mobile communication signal strength. Ofure et al. (2017) conducted a 19-month study in Minna, Nigeria, titled *Impact of Some Atmospheric Parameters on GSM Signal*, to assess how atmospheric conditions affect GSM signal strength. Measurements were taken near a Base Transceiver Station (BTS) on the Bosso Campus of the Federal University of Technology, Minna. Using a weather station and a spectrum analyzer (SPECTRAN HF 6065) linked to a laptop running Aarisona data logging software, they collected data on temperature, pressure, relative humidity, and dew point, alongside the received signal level from the MTN network. Their findings showed no consistent relationship between atmospheric pressure and GSM signal strength.

Similarly, Osahenvemwen and Omatahunde (2018) investigated the *Impacts of Weather and Environmental Conditions on Mobile Communication Signals* in Benin City, Nigeria.

Their study focused on the Glo mobile network (900 MHz) and used Frequency-Signal Tracker software (version 2.5.1) to record signal strength at a fixed Glo BTS between July 28 and August 31, 2016. Data were collected hourly at a distance of 200 meters from the BTS. The analysis revealed a negative correlation of -0.44 between atmospheric pressure and signal strength, implying that higher pressure may degrade signal quality.

In India, Dalip and Kumar (2014) assessed the *Effect of Environmental Parameters on GSM and GPS* along a 50 km route in Haryana. Their study included rural and urban settings with varying environmental conditions such as fog, clouds, rain, and clear skies. Weather data were sourced from the Weather2 website, and signal strength and GPS accuracy were recorded under these different conditions. Their graphical analysis indicated that atmospheric pressure and other environmental factors significantly impact both GSM signal strength and GPS precision.

Ukhurebor and Umukoro (2018) focused on the *Influence of Meteorological Variables on UHF Radio Signals* in Benin City. Using a Digital Community-Access/Cable Television (CATV) analyzer and a custom-built portable weather monitoring system, they collected data at 8-hour intervals throughout 2017. The UHF signal at 743.25 MHz transmitted by EBS Television exhibited a strong inverse correlation with atmospheric pressure (r = -0.92), under stable conditions of other meteorological variables.

Joseph (2016c) reported similar findings in a study conducted in Calabar, Nigeria, examining the *Impact of Atmospheric Pressure on UHF Radio Signals*. Using data collected every 30 minutes from CRBC transmissions at 519.25 MHz (35 mDB), the study found a very strong inverse correlation (r = -0.99) between atmospheric pressure and signal strength, reinforcing the view that higher pressure dampens radio signal quality when other variables remain constant.

Unlike these studies, which typically measured signal strength near broadcasting stations or BTS without isolating specific signal sources, the present research adopts a more targeted approach by measuring signals from specific, identified cells within the MTN and 9Mobile networks. This method enhances precision and allows for a more accurate assessment of the relationship between atmospheric pressure and mobile communication signal strength. Thus, this study addresses an important gap in the literature by providing location-specific, cell-based data across multiple cities in southern Nigeria.

3.0 Materials and Methods

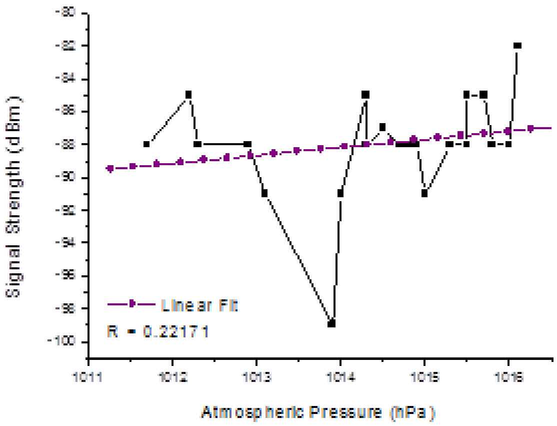
This study investigated the influence of atmospheric pressure on mobile phone signal strength across five Nigerian cities: Calabar, Uyo, Port Harcourt, Yenagoa, and Warri. Signal strength data were collected for two major mobile network operators—MTN and 9Mobile—operating on both 3G and 4G frequency bands. Specifically, MTN's downlink frequencies included 2110–2120 MHz for 3G and 2620–2690 MHz for 4G, while 9Mobile operated within 2130–2140 MHz (3G) and 1805–1880 MHz (4G) (Nigerian Communications Commission [NCC], 2020).

Signal measurements were obtained using Android smartphones equipped with the Cell Signal Monitor application (version 5.1.1), which logged received signal strength indicators (RSSI) at one-minute intervals. To ensure consistency and minimize temporal variability, data collection in each city was restricted to the first fifteen minutes of every hour and confined to specific, pre-identified cell sites.

Atmospheric pressure data corresponding to the measurement intervals were sourced from hourly meteorological bulletins provided by the Nigerian Meteorological Agency (NIMET). For each logged signal strength value, the corresponding atmospheric pressure reading was recorded concurrently, allowing for direct correlation analysis between atmospheric pressure and mobile signal strength.

4.0 Results and Discussions

Based on the linear plots (Figures 1 to 5) illustrating the relationship between received signal strength and atmospheric pressure across the eighty-eight (88) analyzed cell sites, a majority—fifty-five (55) cells—exhibited a negative correlation, whereas thirty-three (33) demonstrated a positive correlation. The computed Pearson correlation coefficients ranged from –0.62224 to 0.64639, indicating varying degrees of association between atmospheric pressure and signal strength across different locations and network cells.



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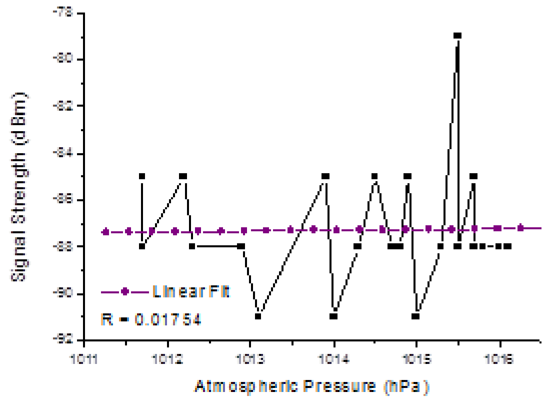

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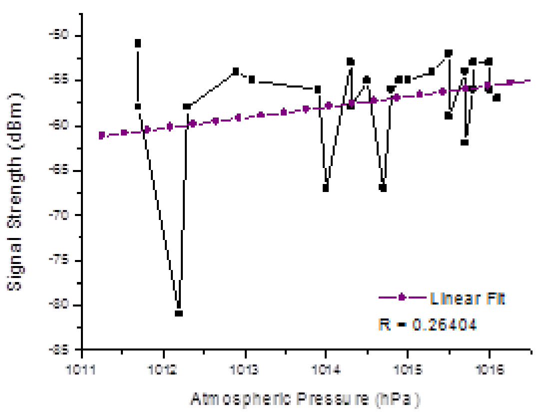

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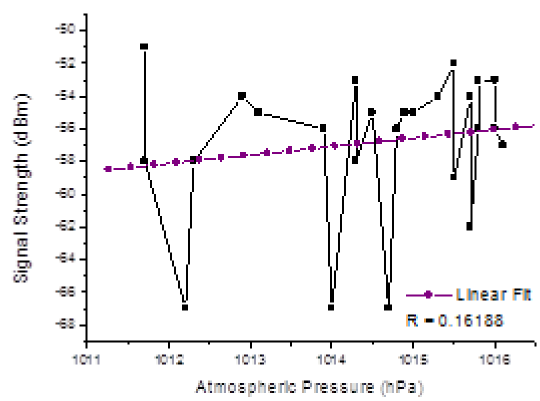

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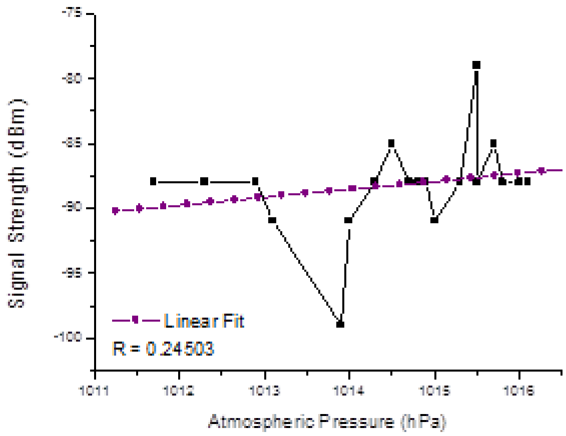
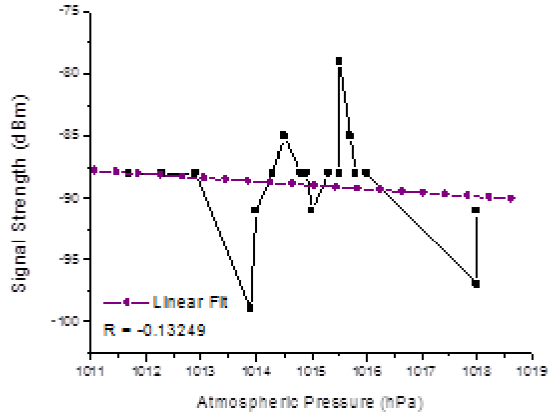

Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.24503

(e)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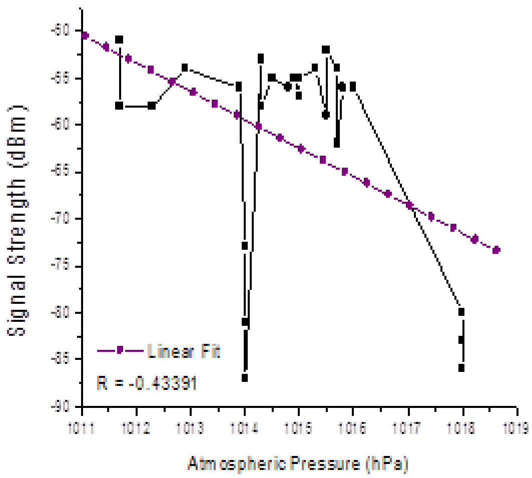
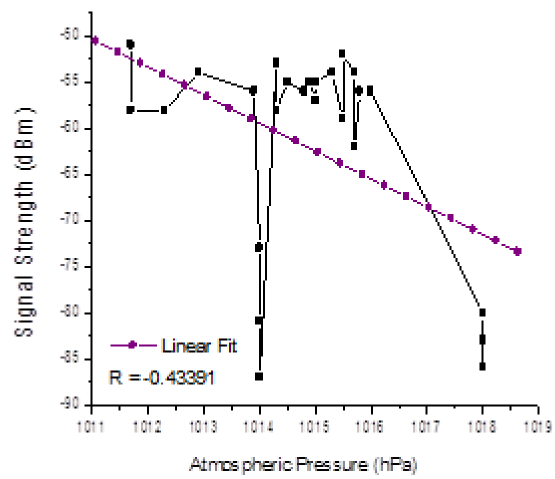
Atmospheric Pressure (hPa)
Linear Fit
R = -0.13249

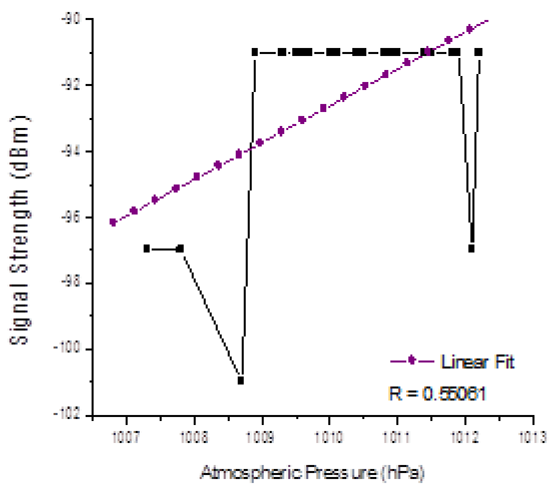
(f)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.43391

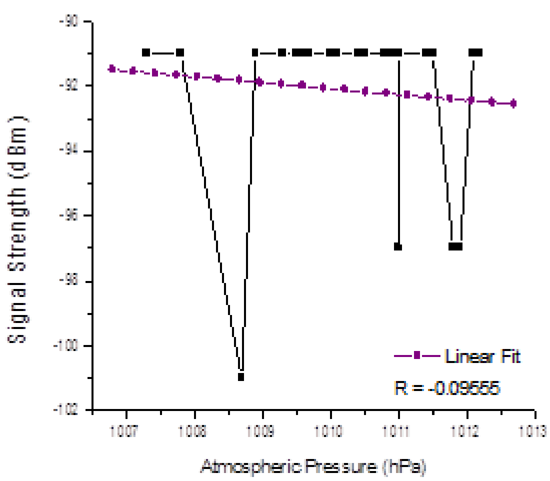
(g)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.43391

(h)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.55061

(i)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.09555

(j)

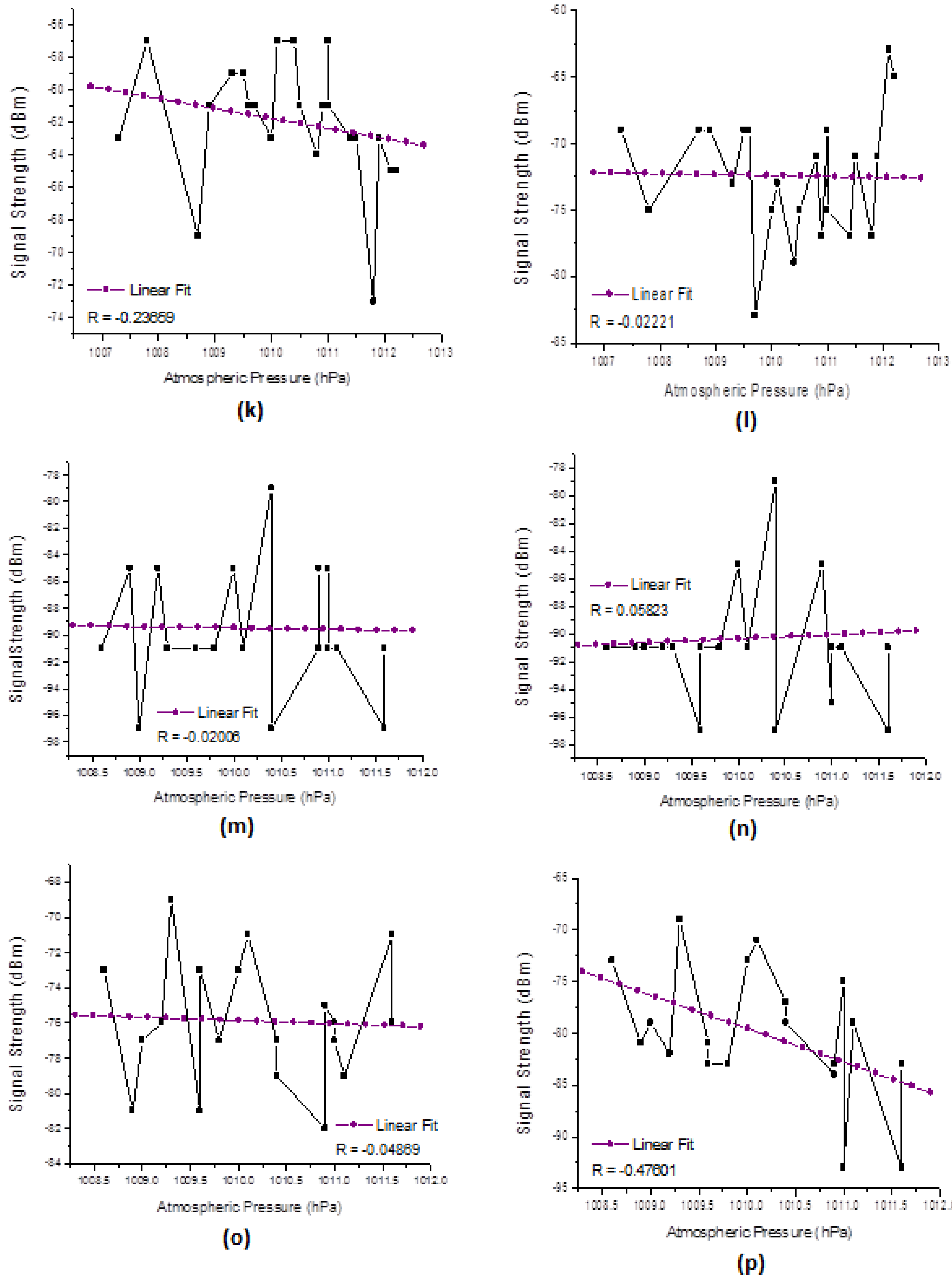
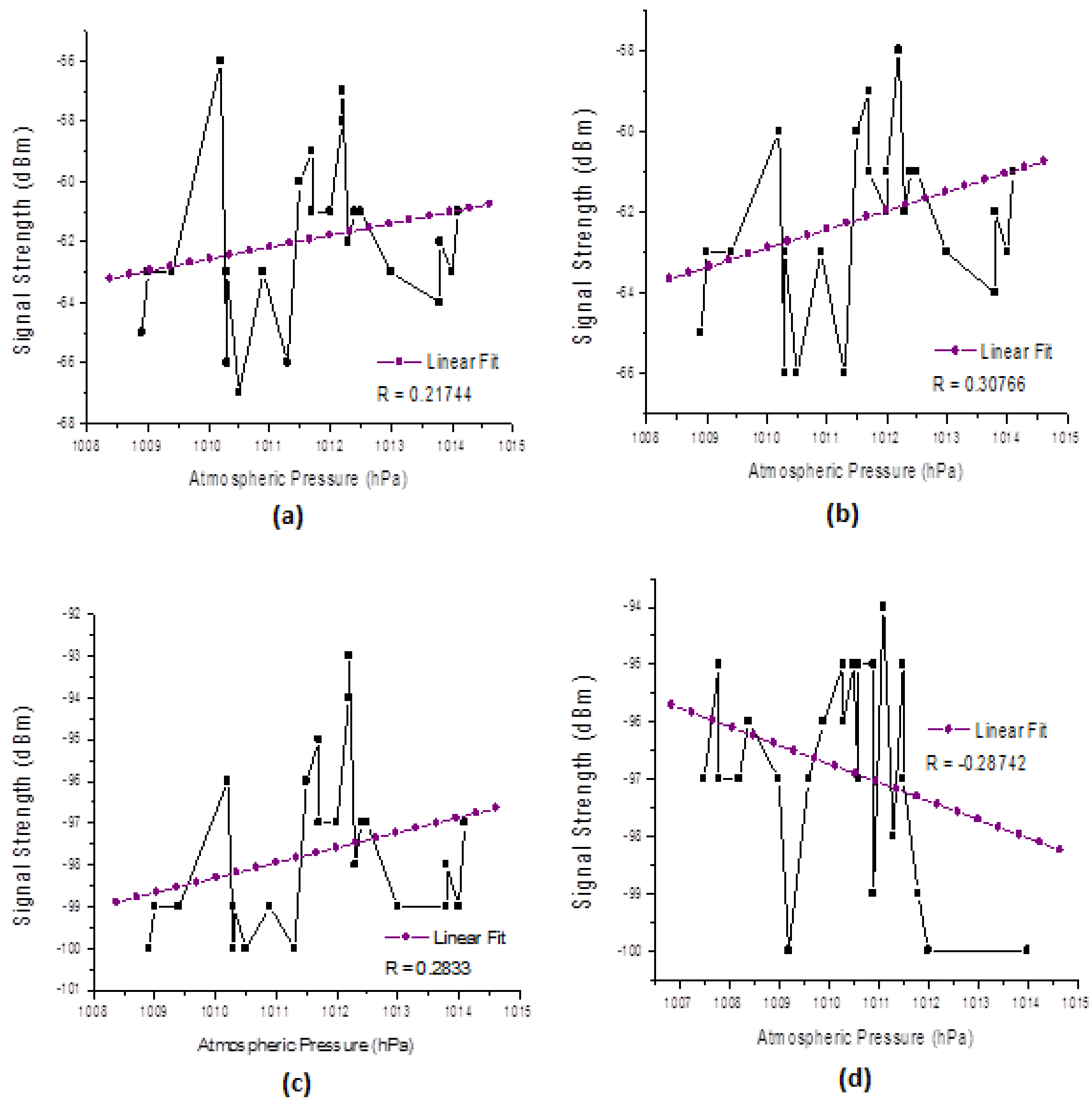
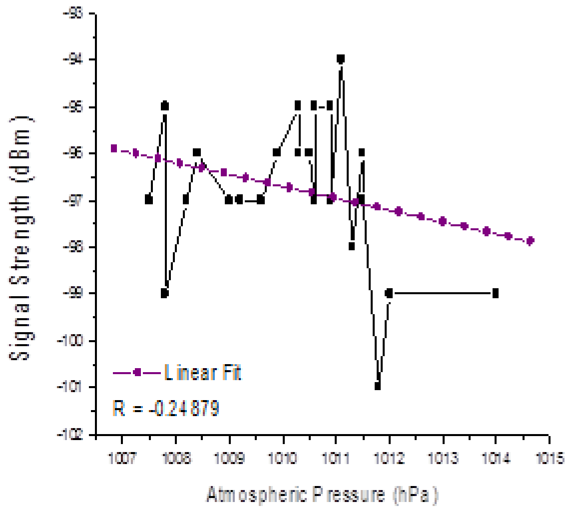
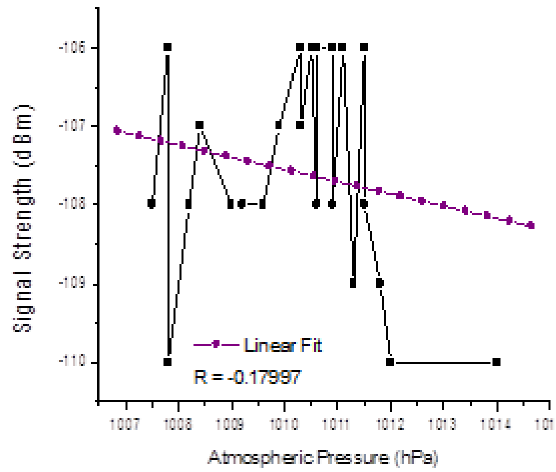


Fig. 1 Signal strength VS atmospheric pressure from some selected cells in Calabar

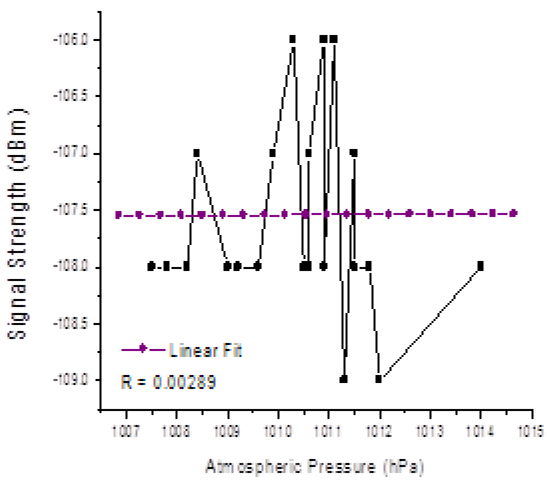

Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.21744
(a)
Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.30766
(b)
Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.2833
(c)
Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.28742
(d)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.24879

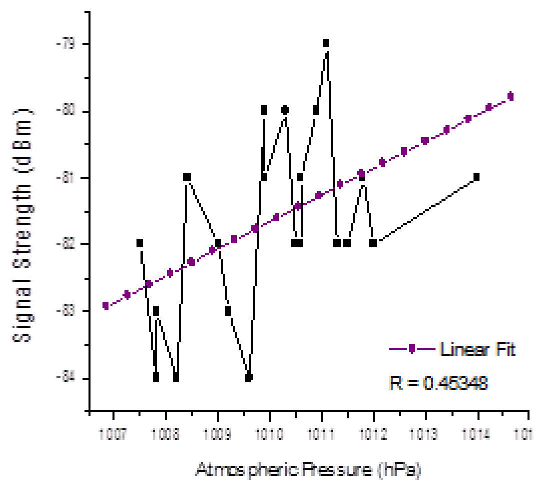
(e)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.17997

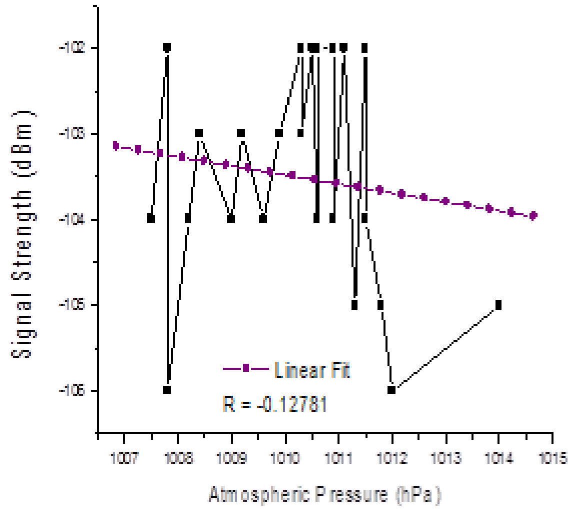
(f)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.00289

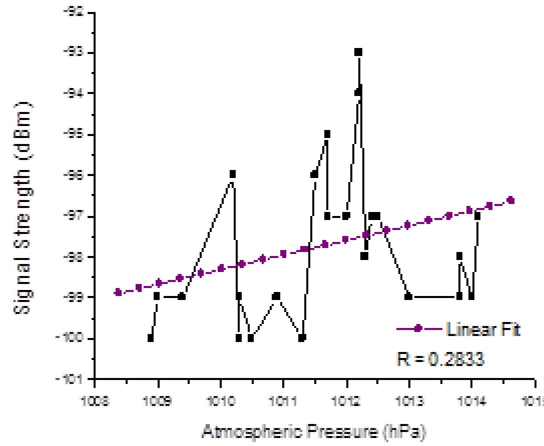
(g)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.45348

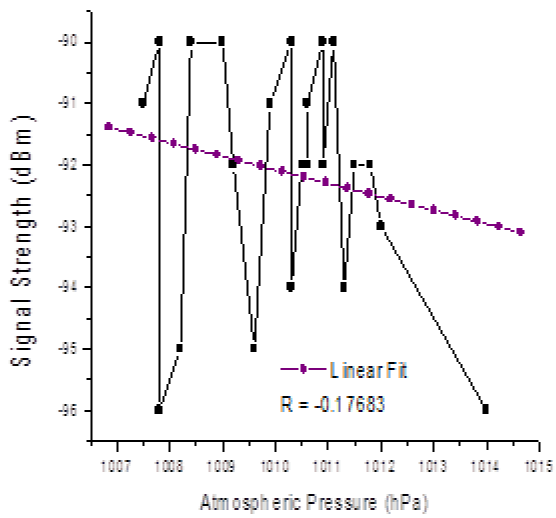
(h)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.12781

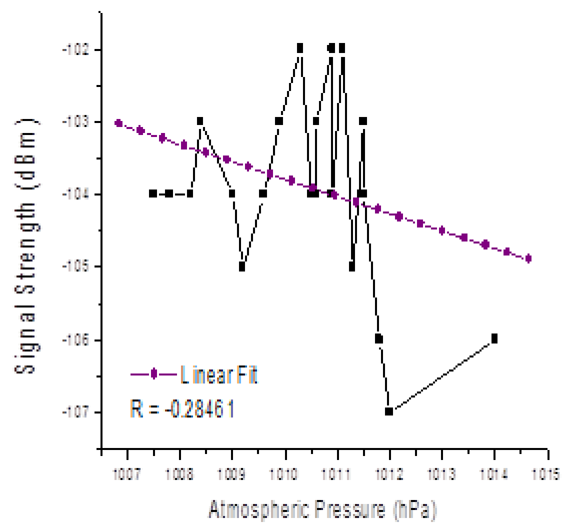
(i)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.2833

(j)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.17683

(k)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.28461

(l)

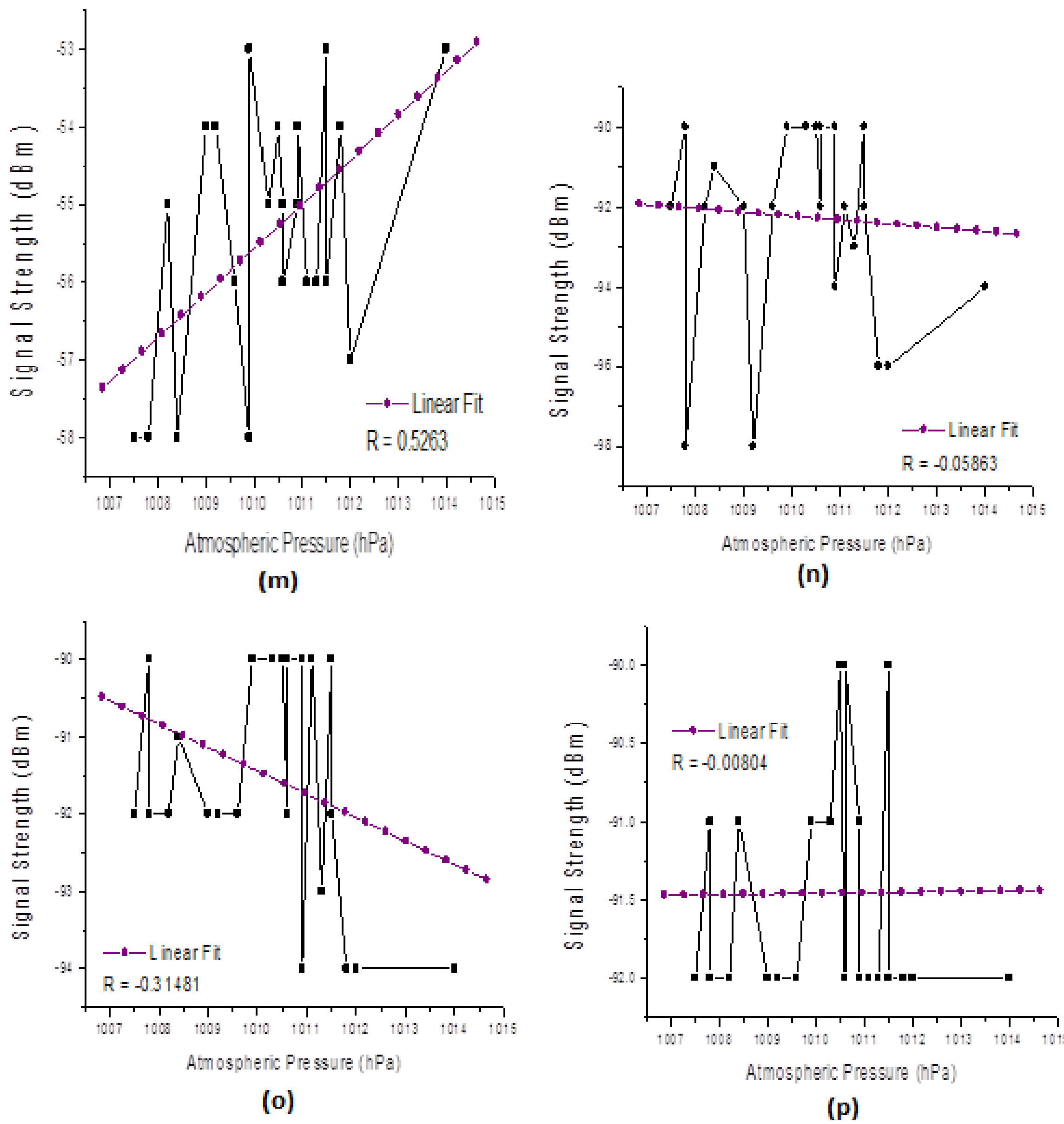
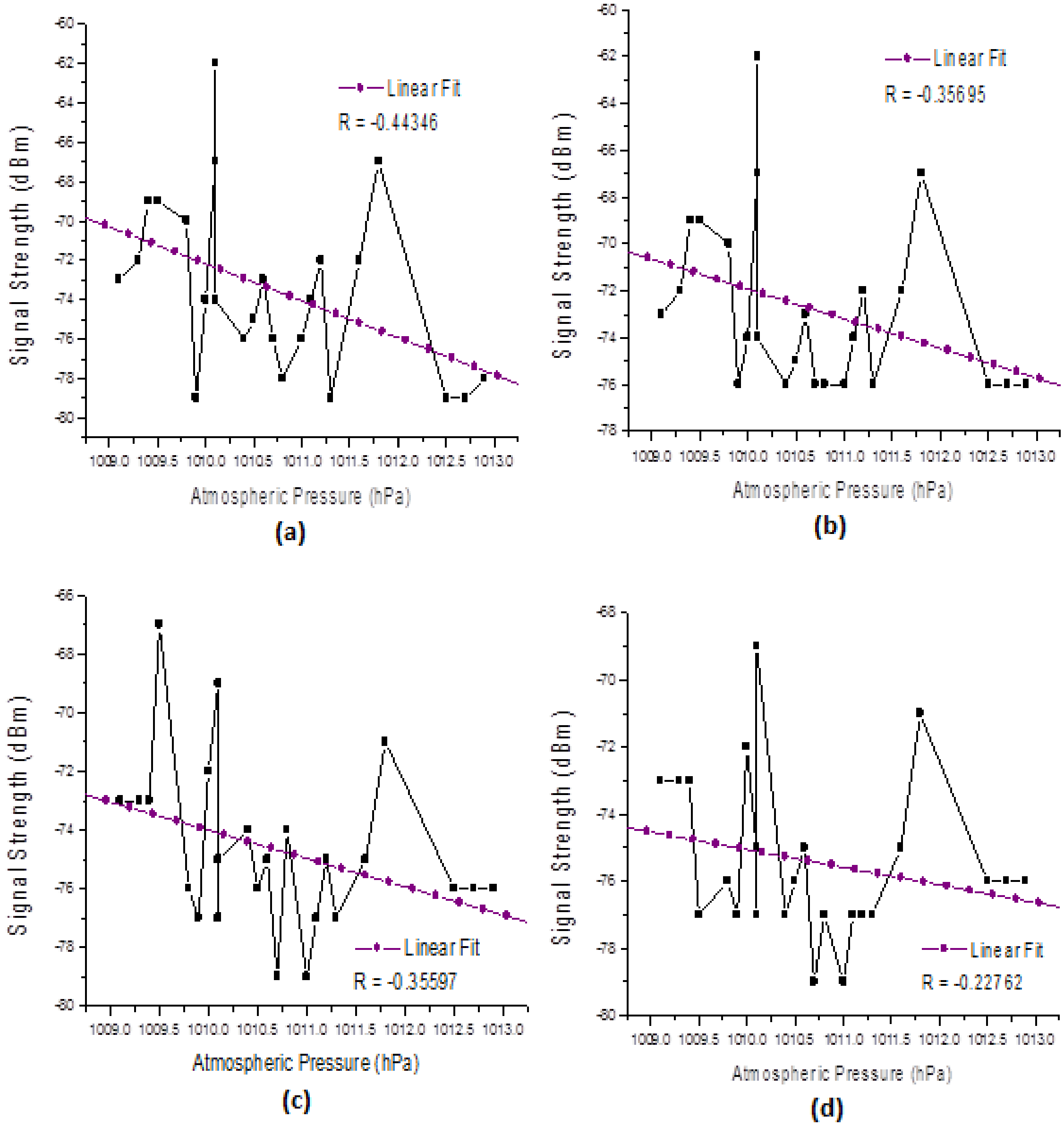
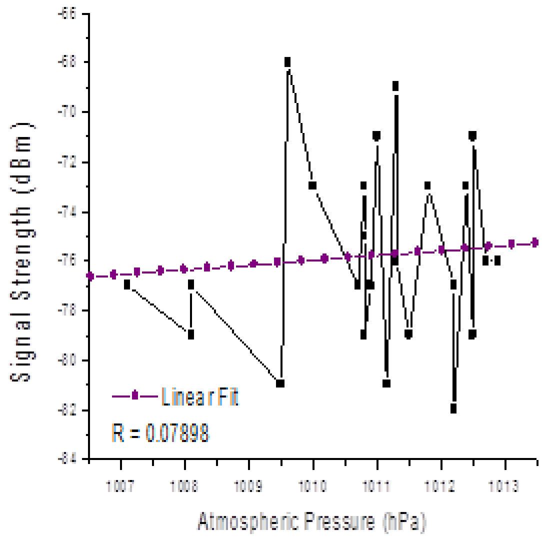
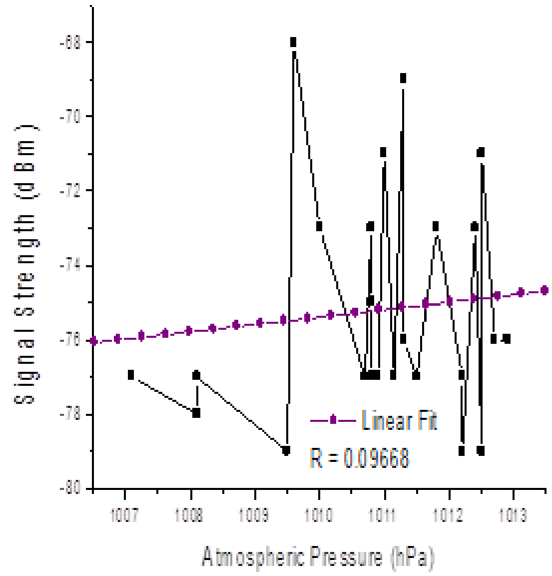


Fig. 2 Signal strength VS atmospheric pressure from some selected cells in Uyo

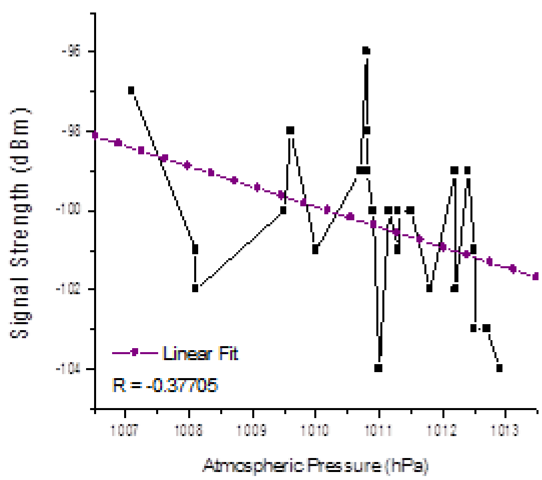

Linear Fit
R = -0.44346
Signal Strength (dBm)
Atmospheric Pressure (hPa)
(a)
Linear Fit
R = -0.35695
Signal Strength (dBm)
Atmospheric Pressure (hPa)
(b)
Linear Fit
R = -0.35597
Signal Strength (dBm)
Atmospheric Pressure (hPa)
(c)
Linear Fit
R = -0.22762
Signal Strength (dBm)
Atmospheric Pressure (hPa)
(d)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.07898

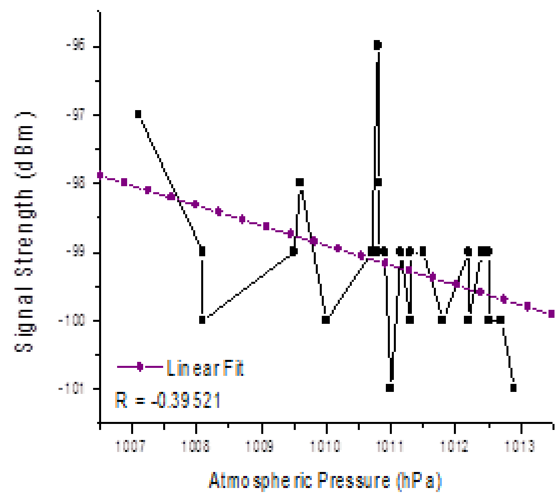
(e)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.09668

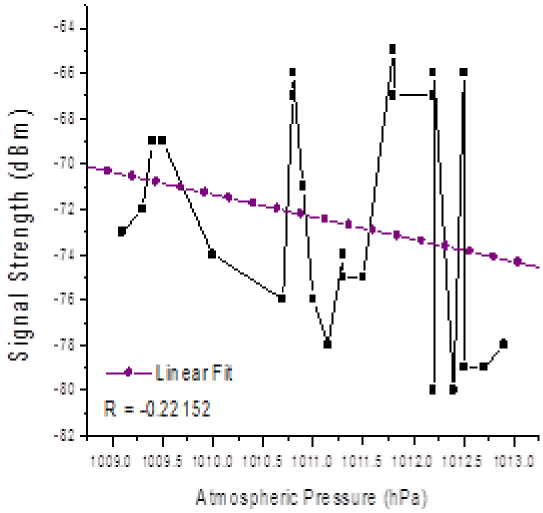
(f)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.37705

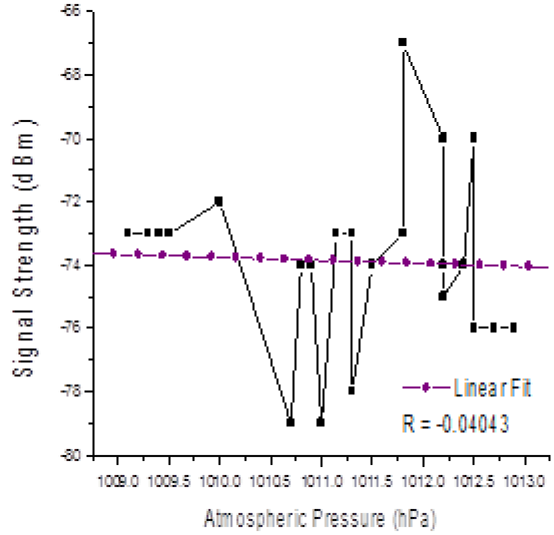
(g)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.39521

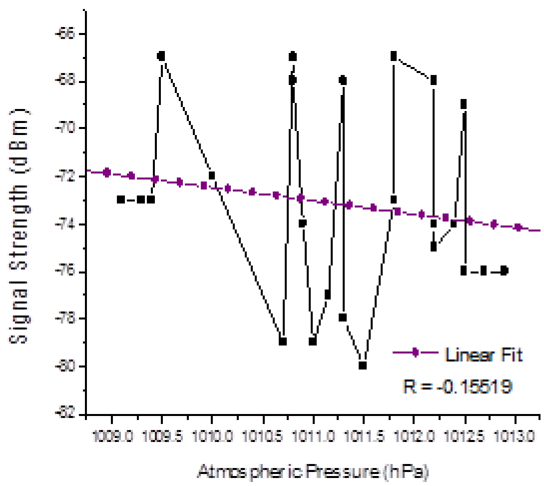
(h)


Signal Strength (dBm)
-64
-66
-68
-70
-72
-74
-76
-78
-80
-82
1009.0 1009.5 1010.0 1010.5 1011.0 1011.5 1012.0 1012.5 1013.0
Atmospheric Pressure (hPa)
Linear Fit
R = -0.22152

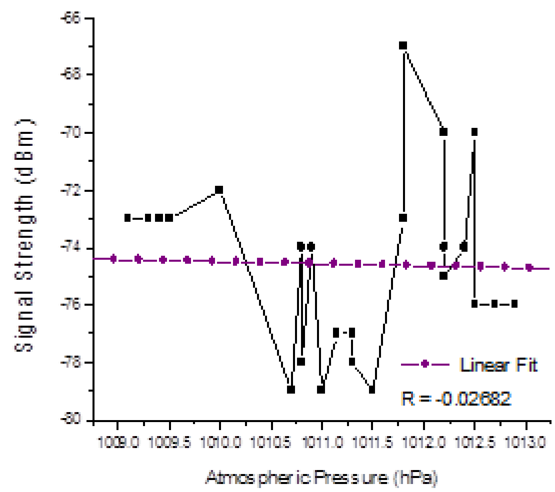
(i)


Signal Strength (dBm)
-66
-68
-70
-72
-74
-76
-78
-80
1009.0 1009.5 1010.0 1010.5 1011.0 1011.5 1012.0 1012.5 1013.0
Atmospheric Pressure (hPa)
Linear Fit
R = -0.04043

(j)


Signal Strength (dBm)
-66
-68
-70
-72
-74
-76
-78
-80
-82
1009.0 1009.5 1010.0 1010.5 1011.0 1011.5 1012.0 1012.5 1013.0
Atmospheric Pressure (hPa)
Linear Fit
R = -0.15519

(k)


Signal Strength (dBm)
-66
-68
-70
-72
-74
-76
-78
-80
1009.0 1009.5 1010.0 1010.5 1011.0 1011.5 1012.0 1012.5 1013.0
Atmospheric Pressure (hPa)
Linear Fit
R = -0.02682

(l)

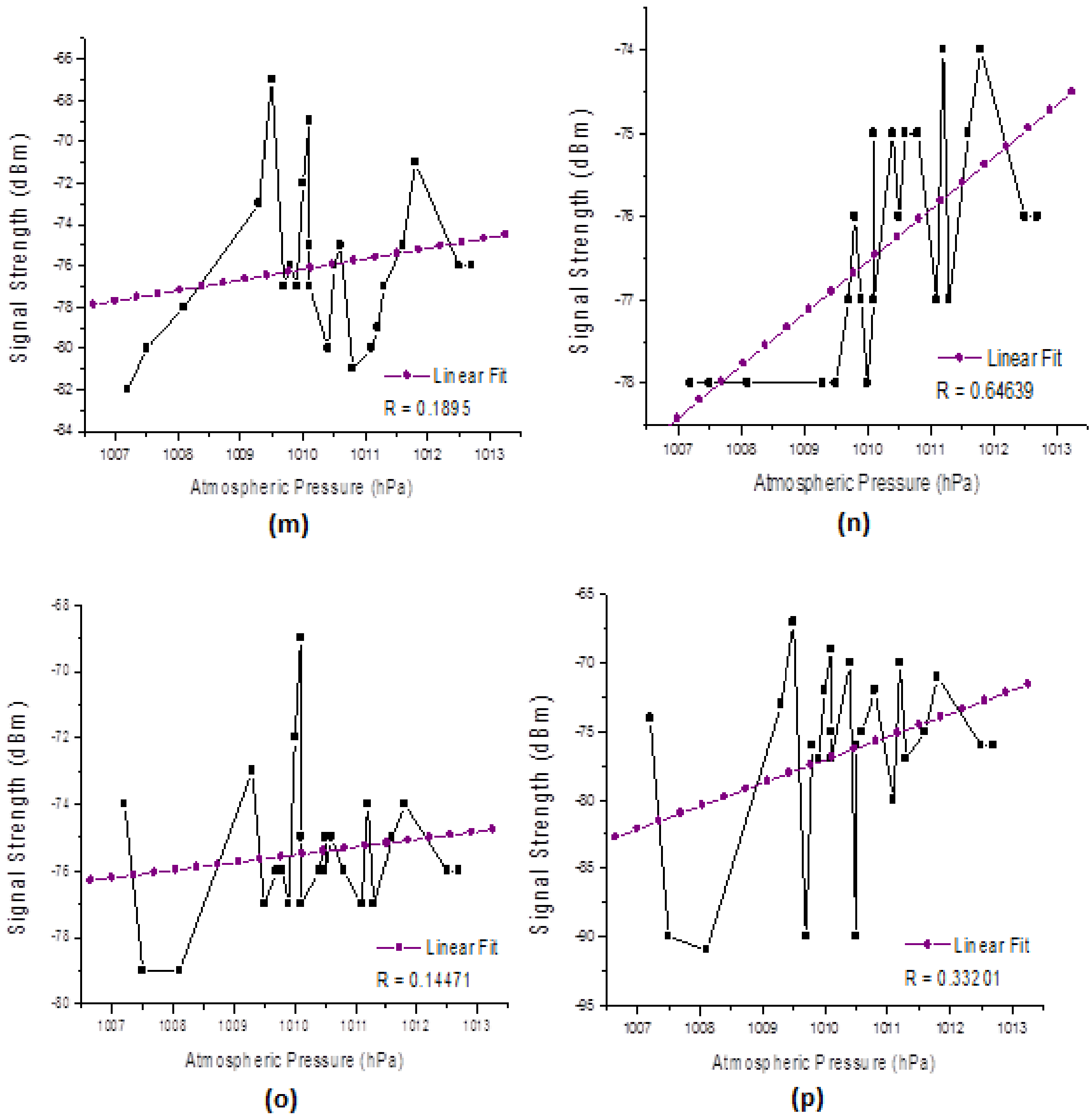
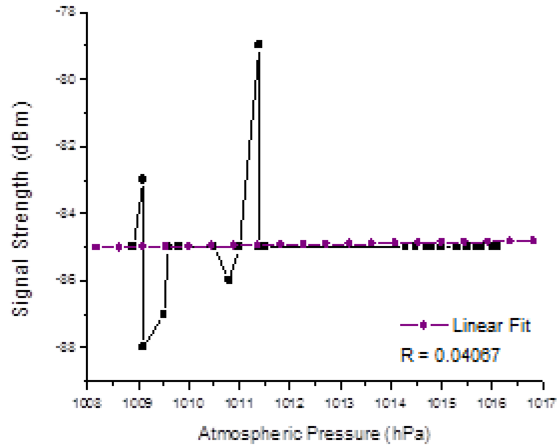
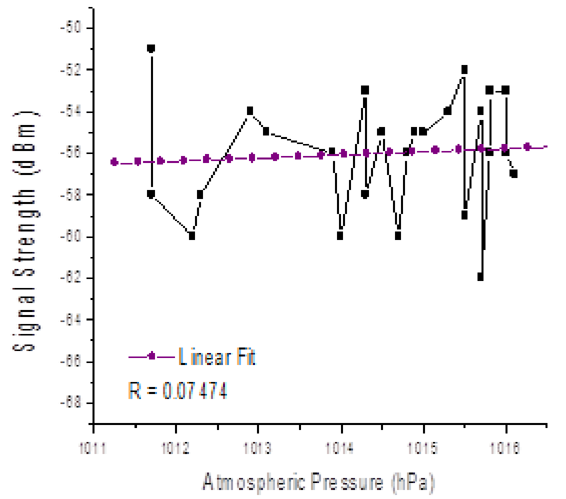


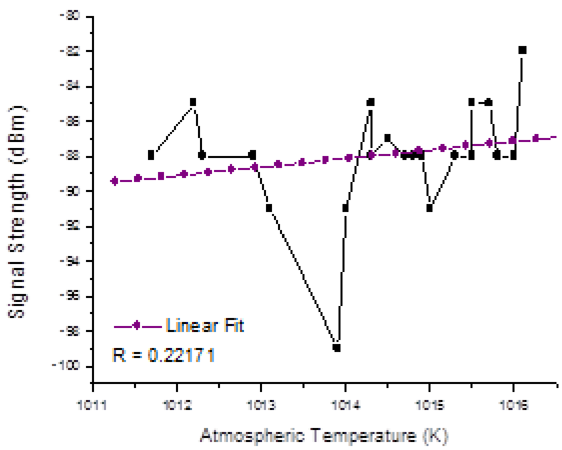
Fig. 3 Signal strength VS atmospheric pressure from some selected cells in Port Harcourt


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.04067

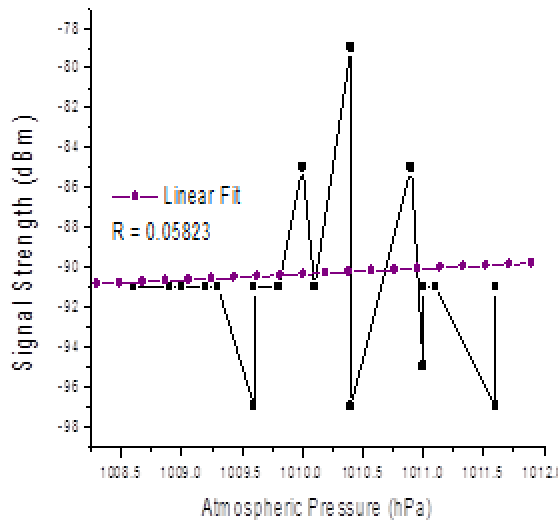
(a)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.07474

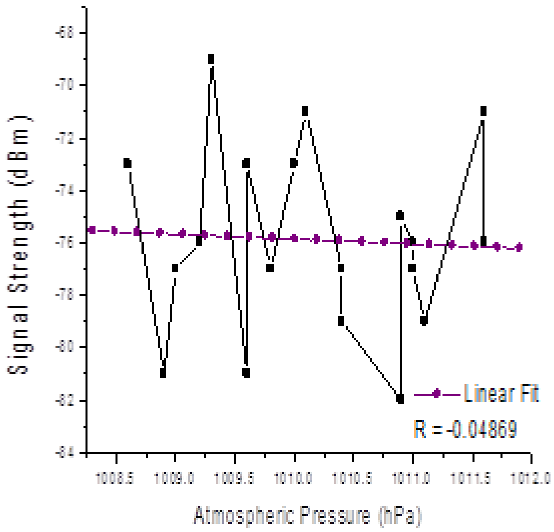
(b)

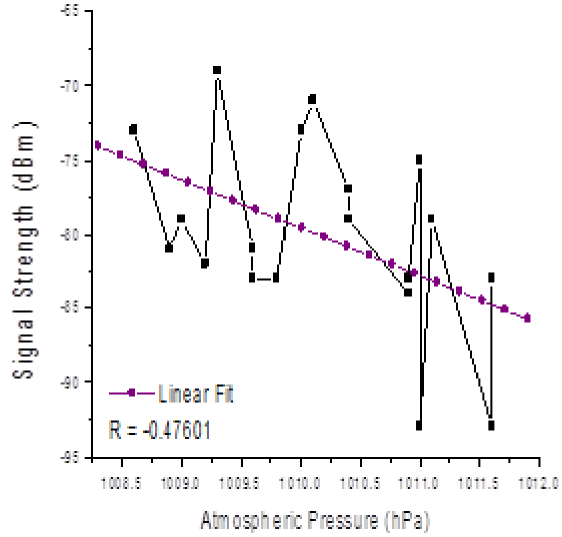

Signal Strength (dBm)
Atmospheric Temperature (K)
Linear Fit
R = 0.22171

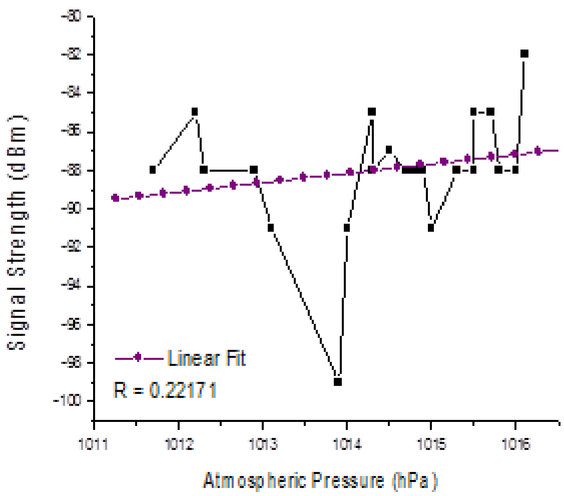
(c)

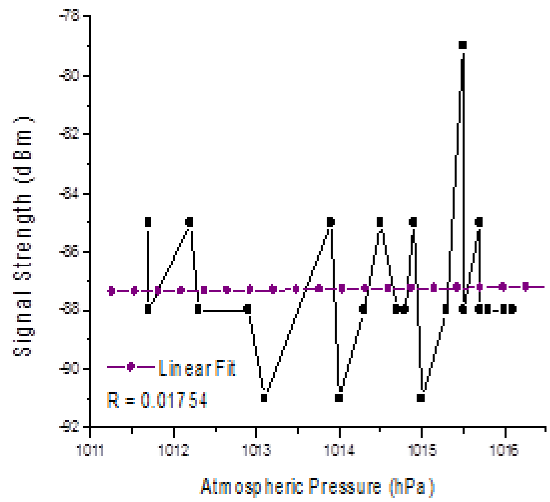

Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.05823

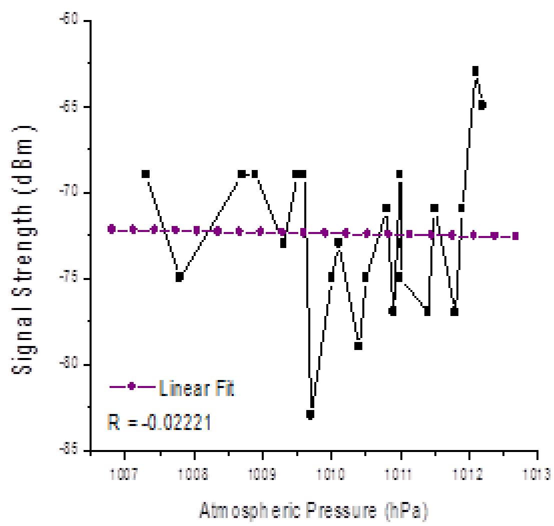
(d)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.04869
(e)

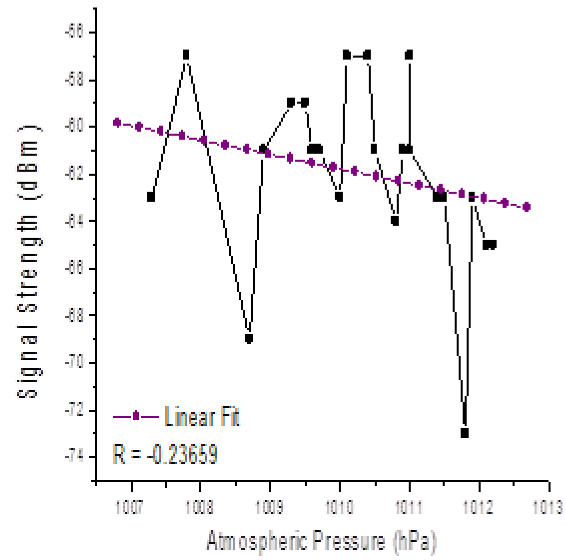

Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.47601
(f)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.22171
(g)

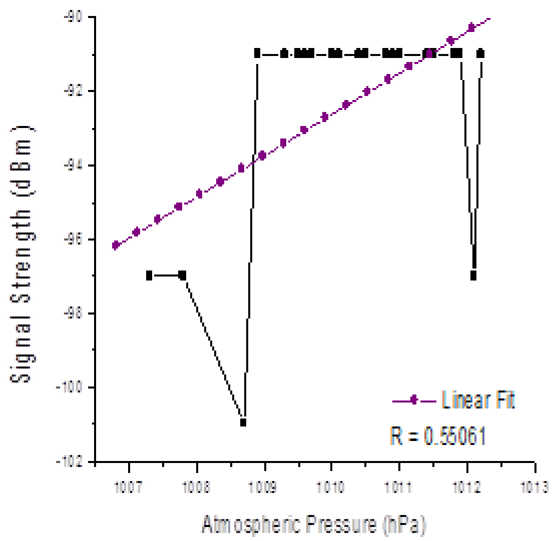

Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.01754
(h)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.02221

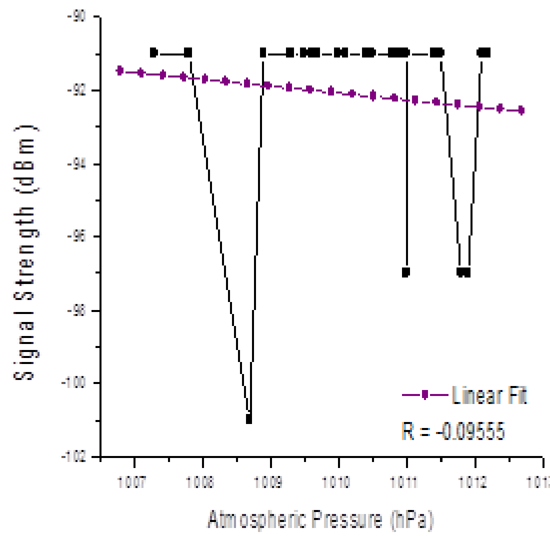
(i)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.23659

(j)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.55061

(k)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.09555

(l)

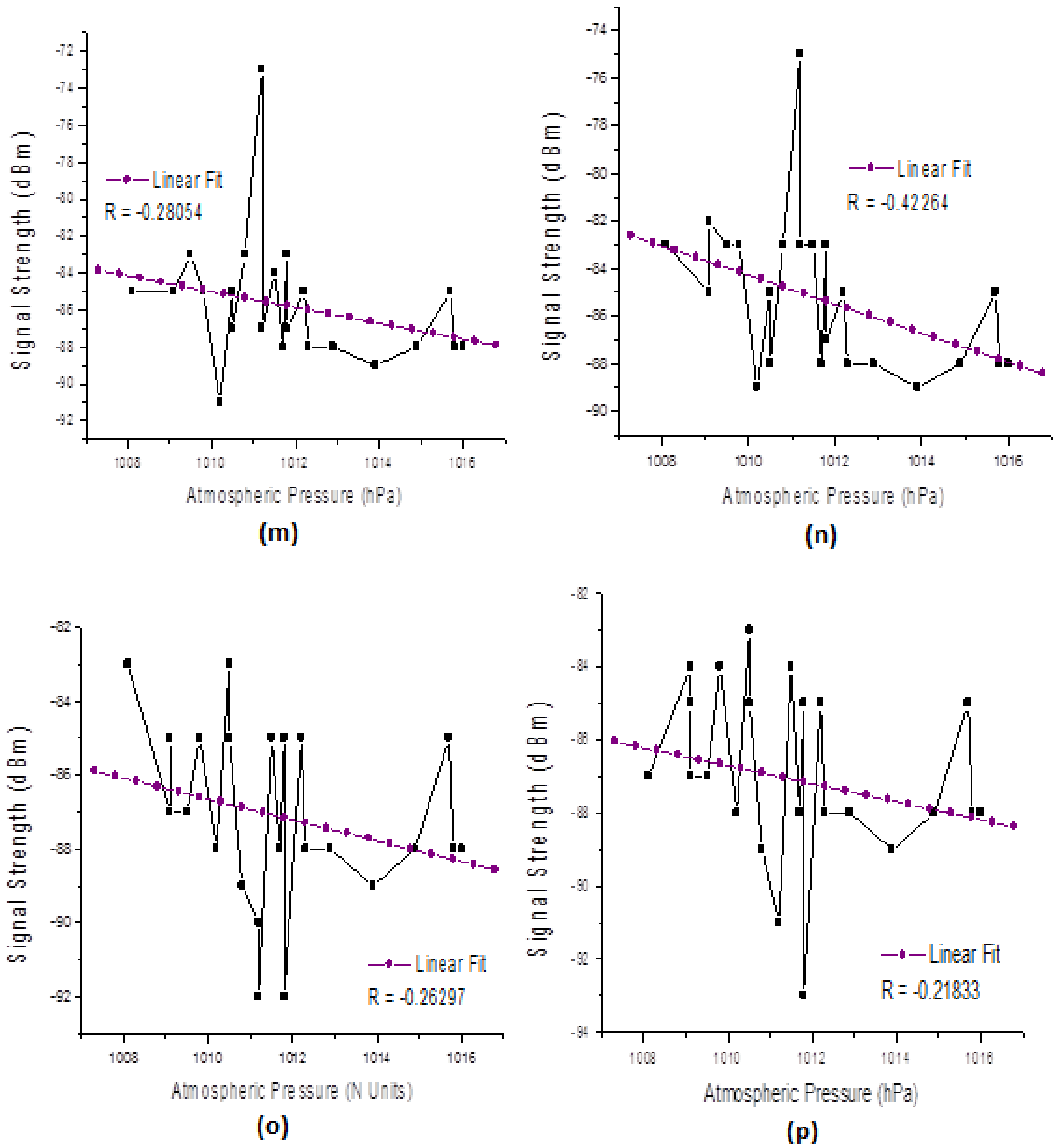
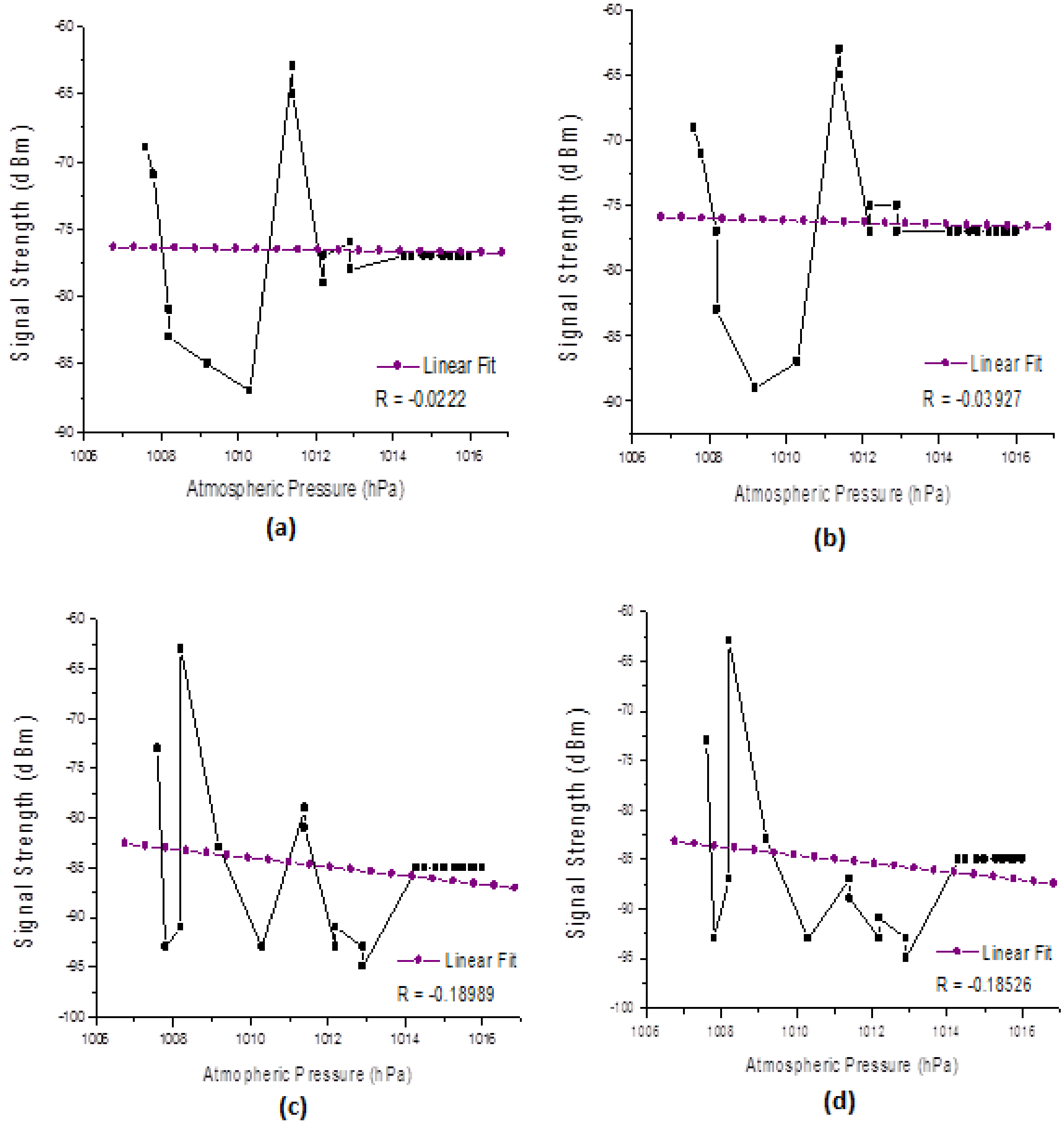
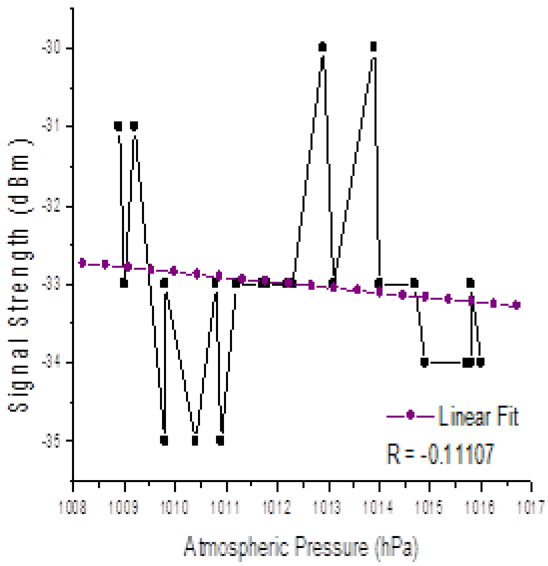


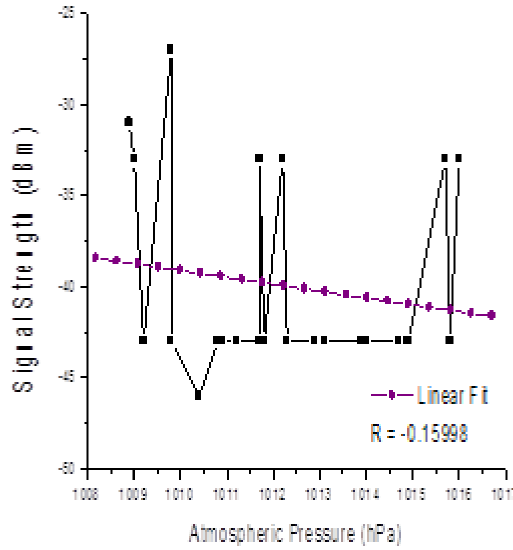
Fig. 4 Signal strength VS atmospheric pressure from some selected cells in Warri



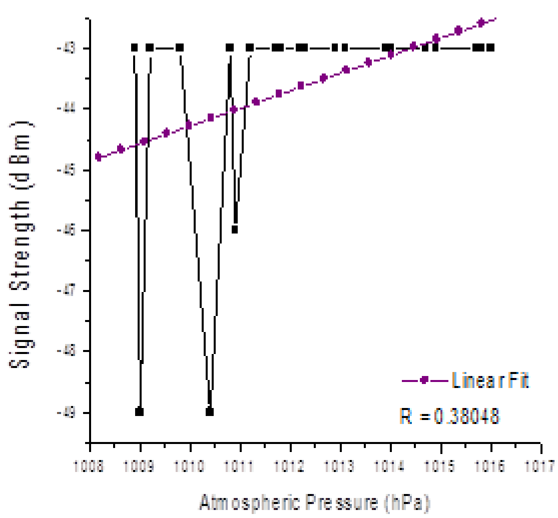
Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.0222
(a)
Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.03927
(b)
Signal Strength (dBm)
Atmopheric Pressure (hPa)
Linear Fit
R = -0.18989
(c)
Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.18526
(d)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.11107

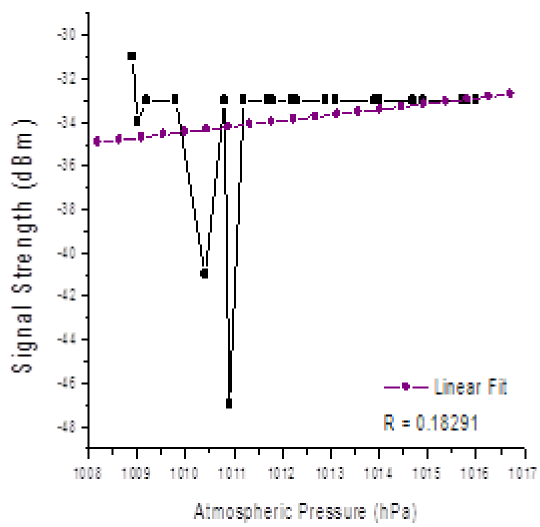
(e)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.15998

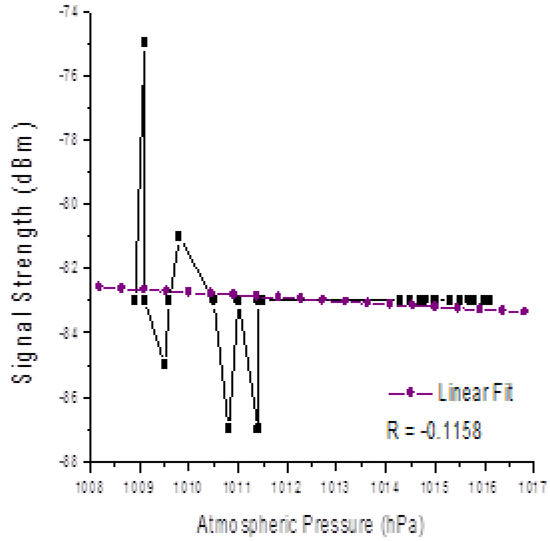
(f)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.38048

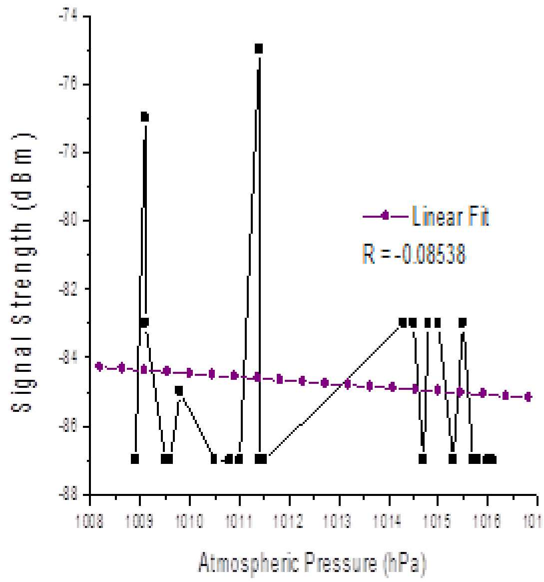
(g)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.18291

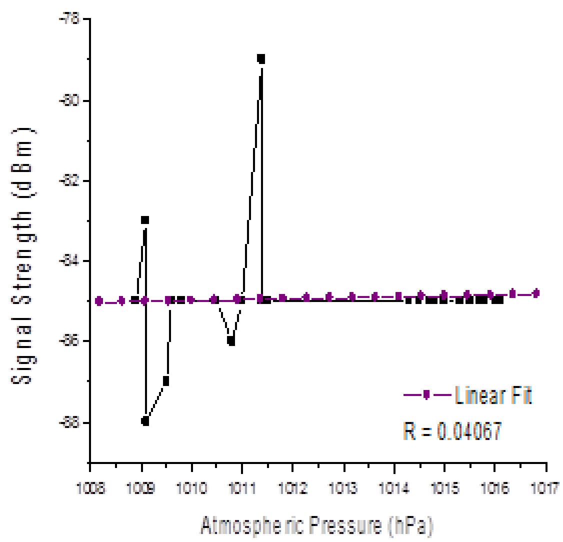
(h)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.1158

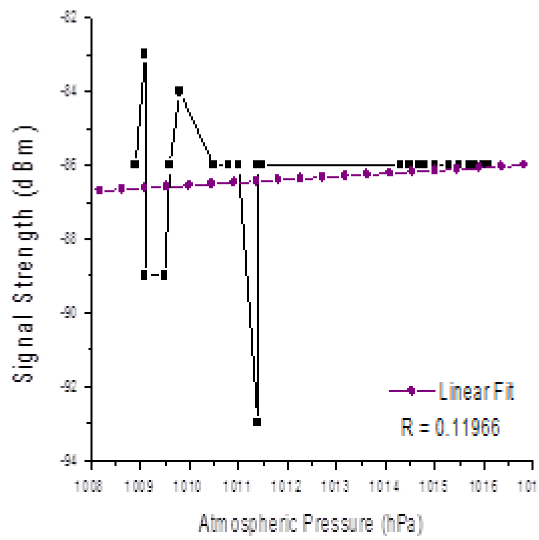
(i)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = -0.08538

(j)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.04067

(k)


Signal Strength (dBm)
Atmospheric Pressure (hPa)
Linear Fit
R = 0.11966

(l)

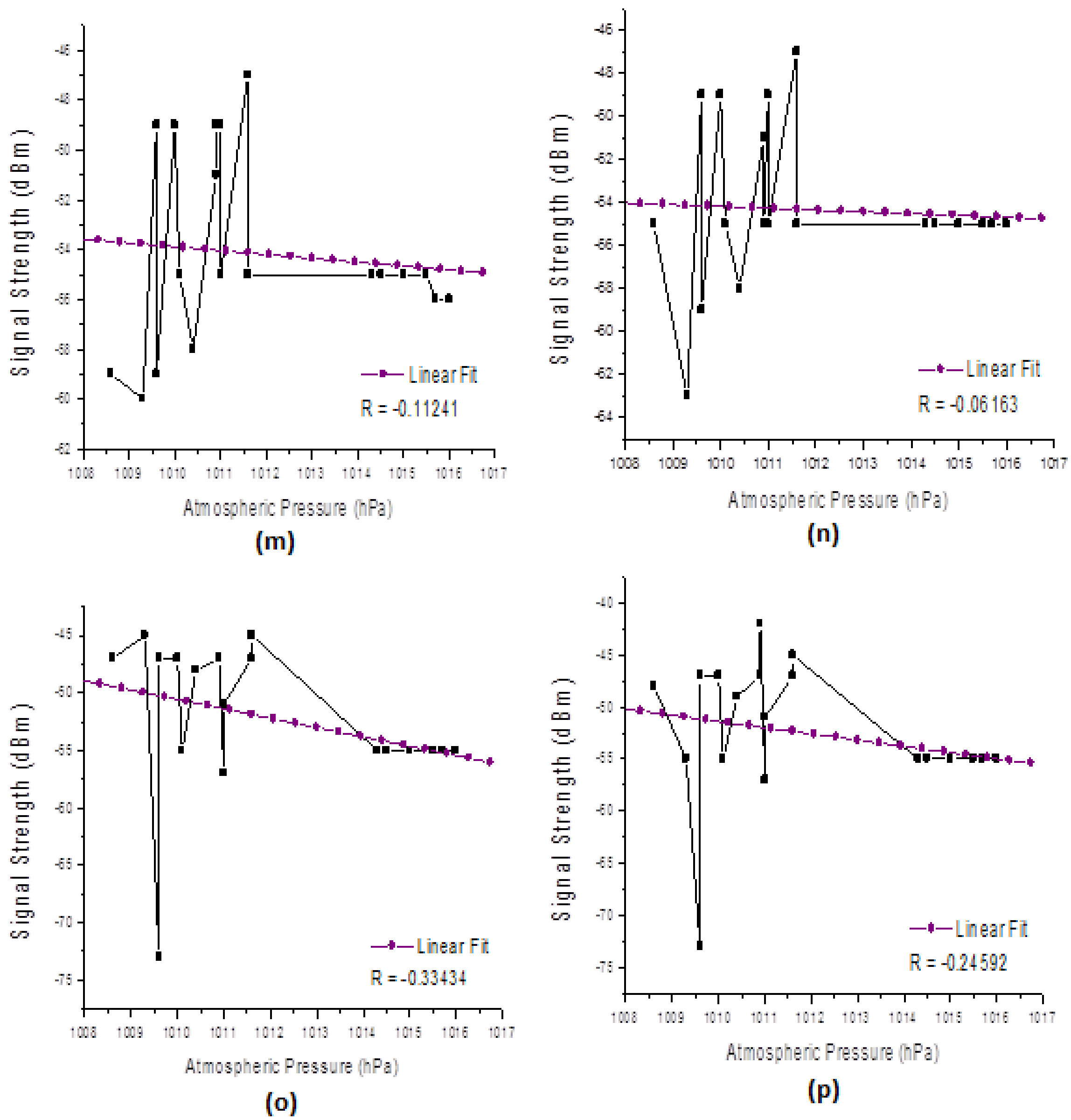


Fig. 5 Signal strength VS atmospheric pressure from some selected cells in Yenagoa

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 discrepancies observed in the results can be primarily attributed to topographical differences among the measurement locations. Since communication between base station transmitters and mobile station receivers relies predominantly on point-to-point or line-of-sight propagation, variations in terrain and elevation can significantly affect signal strength. This observation is consistent with the findings of Dalip and Kumar (2014), who reported that greater transmitter heights typically result in improved signal reception due to reduced obstruction.

Table 1 Summary of results

Location	Average R-value	Overall average R-value
Calabar	-0.06507	-0.042771
Uyo	0.012326	
Portharcourt	-0.069497	
Warri	-0.05449	
Yenagoa	-0.037124	

In addition to topographical influences, atmospheric factors—particularly wind speed and direction—may also have contributed to the observed variability, despite not being explicitly accounted for in this study. Water vapor, a key atmospheric constituent, affects the density and stratification of atmospheric layers, which in turn can influence radio wave propagation. Since radio waves can be modeled as particles, their dispersion and path can be influenced by wind, thereby affecting the received signal strength. Chima et al. (2018) supported this notion, observing that although wind may not directly affect signal transmission, it can alter the refractive properties of the wave, with even minor wind variations resulting in noticeable changes in signal strength. Similarly, Meng et al. (2009) demonstrated experimentally that both wind and rain introduce additional attenuation, with the magnitude of signal degradation increasing alongside wind speed, rainfall intensity, and frequency. They reported significant signal fluctuations and deep fading during high wind and rain conditions. Zafar et al. (2019) also found that wind and rain contribute to signal attenuation, with a stronger negative correlation between signal strength and wind speed observed during the wet season. Their study suggested that rainfall, accompanied by breezes, leads to increased scattering and absorption of radio waves, reducing signal quality. In contrast, the dry season—with lower humidity and minimal rainfall—was associated with stronger signal strength and less detrimental refractive effects, occasionally enhancing signal propagation. Joseph and Oku (2016) posited that under stable atmospheric conditions (i.e., constant temperature, pressure, and humidity), wind direction relative to wave propagation can significantly impact signal strength—being more favorable when aligned and more disruptive when opposing.

While UHF signals typically propagate via line-of-sight, this ideal condition is not always achievable in real-world environments (Wayne, 2001). Variability in receiver location and antenna height can lead to fluctuations in received signal strength due to multipath propagation—where signals reflect off surfaces and arrive at the receiver along multiple paths. This phenomenon may result in constructive or destructive interference, depending on the relative phase of the signals, a process known as Rayleigh fading. Elevating the antenna generally mitigates such issues by improving line-of-sight and reducing obstruction. Anyasi and Uzairue (2014) highlighted that mobile station location and elevation significantly influence signal strength, along with antenna characteristics. The antenna radiation pattern or directivity also plays a critical role. Not all antennas are omnidirectional; directional antennas (e.g., unidirectional or bidirectional) must be properly oriented relative to the transmitter to optimize signal reception (Rappaport, 1996).

Seasonal variability in weather conditions likely introduced further uncertainty into the measurements. The data collection spanned the year 2019 across multiple sites, with some regions, such as Calabar and Bayelsa, predominantly covered during the wet season, while others, including Uyo, Port Harcourt, and Warri, encompassed both wet and dry periods. In Nigeria's tropical monsoon climate, temperature and humidity show only modest seasonal variation; however, atmospheric refractivity tends to be higher in the wet season and lower in the dry season (Oku et al., 2015). These refractivity differences, coupled with seasonal moisture content, may significantly influence signal propagation.

Regarding atmospheric pressure specifically, the study's results generally pointed to a negative correlation with signal strength. As atmospheric pressure increases, a greater downward force is exerted on the wave-particle flow, potentially limiting propagation distance. The impact, however, depends on the relative elevation of the transmitter and receiver. When the receiver is situated at a higher elevation, increased atmospheric pressure may impede signal reach by pulling waves downward. Conversely, if the receiver is lower, increased pressure may enhance reception by concentrating wave energy at the antenna. These observations align with Joseph's (2016c) findings, which showed a strong inverse relationship between atmospheric pressure and UHF signal strength under controlled meteorological conditions. Similarly, Osahenvemwen and Omatahunde (2018) reported a negative correlation coefficient of –0.44 between atmospheric pressure and GSM signal strength. On the other hand, Ofure et al. (2017) found no consistent correlation, suggesting that other modulating variables may influence this relationship. Overall, while atmospheric pressure appears to affect GSM signal strength, its influence is variable and highly dependent on local environmental and system-specific factors.

In conclusion, the variations in received signal strength observed in this study are the result of a complex interplay among topographical features, atmospheric dynamics—including wind, humidity, and pressure—and antenna characteristics such as height and radiation pattern. Seasonal climatic differences further complicate the propagation environment. Together, these factors underscore the multifaceted and dynamic nature of radio wave transmission in terrestrial wireless communication systems.

5.0 Conclusion

Overall, atmospheric pressure exhibited a weak and statistically insignificant inverse relationship with mobile phone signal strength, with an average correlation coefficient of R = −0.042771. However, considerable variability was observed across different locations and individual cells. These inconsistencies are likely due to a combination of factors, including local topographical differences, antenna characteristics, seasonal climatic variations, and the relative positioning and separation between transmitters and receivers. Despite the overall weak correlation, these findings offer meaningful insights for radio scientists and communication engineers, especially in the context of link budget design and the optimization of terrestrial mobile communication systems.

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Authors' Contribution

Joseph Amajama: Conceptualization, methodology, supervision, atmospheric pressure and mobile network signal data collection, initial data analysis. Julius Ushie Akwagiobe: Experimental setup, data acquisition and management, data interpretation, manuscript review. Eyime Echeng Eyime: Literature review, data analysis assistance, results discussion, manuscript drafting. Efa Ubi Ikpi: Data validation, statistical analysis, manuscript revision, findings interpretation.