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Examining the Impacts of Atmospheric Temperature, Wind Speed and Atmospheric Moisture on Satellite Signal

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Abstract: This study examined the impact of atmospheric temperature, wind speed, and atmospheric moisture on satellite signal strength in Galadima, Abuja, Federal Capital Territory, Nigeria. The research was carried out to determine how variations in atmospheric conditions influence the quality and stability of satellite signal reception, using the frequency of 505.6 MHz. Experimental measurements were conducted hourly from 7:00 AM to 6:00 PM on Saturday, April 11, 2026, using portable atmospheric measuring instruments and a digital TV signal meter. The atmospheric temperature and relative humidity were measured using a digital thermo-hygrometer, while wind speed was measured using a handheld digital anemometer. The results showed that as the temperature and wind speed were increasing, there was a decrease in satellite signal. That is, an increase in temperature and wind speed will result in a reduction in signal strength. Also, the result showed that an increase in relative humidity will lead to an increase in satellite signal strength. This is also confirmed in the correlation analysis results, which show that the coefficient of correlation between the atmospheric temperature and satellite data or signal is -0.796, which means that when atmospheric temperature is increasing, there will be a decrease in the signal of the satellite; between the satellite data or signal and wind speed is -0.44, which means that when the speed of wind in the area increases, the satellite signal will be decreasing; and between the satellite signal and relative humidity is 0.714, which means that when the relative humidity is increasing, the satellite signal is also increasing. The study further revealed that atmospheric temperature had an inverse relationship with satellite signal strength, while relative humidity exhibited a direct relationship with signal reception quality. The findings of this study demonstrate the importance of atmospheric parameters in satellite signal or data quality studies and provide useful information for improving signal reliability under varying weather conditions. It was concluded that atmospheric temperature and atmospheric moisture (relative humidity) are the major atmospheric parameters affecting satellite signal propagation in the study area. The findings of this research are important for satellite communication planning, satellite data transmission, signal monitoring, and improving the reliability of wireless communication systems under changing atmospheric conditions.

Keywords: Anemometer, Correlation coefficient, Relative humidity, Satellite Signal, Temperature, Wind speed.

1.0 Introduction

A satellite signal is defined as the radio or electromagnetic wave transmitted between a satellite in space or orbit and a receiving device on earth in order to receive the satellite signal or for the satellite to send a signal to the satellite in space to be received. But this signal, either from the satellite to the ground or from the ground to the satellite, must pass through the atmosphere, which is every dynamic or changing based on its components. These changes in the atmospheric components affect the satellite signal in one way or the other, either in negative form or positive form. Satellites in Earth's orbit are exposed to Earth radiation, consisting of reflected solar and emitted thermal radiation, thereby exerting a non-conservative force that causes acceleration and affects the orbits (Motlaghzadeh et al, 2024). And so, during real-time navigation to reach the receiver on earth, a satellite signal must travel a great distance and pass through all layers of the Earth’s atmosphere, the variability of which causes errors and delays (mainly ionospheric and tropospheric). Moreover, the weather conditions for receiving data from satellites are not always favorable, while navigated machines/robots must operate independently of them (Nowakowski et al., 2023). Having the knowledge of the atmospheric condition before it occurs helps to reduce its impacts on satellite data or signals. As reported by Song et al. (2024), some convective parameters calculated from the satellite-derived profiles showed significant and rapid changes before the severe precipitation, indicating the feasibility of using satellite-derived temperature and humidity profiles as precursors to severe convective precipitation. In work by Careau and Fredriksson (2024) & Muhammad et al. (2025), in which measurements were conducted under cloudy weather conditions, it showed that the signal download throughput was reduced in value, but no significant impact was observed on upload throughput. In other words, even though much effect was not recorded on the upload, the download experienced much delay due to the cloudy condition of the area or period of the experiment. In the work by Ayantunji et al. (2018), which was carried out in Enugu State, it was observed that there was a strong inverse relationship between the temperature and the received signal strength. This implies that the increase in atmospheric temperature does not favor satellite signals. Though related work to this has been done in Enugu and some other areas, this particular work investigated the impact of these weather components on satellite signals based on the recent weather condition in 2026, as the experimental work was done in April 2026, making it a current research work.

2.0 Definition of some terms

Atmospheric temperature: Atmospheric temperature is defined as the degree of coldness or hotness of an object, place or location. It also deals with how hot or cold the air is at a particular place and time. It changes throughout the day depending on weather conditions and the amount of heat received from the sun. In satellite and wireless communication systems, temperature is very important because changes in air temperature can affect how signals travel through the atmosphere.

Relative humidity: Relative humidity is defined as the amount of moisture or water vapour present in the air compared to the maximum amount the air can hold at a given temperature. When the atmosphere contains a large amount of moisture, the relative humidity is said to be high, while dry air indicates low humidity. In communication systems, atmospheric moisture can influence the movement of electromagnetic waves which may affect the strength and quality of satellite reception.

Wind speed: Wind speed is defined as the measure of how fast air moves within the atmosphere from one place to another. It is usually measured in metres per second (m/s) with the aid of an anemometer. Wind speed also contributes to changes in weather conditions that may also influence signal propagation.

Satellite signal: Satellite signal is defined as the electromagnetic wave transmitted between a satellite in space and a receiving device on earth for communication purposes. These signals are used for television broadcasting, internet services, navigation, and other communication activities. The quality of a satellite signal depends on how effectively the signal travels through the atmosphere without being weakened or interrupted. Atmospheric conditions such as temperature, humidity, rain, and wind can affect the signal in one way or the other.

3.0 Research Methodology

The methodology adopted for this study was the experimental measurement method, which involved the direct observation and collection of atmospheric data and satellite signal data at a fixed study location in Galadima, Abuja, Federal Capital Territory, Nigeria. The study was conducted on Saturday, April 11, 2016, between the hours of 7:00 AM and 6:00 PM. Measurements were taken hourly in order to monitor the variations in atmospheric parameters and their corresponding effects on satellite signal strength throughout the day. The atmospheric parameters considered in this research were atmospheric temperature, relative humidity, and wind speed. Atmospheric temperature and relative humidity were measured using a portable digital thermo-hygrometer (fig 3.2), while wind speed measurements were done using a handheld digital anemometer (fig. 3.3). The received satellite signal strength was measured using a digital TV signal meter (fig. 3.1) on a frequency of 505.6 MHz within the UHF band. The measured values of atmospheric temperature, relative humidity, wind speed, and satellite signal strength were recorded hourly and organised into tables for analysis. Graphical representations were also plotted to show the relationship between each atmospheric parameter and the satellite signal strength. Correlation analysis was also carried out in order to determine the nature of the relationship between the satellite signal and the atmospheric parameters.

Fig. 3.1: Satellite Signal meter

Fig. 3.2: Digital Thermo-hygrometer

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Fig. 3.3: Digital Anemometer

4.0 Results and Discussion

Table 4.1 shows the hourly variation of atmospheric temperature, relative humidity, wind speed, and satellite signal strength measured in Galadima, Abuja, on April 11, 2016. From the table, it can be observed that the atmospheric conditions changed significantly throughout the day, and these variations influenced the received satellite signal strength. It can be observed that, during the early morning period between 7:00 AM and 9:00 AM, the temperature was relatively low, ranging from 20.4°C to 24.99°C, while the relative humidity remained high between 73.91% and 56.59%. At this period, the satellite signal strength was strong and stable, with values close to 47 dBmV. This suggests that cooler atmospheric conditions with higher moisture content supported better signal reception. As the day progressed toward noon and afternoon, the atmospheric temperature increased steadily, reaching a peak value of 31°C at 2:00 PM, while at the same time, the relative humidity reduced to values around 46% and the wind speed remained moderately high between 3.48 m/s and 3.98 m/s. During the same period, the satellite signal strength dropped gradually from 46.98 dBmV at 9:00 AM to its lowest value of 45.15 dBmV at 4:00 PM. This decline indicates that increased atmospheric temperature may have introduced greater signal attenuation and atmospheric instability, thereby weakening the received satellite signal. The reduction in atmospheric moisture during the hotter hours may also have contributed to changes in signal propagation characteristics.

Furthermore, the data show that wind speed had a less pronounced effect on the satellite signal compared to temperature and humidity, although periods of stronger wind coincided with slight fluctuations in signal levels. Toward the evening period, from 5:00 PM to 6:00 PM, the temperature reduced again while relative humidity increased, and the satellite signal improved slightly from 45.28 dBmV to 45.79 dBmV. Summing the trends, it can be said that atmospheric temperature and atmospheric moisture have noticeable impacts on satellite signal strength, with higher temperatures generally reducing signal quality, while cooler and more humid conditions tend to enhance signal reception.

Table 4.1: Data of hourly atmospheric temperature, relative humidity or atmospheric moisture and wind speed.

Time	Temp (ºC)	RH (%)	Wind speed (m/s)	Sat Signal (dBmV)
7:00 AM	20.4	73.91	1.34	46.99
8:00 AM	22.64	64.98	2.1	46.94
9:00 AM	24.99	56.59	3.95	46.98
10:00 AM	26.79	51.19	3.98	45.74
11:00 AM	29	48.22	3.88	45.63
12:00 PM	30	46.61	3.8	45.86
1:00 PM	29.01	46.01	3.72	45.47
2:00 PM	31	46.34	3.62	45.28
3:00 PM	28.54	47.79	3.48	45.32
4:00 PM	27.62	50.93	3.21	45.15
5:00 PM	27	58.02	2.61	45.28
6:00 PM	24.89	62.41	2.42	45.79

Figure 4.1 illustrates the relationship between atmospheric temperature and satellite signal strength measured during the study period. From the graphical representation, it can be observed that there is an inverse relationship between atmospheric temperature and the received satellite signal strength. In the early hours of the day, when the atmospheric temperature was relatively low, the satellite signal strength remained high and stable. For example, between 7:00 AM and 9:00 AM, temperatures ranged from about 20.4°C to 24.99°C, while the satellite signal maintained values close to 47 dBmV. This indicates that cooler atmospheric conditions favour better signal reception in the area. However, as the atmospheric temperature increased toward the afternoon period, the satellite signal strength gradually decreased. This reduction in signal strength may be attributed to increased atmospheric heating, which can affect the refractive properties of the atmosphere and lead to greater signal attenuation or scattering along the transmission path. The graph further reveals that when the temperature began to decrease later in the evening, the satellite signal slightly improved again. This trend confirms that atmospheric temperature plays a significant role in determining the quality of satellite signal reception.

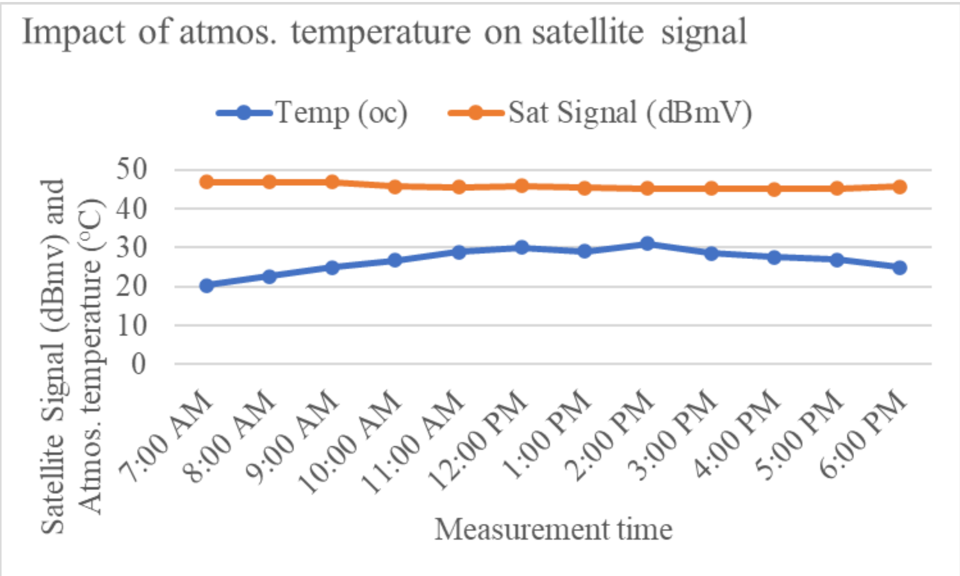

Fig 4.1: Graphical representing the relationship between atmospheric temperature and satellite signal

Figure 4.2 shows the graphical relationship between wind speed and satellite signal strength measured during the study period in Galadima, Abuja. It can be observed from the graph that wind speed varied throughout the day, with lower values recorded in the early morning and evening hours, while higher wind speeds occurred during the late morning and afternoon periods. The satellite signal strength also showed slight fluctuations corresponding to these atmospheric changes. In the early morning hours, when wind speeds were relatively low, ranging between 1.34 m/s and 2.10 m/s, the satellite signal strength remained high and stable at approximately 46.9 dBmV. As the wind speed increased toward midday, the signal strength gradually reduced to certain lower level. This suggests that stronger wind movement in the atmosphere may have contributed to slight disturbances along the signal propagation path, leading to minor signal degradation. However, the graph also shows that the changes in satellite signal strength due to wind speed were not as significant as those caused by atmospheric temperature or relative humidity. Even at higher wind speeds, the signal fluctuations remained relatively moderate and stable. Towards the evening period, when wind speed decreased again to about 2.42 m/s, the satellite signal slightly improved to approximately 45.79 dBmV, which indicates that wind speed has a measurable but weaker influence on satellite signal strength.

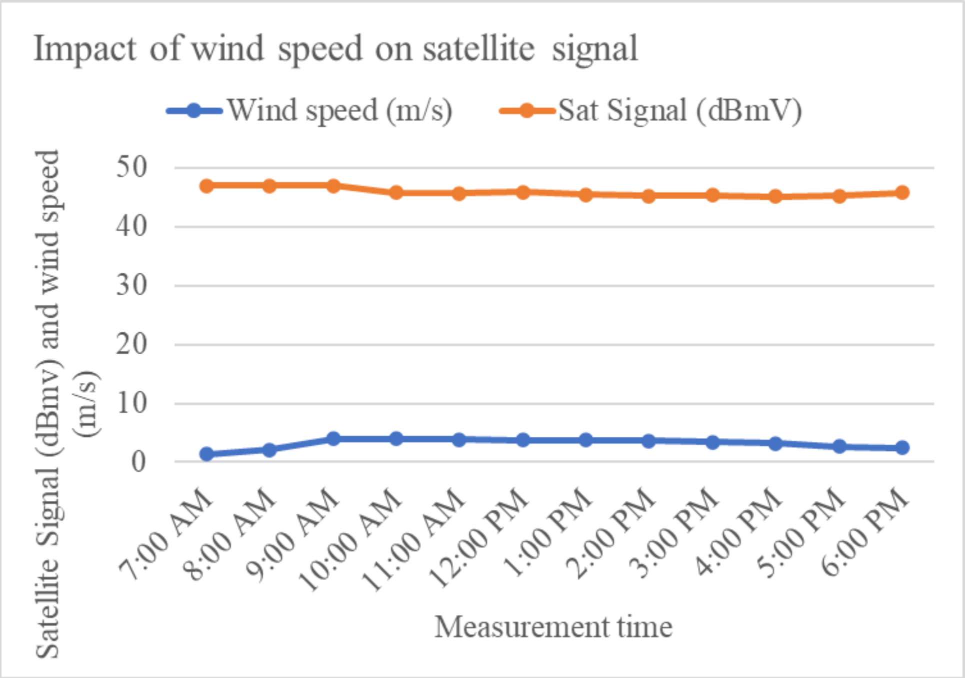

Fig 4.2: Graphical representing the relationship between wind speed and satellite signal

Figure 4.2 presents the graphical relationship between wind speed and satellite signal strength measured during the study period in Galadima, Abuja. From the graph, it can be observed that wind speed varied throughout the day, with lower values recorded in the early morning and evening hours, while higher wind speeds occurred during the late morning and afternoon periods. The satellite signal strength also showed slight fluctuations corresponding to these atmospheric changes. In the early morning hours, when wind speeds were relatively low, ranging between 1.34 m/s and 2.10 m/s, the satellite signal strength remained high and stable at approximately 46.9 dBmV. As the wind speed increased toward midday, reaching values close to 3.98 m/s, the signal strength gradually reduced to values around 45.6 dBmV and below. This suggests that stronger wind movement in the atmosphere may have contributed to slight disturbances along the signal propagation path, leading to minor signal degradation. However, the graph also shows that the changes in satellite signal strength due to wind speed were not as significant as those caused by atmospheric temperature or relative humidity. Even at higher wind speeds, the signal fluctuations remained relatively moderate and stable. Towards the evening period, when wind speed decreased again to about 2.42 m/s, the satellite signal slightly improved to approximately 45.79 dBmV. Overall, Figure 4.2 indicates that wind speed has a measurable but weaker influence on satellite signal strength, mainly causing small variations in signal quality rather than major reductions in reception performance.

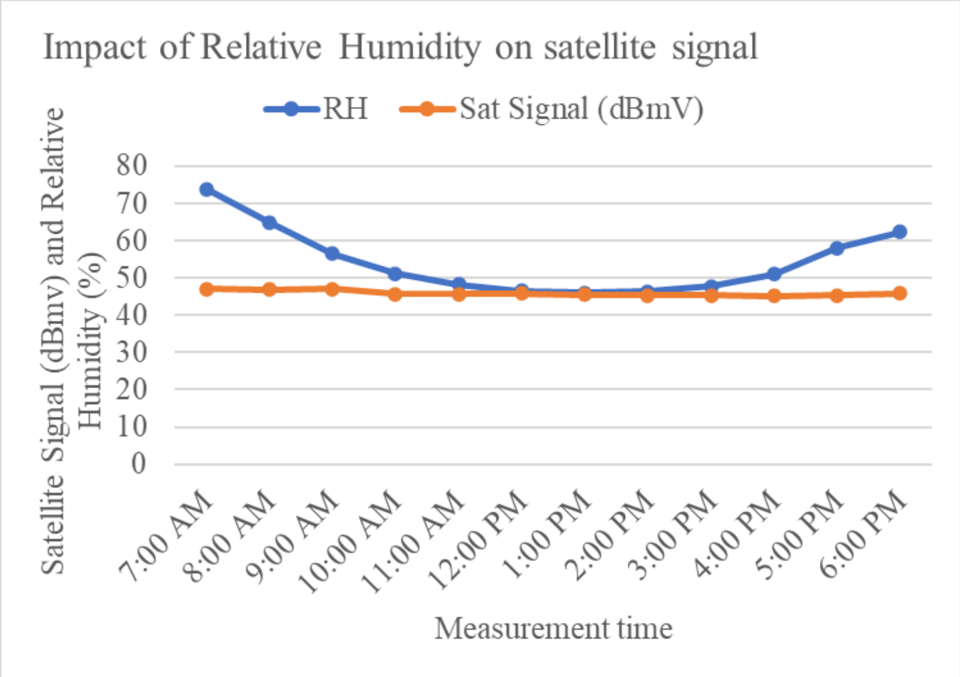

Fig 4.3: Graphical representing the relationship between Relative Humidity and satellite signal

Summarily, the graphical results presented in Figures 4.1, 4.2, and 4.3 collectively demonstrate that atmospheric conditions have noticeable effects on satellite signal strength in the study area. While figure 4.1 showed that atmospheric temperature has an inverse relationship with satellite signal reception given that during periods of lower temperature, especially in the early morning and evening hours, the satellite signal remained stronger and more stable. Also, Figure 4.2 revealed that wind speed also affects satellite signal strength, although its impact was less significant compared to temperature and relative humidity, given that moderate fluctuations in signal strength were observed as wind speed increased during the day. And figure 4.3 displayed a positive relationship between relative humidity and satellite signal strength, given that higher humidity levels recorded during the cooler morning and evening periods corresponded with stronger satellite signals, while lower humidity levels during the hotter afternoon period coincided with weaker signal reception.

Correlation analysis

The correlation analysis was carried out to determine the relationship between the satellite data and the temperature, relative humidity and wind speed. The results shows the coefficient of correlation between atmospheric temperature and satellite data or signal to be -0796. This negative sign means inverse relationship between the two. This means that when atmospheric temperature is increasing, there will be a decrease in the signal of the satellite. Also, the correlation coefficient between the satellite data or signal and wind speed is -0.44. This is also shows inverse relationship between the satellite signal and wind speed. That is, when the speed of wind in the area increases, the satellite signal will be decreasing. Furthermore, the correlation coefficient between the satellite signal and relative humidity is 0.714. This is a direct relationship. This means that, when the relative humidity is increasing, the satellite signal is also increasing, and when the relative humidity is decreasing, the satellite signal is also decreasing.

5.0 Conclusion

This study investigated the impact of atmospheric temperature, wind speed, and atmospheric moisture on satellite signal strength in Galadima, Abuja, using experimental measurements carried out over a twelve-hour period. From the results obtained, it was established that atmospheric conditions play an important role in determining the quality and stability of satellite signal reception. The findings revealed that variations in atmospheric temperature, relative humidity, and wind speed influenced the propagation characteristics of the satellite signal measured on the 505.6 MHz UHF frequency band. The results showed that atmospheric temperature had a significant inverse effect on satellite signal strength, given that higher temperatures recorded during the afternoon period corresponded with weaker signal levels, while lower temperatures observed during the morning and evening periods supported stronger signal reception. Relative humidity also demonstrated a strong influence on signal quality, as higher atmospheric moisture levels were associated with improved signal strength and stability. Wind speed produced only slight fluctuations in the satellite signal, indicating that its impact was relatively smaller compared to temperature and humidity. The correlation analysis also showed that the coefficient of correlation between atmospheric temperature and satellite data or signal to be -0796, in which the negative sign means inverse relationship between the two. Also, the correlation coefficient between the satellite data or signal and wind speed is -0.44, which also shows inverse relationship between the satellite signal and wind speed. While the correlation coefficient between the satellite signal and relative humidity is 0.71, which means that, when the relative humidity is increasing, the satellite signal is also increasing, and when the relative humidity is decreasing, the satellite signal is also decreasing. It can be concluded that atmospheric temperature and atmospheric moisture are the major atmospheric parameters affecting satellite signal propagation in the study area. The findings of this research are important for satellite communication planning, satellite data transmission, signal monitoring, and improving the reliability of wireless communication systems under changing atmospheric conditions.

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