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Research article

Effects of some weather variables on the signal strength of Maloney FM radio, Nasarawa State, Nigeria

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ABSTRACT

This study aims to assess the effects of atmospheric temperature, relative humidity, and atmospheric pressure on the signal strength of Maloney FM Radio, 95.9 MHz, Keffi, Nasarawa State. It is essential to measure the signal strength of the new radio station in relation with some parameters of weather to provide effective service delivery to the critical sectors and the entire populace. The research was conducted using the data of atmospheric temperature, atmospheric pressure, relative humidity, and the strength of the Maloney radio signal acquired from 6.00 a.m. to 6.00 p.m. daily at a 30 min interval, from January 2023 to June 2023, in Karshi, Abuja, a neighbouring town to Nasarawa state where the radio station is located. The data analysis involving cointegration and descriptive statistics of the effects of atmospheric variables on the radio signal strength was implemented using Eviews and Microsoft Excel Software. The results showed daily and monthly variations of the radio signal strength as well as the atmospheric temperature, atmospheric pressure and relative humidity. The variation is such that the lowest monthly signal strength was in June, probably due to higher rainfall in the area in June being the last month in this work (Jan.–Jun.) compared to other months which are dry season (January–March) or when the rain was just starting (April–May), in the study area. It was observed that atmospheric temperature and pressure negatively correlate with signal strength while relative humidity positively correlates with received signal strength in all the six months under study. The cointegration analysis also showed a long-term relationship between the radio signal strength and the atmospheric components, as the probability on the first row on the tables of both Trace Test and Maximum Eigenvalue methods were 0.0016 and 0.0008, which are less than the 5% (0.05) set critical value. In the same way, the critical value results on the same first row in both methods are smaller than the Trace statistics values. This implies that there is a long-term relationship between the atmospheric variables and the Maloney FM radio signal strength. These results will help mitigate the attenuation effect, and attendant signal loss of the radio station's signal strength. By proxy, the results will support the operations and regulations of spectrum management in the design of satellite communications and satellite microwave band specifications in Nigeria. In addition, the pre-determination of the radio station location will depend on this study's result analyses, considering that the effects of atmospheric temperature, pressure, and humidity conditions are inevitable. Governments, policymakers, stakeholders, and other relevant authorities should ensure the domestication of the study by providing the necessary research

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materials and facilities for wider studies. As regards the Maloney FM radio station, Keffi, studied in this work, there is no similar or related work done on it before now, hence, providing the detailed relationship between the signal strength of the radio station and some weather variables will go a long way in the improvement of the quality of signal transmission from Maloney radio station. The results when provided to the station, will enable the management to also evaluate if their set target of the station such as the radio horizon, radio signal coverage, and the link budget have been met.

1. Introduction

The transmission of radio signal is affected by primary meteorological variables like atmospheric pressure, temperature and water vapor and secondary weather conditions in the troposphere [1]. Radio waves are characterized by the reflection, refraction, diffraction, absorption, polarization and scattering occurrences [2] which are caused mostly by both primary and meteorological variables as stated above. Atmospheric temperature is observed to be relatively high when the rain is about to start like in April, while Air temperature reduces with increase in the amount of rainfall and relative humidity [3].

Temperature is defined as the measure of the average kinetic energy of a body or an object. Atmospheric temperature is defined as a measure of temperature at different levels of the Earth's atmosphere or the temperature of the Earth's atmosphere at various layers. It is affected by some factors such as solar radiation, humidity, and altitude, changes in state of water [4,5]. Atmospheric pressure is defined as the pressure exerted by the earth's atmosphere at any given point, being the product of the mass of the atmospheric column of the unit area above the given point and of the gravitational acceleration at the given point. Also, relative humidity is a measure of how much water vapor is in a water-air mixture compared to the maximum amount possible. It deals with the amount of water vapor present in air expressed as a percentage of the amount needed for saturation at the same temperature [4].

As a result of the absorption and scattering of radio signal by atmospheric or space particles, the quality of the radio frequency signal diminishes as it travels through the atmosphere and across the link, and this reduction in signal strength has a significant effect on the information received at any point [6]. In this case, as the radio signal travels from the Maloney station, the radio strength will be diminishing due to due to the effects of atmospheric components, but this is also dependent on the geographical locations and seasons. In other words, as the weather conditions across Nigeria is not uniform, its effects on radio signal strength across Nigeria will not be the same. That is why it is important to carry out such studies on newly established radio or television station to finding out its performance under the weather condition of the location that it is sited.

According to Ref. [7], some of the factors that influence radio wave propagation such as rain, temperature, wind, and water content can combine in different forms to affect radio wave propagation in a way that may cause radio signals to be heard far away beyond its designed horizon or resulting in its attenuation or loss thereby making it not reaching its designed horizon. In communications, radio wave propagation is concerned mainly with the properties and effects of the medium through which the signal is being transmitted [8]. Also, the quality of terrestrial television signals received by viewers is very important to stakeholders in the world of broadcast [5,9]. Although the transmitter transmits these radio waves which are being received by the receiver, the received signal strength of these radio waves is an important factor to be put into consideration [10] especially as it relates to some major atmospheric components. Relative humidity is the amount of moisture in the air or atmosphere, and when the quantity of moisture in the air at a particular location changes, it affects the signal transmitted or received at that location [11]. In an ideal environment, some of the factors that affect radio signals are the earth's shape, atmospheric parameters like temperature, humidity, wind, and interaction with the object on the ground such as hills, trees, water bodies, valleys, mountains, buildings [11]. Though some related works have been done such as the works by Refs. [12–14] in Benin city [15], in Enugu state [5] in Abuja and Jos, no work has been done on this radio station, Maloney FM Radio, Keffi since it was established in 2016, hence, making this research work very necessary.

This work which focused on providing some relationship between the signal strength of theMaloney FM radio station and some weather variables will go a long way in the improvement of the quality of signal transmission from Maloney radio station. The work is done to determine if Maloney FM signal is steady in Abuja, which is a neighbouring "state" to Nasarawa where the radio station is located. The results when provided to the station, will enable the management to also evaluate if their achieved aim such as the radio horizon, radio signal coverage, and the link budget have been met. It will also provide the management of the Maloney FM with the idea if their radio signal is causing interference to other radio stations, or its being interfered with the signals from other radio stations, hence making them finding the way to improve on the quality of the signal or prevent the signal transmitted from being interfered with or vice versa.

2. Study area

Karshi is one of the satellite towns in the Federal Capital Territory, Abuja. It is located in Abuja Municipal Area Council (AMAC), which is one of the six council areas of the Federal Capital Territory. It is situated between Latitude 8° 47′ 24″ and 9° 22′ 21″ North and Longitude 7° 15′ 0″ and 8° 11′ 59″ East. Its vegetation is the guinea forest savanna, with rainy seasons from April to September and the dry season from October to March. It has some high mountains and a few trees and short grasses.

2.1. Maloney radio station

The radio station was established by a Politician, Hon Ahmed Aliyu Wadada, in May 2016. The FM radio station which is located in Keffi, the Capital of Nasarawa State, operates on the frequency of 95.9 MHz. The radio signal is received in some parts of Abuja, especially Karshi town which is at the boundary between Nasarawa State and Abuja. The radio signal is also received in some neighbouring States to Nasarawa State such as Kogi, Kaduna, Plateau, and Niger States.

2.2. Materials and method

The research work makes use of primary data. The data used were atmospheric pressure, atmospheric temperature, relative humidity, and the radio signal strength of Maloney FM Radio. The atmospheric temperature, pressure, and relative humidity were measured with an automatic weather station (Fig. 7) installed in Mathson Space School in Karshi, Abuja, while the signal strength was measured with a CATV signal strength meter (Fig. 6) at the same fixed location. Table 1 shows the features of the measurement instrumentation. The measurements were done from January 2023 to June 2023, from 6.00 a.m. to 6.00 p.m. daily at 30 min interval. The readings were averaged to have a daily average atmospheric temperature, pressure, relative humidity, and radio signal strength for each of the months, and the six months' data were later averaged for further analysis. Graphical representations of the parameters, as well as the correlation analysis, were carried out to determine the effect of the atmospheric components on the Maloney radio signal strength. In addition, the long-term relationship between the parameters and the radio signal strength was accessed using Johansen co-integration analysis since the variables are more than two. There will be a co-integration (long-term relationship) when the probability is equal to or less than the critical value of 0.05 (5%) which is the generally acceptable value [5,16], otherwise the null hypothesis of no cointegration will be accepted. The analyses were done using EViews and Excel software (see Table 2).

3. Results and discussion

Figs. 2–5 show the graphical representations of the monthly atmospheric temperature, relative humidity, pressure, and the radio signal strength of Maloney FM measured at the study location, Karshi, Abuja, from January 2023 to June 2023 (see Fig. 1). From the result in Fig. 2, it is shown that there was a variation in the average monthly temperature of the area, and that it was lower in June compared to the temperature in other months even though there was a surge in temperature around the first week of June. Also, the average monthly temperature was higher in March than in the rest of the months. The reason for these observations was as a result of rain from April to June, and the effect of Harmattan in January and February, which makes the temperature to be low in these periods. As shown in Fig. 3, the highest monthly relative humidity was recorded in June, followed by May, and April. The minimum monthly relative humidity was observed in February. The higher relative humidity in April and its increment till June was as a result of the commencement of rainfall in the study area from April, and the increase in rain frequency with time, thus making much moisture to be available in the atmosphere. The higher humidity in June could also be part of the factors responsible for the monthly lowest temperature recorded in June (Fig. 2). The variation in the monthly atmospheric pressure is not well pronounced as in temperature and relative humidity. Though there are some sharp decrements occasionally experienced in some months, the highest monthly atmospheric pressure occurred in June, while the lowest was not stable as it oscillates between April and March. This result is in conformity with the work by Ref. [3], in Aliero, Kebbi state of Nigeria, in which it was shown that the maximum relative humidity occurred in August, and that the air or atmospheric temperature decreases with increase in relative humidity. It also confirms the works by Ref. [5] done on Abuja and Jos, as well as the works by Refs. [13,17].

The radio strength measured in the time under study showed a daily variation in each of the months (Fig. 5). The lowest monthly radio signal strength was observed in June while the highest monthly signal strength was in April. The lowest signal strength observed in June could probably be as a result of rainfall frequency in June when compared to April or May when the rainfall was just beginning. From the various changes in the components of weather studied here, there is every tendency that the signal strength might have been affected in one way or the other by the temperature, pressure or relative humidity, or their combination. Thus, the relationships between the signal strength and the atmospheric parameters were determined using correlation analysis. In January, the correlation coefficients between temperature, atmospheric pressure, and relative humidity were −0.018, −0.035, and 0.351 respectively. In February, the correlation coefficients between temperature, atmospheric pressure, and relative humidity were −0.043, −0.219, and 0.040, respectively. In March, the correlation coefficients between temperature, atmospheric pressure, and relative humidity were

Table 1
Features of the measurement instrumentation.

S/N	Instrument	Model	Function	Range	Accuracy
1	CATV signal strength meter	S110	For measuring the signal strength of the TV stations	47–870 MHz spectrum	+/−2 dB
Automatic weather station, transmit on 433 MHz over a maximum distance of 100 m (300 Feet)					
2	Temperature sensor	Part of the automatic weather station	For measuring the atmospheric temperature	−40 – 65 °C	±1 °C
3	Relative Humidity sensor	Part of the automatic weather station	For measuring relative humidity	10–99 %	±10 %
4	Wind speed meter	Part of the automatic weather station	For measuring wind speed	0–160 km/h	+/− 1 m/s
5	Pressure sensor	Part of the automatic weather station	For measuring atmospheric pressure	700 -1100 hpa	±1 hpa
6	Rainfall sensor	Part of the automatic weather station	For measuring rainfall	0–9999 mm	±10 mm

Tabel 2
Average of the average daily half-year atmospheric temperature, relative humidity, atmospheric pressure and signal strength.

Days	Average Atmos Temp (°c)	Average Rel. Humidity (%)	Average Atmos Pressure (hPa)	Average Radio Signal strength (dBμv)
1	30.84	48.44	975.69	39.47
2	30.42	47.72	975.89	38.34
3	31.25	44.02	971.61	38.35
4	31.44	47.94	975.41	38.53
5	31.99	44.99	975.79	37.82
6	30.71	45.57	975.91	38.71
7	32.30	48.10	971.48	38.57
8	32.16	47.89	970.63	39.20
9	31.77	50.16	975.30	39.45
10	32.61	47.82	974.80	38.90
11	31.73	46.39	975.17	38.07
12	31.89	40.05	975.75	37.91
13	31.52	39.81	975.73	37.87
14	31.37	40.53	975.82	37.81
15	31.99	42.65	975.41	37.92
16	31.62	46.85	970.49	38.03
17	31.74	46.72	975.77	37.93
18	31.76	44.76	976.38	37.80
19	31.13	47.31	976.39	37.23
20	30.32	49.54	975.70	38.06
21	30.41	49.11	975.34	38.08
22	29.69	49.32	975.81	38.81
23	30.14	48.79	975.45	39.15
24	31.28	48.53	970.88	38.68
25	30.54	49.32	974.86	38.98
26	30.98	49.70	974.91	38.80
27	30.78	48.80	975.02	39.84
28	30.54	50.85	974.94	39.24
29	30.20	56.45	969.34	39.56
30	29.83	57.62	975.91	38.97
31	32.00	47.34	974.67	38.56

−0.029, −0.041, and 0.652 respectively. In April, the correlation coefficients between temperature, atmospheric pressure, and relative humidity were −0.600, −0.071, and 0.583 respectively. In May, the correlation coefficients between temperature, atmospheric pressure, and relative humidity were −0.303, −0.014, and 0.069 respectively. And in June, the correlation coefficients between temperature, atmospheric pressure, and relative humidity were −0.100, −0.160, and 0.027 respectively. This shows that in all the months, there was a negative correlation between temperature and radio signal strength, and atmospheric pressure and radio signal strength of the radio station. It also shows that there was a positive correlation between the Maloney FM radio station signal strength and the relative humidity. This implies that in all the months, there was a direct relationship between radio signal strength and relative humidity, but there was an inverse relationship between the signal strength and the temperature as well as the atmospheric pressure. In other words, the Maloney FM radio signal strength is directly proportional to the relative humidity but inversely proportional to the temperature and atmospheric pressure. As seen in Fig. 5, the least monthly signal strength occurred in June. Also, from Fig. 4, the highest atmospheric pressure occurred in June. This confirms the inverse relationship between the radio signal strength and the atmospheric pressure. Also, the higher monthly signal strength in April and May compared to March (Fig. 5) which has a higher temperature (Fig. 2) is an indication that lower temperature in April and May favours the signal strength received in the area. The increase in humidity in these months compared to March also contributed to the decrease in temperature, and by implication, increase in the signal strength. This result conforms with the works of [11,14,15,13,&6]] in which the signal strength recorded was found to be inversely proportional to temperature, wind speed, and atmospheric pressure, and directly proportional with relative humidity in their separate research works done in Benin city-Edo State, Enugu State, and Jos, Plateau State respectively.

Table 2.0 shows the mean values of the average daily half-year (January–June 2023) atmospheric temperature, relative humidity, atmospheric pressure, and Maloney FM signal strength. In other words, each of the variables measured from January to June were added and the average was taken based on daily record. The results in the table (Table 2.0) were used to determine the co-integration between the signal strength and the atmospheric variables. The co-integration determines the long-term relationship between the independent variables and the dependent variable. In this case, the dependent variable is the Maloney FM radio signal strength while the independent variables are the temperature, relative humidity, and atmospheric pressure. Tables 3–5 show the results of the determination of the lag interval or length using Akaike Information Criteria assumption method, and the results of co-integration analysis between the radio signal strength and the atmospheric variables from the trace test method and Maximum Eigenvalue method respectively.

The Akaike information criteria is used to determine the lag interval and the correct assumption criteria for the co-integration analysis. From Table 3, the lag interval is 1, which shows that they are not stationary variables. Also, the correct assumption criterion is the second assumption as indicated by the asterisk (*), that is, Row 2, Column 2 for the lag length or interval and the assumption criteria. Also, in terms of the co-integration, the null hypothesis of no co-integration will be rejected when the probability is equal to or

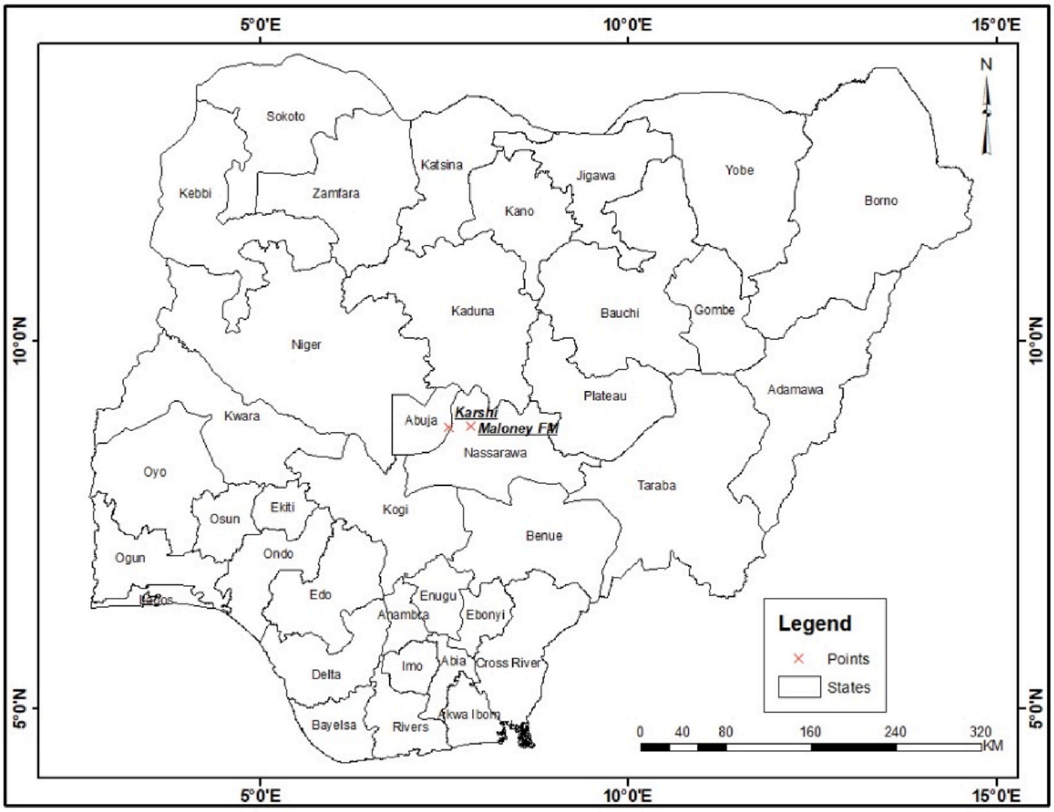

Fig. 1. Map of Nigeria showing the study location.

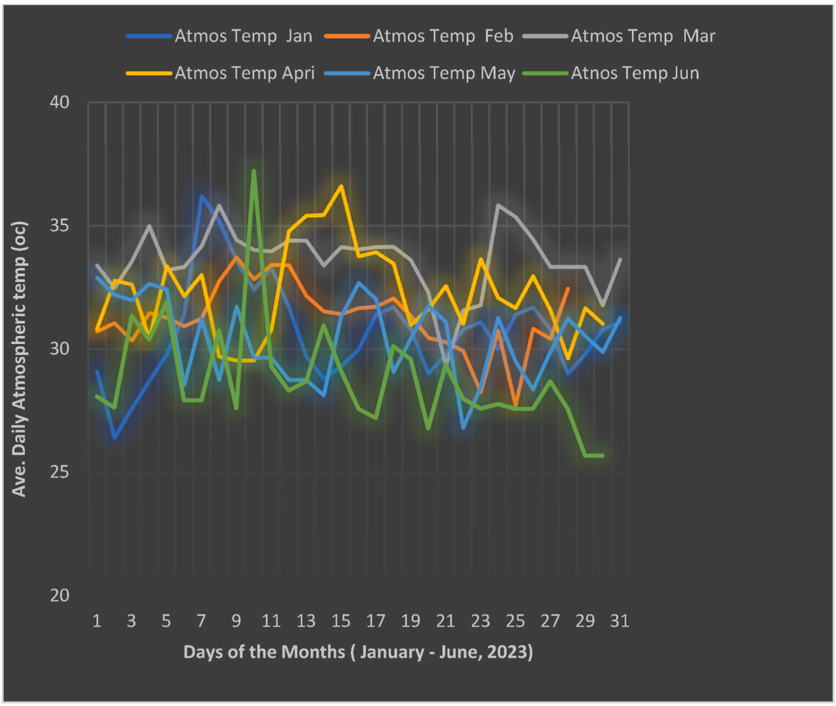

Fig. 2. Graph of monthly atmospheric temperature.

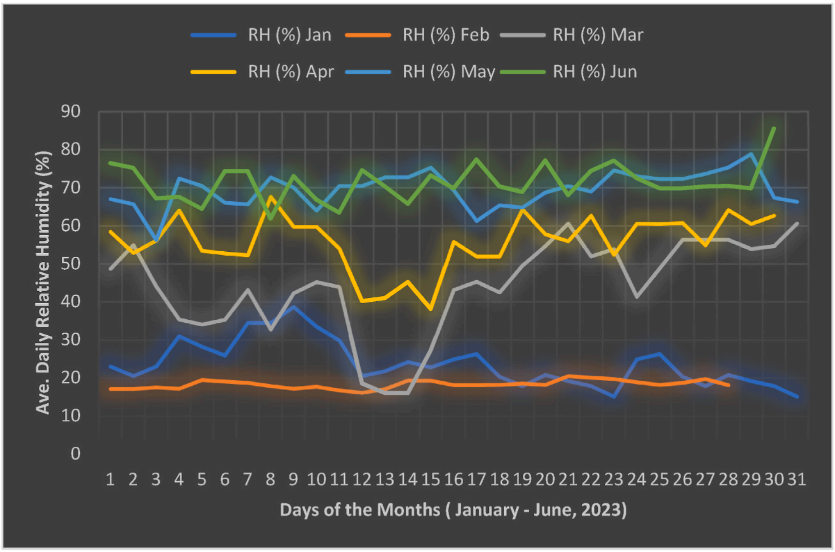

Fig. 3. Graph of monthly relative humidity.

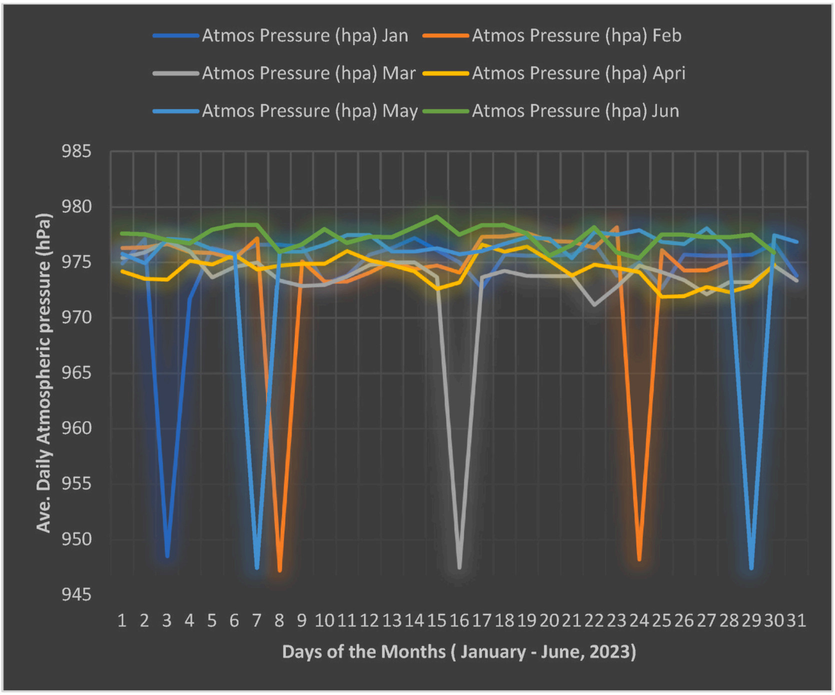

Fig. 4. Graph of monthly atmospheric pressure.

less than 0.05 (5%) critical value. But if the value is greater than the critical value of 0.05, the null hypothesis cannot be rejected, and it means there is no co-integration between the variables.

Also, in both the Trace test and Maximum Eigenvalue test methods, if the value of the Trace statistics is greater than the result of the critical value, the null hypothesis of "no co-integration" will be rejected, otherwise, it will be accepted. However, when there is at least one co-integration in all, it means there is a long-term relationship between the dependent and the independent variables. From Tables 4 and it was observed that the probability value (0.0016) on the first row is less than the 0.05 critical value. This means that the null hypothesis of no co-integration will be rejected. Also, in the same first row, the Trace statistics is greater than the critical value. While the Trace statistics is 68.408, the critical value is 54.079, hence the critical value is less than the Trace statistics value, then fulfilling the condition for the rejection of the null hypothesis of no in-integration. Therefore, it can be said that there is a co-integration

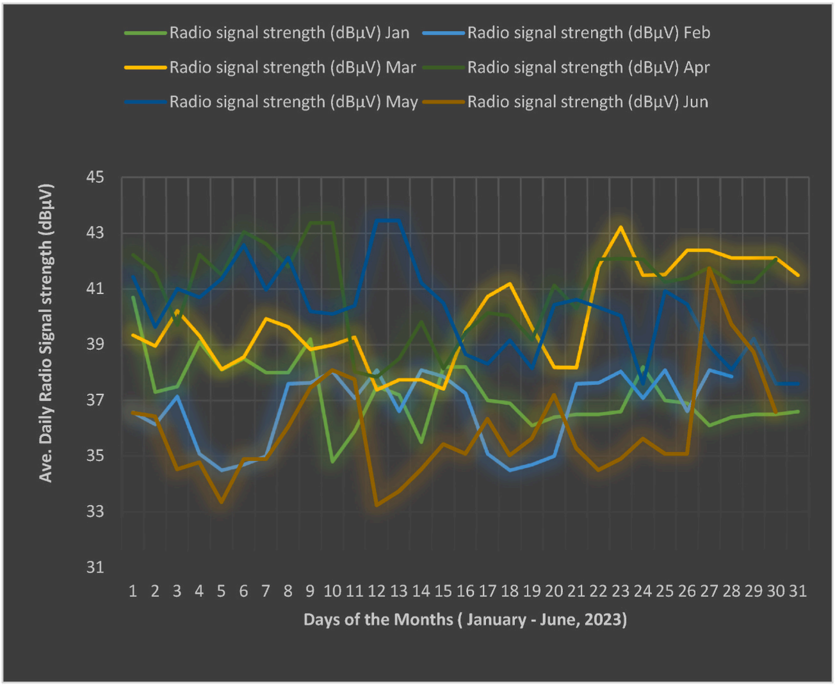

Fig. 5. Graph of monthly radio signal strength.

Fig. 6. Digital CATV signal strength meter (Spectrum 46–870 MHz).

Fig. 7. Automatic weather station.

or long-term relationship between the radio signal strength and the atmospheric variables.

From Table 5, the Maximum Eigenvalue method, it was shown that the probability value on the first row (0.0008) is less than the set critical value of 0.05 (5%), hence, the null hypothesis of no cointegration will be rejected. Also, while the trace statistics is 40.921, the critical value is 28.588. This situation is found only in row 1, as others show the opposite. But since the first row or one of the rows has

Table 3
Result of Akaike Information Criteria for determining the lag length interval and assumption of the variables.

Akaike Information Criteria by Rank (rows) and Model (columns)					
0	12.9485	12.94851	13.2156	13.2156	13.4634
1	12.8735	12.1581*	12.3570	12.4247	12.6046
2	13.1725	12.2238	12.3614	12.3496	12.4830
3	13.5697	12.5947	12.6634	12.6362	12.7017
4	14.1169	13.0724	13.0724	13.0629	13.0629

Table 4
Result of co-integration using Trace test method.

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	**0.7561**	**68.4082**	**54.0790**	**0.0016**
At most 1	0.4259	27.4864	35.1928	0.2650
At most 2	0.2210	11.3926	20.2618	0.5047
At most 3	0.1333	4.14819	9.16455	0.3905

Table 5
Result of co-integration using Maximum Eigenvalue method.

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	**0.7561**	**40.9218**	**28.5881**	**0.0008**
At most 1	0.4259	16.0938	22.2996	0.2916
At most 2	0.2210	7.24438	15.8921	0.6396
At most 3	0.1333	4.14819	9.16455	0.3905

met the condition, it then means that there is a co-integration between the variables. It therefore implies that there is a long-term relationship between the Maloney radio signal and the atmospheric variables studied in this work.

4. Conclusion

The effects of atmospheric temperature, pressure, and relative humidity on the signal strength of Maloney FM Radio 95.9 MHz, Nasarawa State, have been studied using the signal strength of the radio station measured with a CATV signal strength meter, and the atmospheric temperature, relative humidity, atmospheric pressure measured with an automatic weather station installed in Mathson Space School premises in Karshi, a neighbouring town to Nasarawa state. The data were measured daily from 6.00 a.m. to 6.00 p.m. between January to June 2023. The results showed that the monthly signal strength received from the radio station was lowest in June. This is probably because of the amount of rain in June compared to other months such as May or April which are the beginning of the rainy season in the study area. The result also showed that the atmospheric temperature and pressure have negative effects on the radio signal strength while relative humidity has a positive impact on the received signal strength. This was shown in the correlation results in each of the months from January to June, in which there were negative correlation coefficients between the signal strength and the temperature as well as the atmospheric pressure, while positive correlation coefficients were observed in all the months between relative humidity and the radio signal strength. In other words, the radio signal strength of the radio station is directly proportional to the relative humidity and inversely to atmospheric pressure and temperature. In addition, the result also showed that there is a long-term relationship between the signal strength and the atmospheric variables as indicated by the co-integration analysis. It can be concluded that the atmospheric variables have effects on the signal strength of Maloney FM radio station, Keffi. It can also be concluded that there is a long-term relationship between the radio signal strength and the atmospheric variables studied in this work.

The results will help to mitigate the attenuation effect and attendant signal loss of the radio station's signal strength. By proxy, the results will support the operations and regulations of spectrum management in the design of satellite communications and satellite microwave band specifications. Governments, policymakers, stakeholders, and other relevant authorities should ensure the domestication of the study by providing the necessary research materials and facilities. The work is done to determine if Maloney FM signal is steady in Abuja, which is a neighbouring "state" to Nasarawa where the radio station is located. The results when provided to the station, will enable the management to also evaluate if their achieved aim such as the radio horizon, radio signal coverage, and the link budget have been met. It will also provide the management of the Maloney FM with the idea if their radio signal is causing interference to other radio stations, or its being interfered with the signals from other radio stations, hence making them finding the way to improve on the quality of the signal or prevent the signal transmitted from being interfered with or vice versa. This will also act as a benchmark for future radio installation.

5. Recommendation

It is recommended that the effect of rainfall on the signal strength of Maloney Radio station be studied in future.

CRediT authorship contribution statement

Ale Felix: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Ayegba Abdullahi:** Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Agboola Olufemi:** Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Olatunji Paul Jaiyeola:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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