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Analysis of some weather variables' impacts on UHF and VHF receivers in Yenagoa Southern, Nigeria

Chibuzo Emeruwa *

Department of Physics, Faculty of Science, Federal University Otuoke, Nigeria.

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Abstract

In this study, the effects of some important meteorological variables, such as temperature, relative humidity, and mean sea level pressure, were assessed on the Ultra High Frequency (UHF) radio signals from Niger Delta Television (NDTV), transmitting at 743.25 MHz UHF, and the Very High Frequency (VHF) radio signals from Nigerian Television Authority (NTA), transmitting at 189.25 MHz VHF, both in Yenagoa, Southern Nigeria, within 6°20'17"N and 5°37'32″E. The Digital Community- Access/Cable Television (CATV) analyzer was used to measure the radio signal strength from NDTV and the radio signal strength from NTA Yenagoa, and a self-implemented weather monitoring device was used to measure the weather variables simultaneously at an equal distance within the Metropolis. Throughout the entire year of 2022, measurements were made continuously every six hours (respectively between 12 am and 1 am, 6 am and 7 am, 12 pm and 1 pm, and 6 pm and 7 pm local time). The results showed that the radio signals from both UHF and VHF television stations were directly proportional to temperature, inversely proportional to relative humidity, and did not follow any specific pattern of proportionality with mean sea level pressure. Inferentially, it was seen that these meteorological factors mostly affected the radio signals from the UHF television station, and that these impacts were stronger during the months with high relative humidity compared to the months with lower relative humidity. But based on these findings, a postulation has been put out that has to be verified further. These findings and the proposed postulation, it is thought, would undoubtedly be beneficial in supporting and directing the management of radio communication networks for planning and other reasons.

Keywords: Temperature; Relative humidity; Mean sea level pressure; Ultra High Frequency; Very High Frequency; Signal Strength.

1. Introduction

Metrological variables refer to the atmospheric conditions that can affect the propagation of electromagnetic waves. Some of the key variables that can impact this include temperature, humidity, pressure, and atmospheric composition [1]. Temperature can affect the speed of electromagnetic waves, as warmer air tends to have a lower refractive index than cooler air. This can cause the waves to bend or refract differently as they pass through the atmosphere. Humidity can also impact the propagation of electromagnetic waves, as water vapor in the air can absorb and scatter the waves [2]. This can cause attenuation or weakening of the signal, particularly at higher frequencies. Pressure can affect the density of the atmosphere, which in turn can impact the speed of electromagnetic waves [4]. Higher pressure can cause the waves to travel more slowly, while lower pressure can cause them to travel more quickly. Finally, atmospheric composition can also play a role in the propagation of electromagnetic waves. Different gases in the atmosphere can absorb or scatter the waves, particularly at certain frequencies. For example, oxygen and water vapor are particularly effective at absorbing radio waves in the microwave range [5, 23].

* Corresponding author: Chibuzo Emeruwa

Overall, understanding these metrological variables is important for predicting and optimizing the propagation of electromagnetic waves in different environments. In the management and planning stages of radio communication systems, the areas of the atmosphere that radio signals pass through throughout the transmission process from the radio transmitters to the radio receivers, which is primarily controlled by propagation pattern, are crucial [3]. Any radio signal transmission system's radio connections are inevitably vulnerable to fluctuations in climatic variability, which might cause serious system performance degradation [3, 5, 6]. In order to manage and take the appropriate actions and adaption choices for its mitigation and management, it is crucial to examine these aspects that affect the radio link quality in these radio signal communication systems [7]. It is known that some researchers have made significant contributions over the past few decades to their various research projects in analyzing the effects of some of these weather variables on radio signals. As a result, some helpful postulations have been made, which have assisted in raising the caliber of services provided by these radio communication systems [3, 9, 11, 17, 22].

According to the literature we have on hand, there hasn't been much study on how weather factors affect UHF and VHF receivers in tropical climates in several developing nations, like the majority of Nigeria [3].

The Digital Community-Access/Cable Television (CATV) analyzer and a self-implemented weather monitoring device were used in this study to simultaneously measure and evaluate the radio signal strength from two television stations (NDTV transmitting at 743.25 MHz UHF and NTA Yenagoa transmitting at 189.25 MHz VHF) and some weather variables (temperature, relative humidity, and mean sea level pressure). Throughout the whole year of 2022, measurements were continually taken every six hours between the hours of 12 am and 1 am, 6 am and 7 am, 12 pm and 1 pm, and 6 pm and 7 pm local time. The goal of this study is to assess how these three crucial weather factors—temperature, atmospheric pressure, and relative humidity—affect these two television stations in order to understand the current situation and how radio link margins and/or link budgets in this area can be used comprehensively for planning and management of radio communication systems.

1.1. Study area

Yenagoa is the capital city of Bayelsa State, located in the southern region of Nigeria. It is situated on the banks of the Nun River, which flows into the Atlantic Ocean. The city covers an area of approximately 706 square kilometers and has a population of over 300,000 people [8]. The geography of Yenagoa is characterized by a low-lying terrain, with an average elevation of about 2 meters above sea level. The city is surrounded by mangrove swamps and creeks, which are home to a diverse range of flora and fauna. The climate in Yenagoa is tropical, with high temperatures and humidity throughout the year [10].

The Nun River is the main waterway in Yenagoa, and it is used for transportation, fishing, and other economic activities. The city is also home to several lakes and ponds, which provide a source of water for domestic and agricultural use. Yenagoa is located in the Niger Delta region of Nigeria, which is known for its rich oil and gas reserves. The city is surrounded by oil fields and pipelines, which have had a significant impact on the local environment and economy. In terms of transportation, Yenagoa is connected to other parts of Nigeria by road and air. The city has an airport, the Bayelsa International Airport, which serves both domestic and international flights.

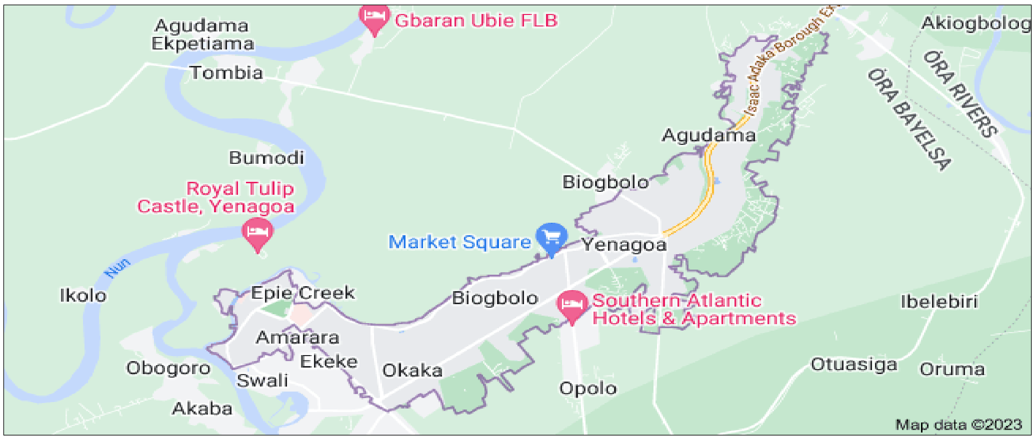

Figure 1 Map of Study Area (Yenagoa)

2. Methodology

The Digital Community-Access/Cable Television (CATV) analyzer, which has about thirty channels and operates on the spectrum 46 - 870 MHz, was used to measure the signal strength from the two television stations. It was connected to a domestic receiver antenna that was positioned at a height of about 4 m above sea level. While, from January to December, measurements of the weather variables were made using a self-implemented weather monitoring equipment every six hours between 12 and 1 am, 6 and 7 am, 12 and 1 pm, and 6 and 7 pm local time, respectively. The design and implementation of this weather monitoring equipment allow it to be operated remotely. It also displays the measurements on a user-friendly LCD display in numerical digital values (the temperature in °C, relative humidity in %, and atmospheric pressure in mbar). These measured weather data may also be sent to a computer via a serial connection or a micro SD card that has been pre-programmed. The system is set up such that the user may select how frequently meteorological variables are monitored, recorded, saved, and shown. On LCD screens, the derived weather variables are shown with the corresponding meteorological readings. Additionally, each file generated with the weather data for a given day is kept on the micro SD card in Microsoft Excel format with a file name that may be related to the precise day and time the weather variable was collected. Additionally, the user has the choice to halt the routine at any point and stop collecting meteorological variables. For more on the design, installation, and validity of the weather monitoring equipment, see Ukhurebor et al., [12]. In order to compare the data, using Eqn. 1 [20], the atmospheric pressure readings were adjusted to mean sea level pressure.

$$P_{(sml)} = P \times \left[1 - \frac{0.0065 \times h}{T + 0.0065 \times h \times 273.15}\right]^{-5.257} \ldots\ldots\ldots\ldots\ldots(1)$$

Equation (1) is further broken down to

$$P_{(sml)} = 0.03414 \times \frac{Ph}{T + 273.15} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Since distance can significantly affect the signal strength of any radio communication system, we took into account the distance from the measurement position to the transmission station [3, 13, 20] during the measurement process. As a result, these measurements were conducted at a location that was evenly spaced from the two television stations in the Yenagoa metropolis and was determined using Google Maps. We only used the mean monthly measured signal strength in addition to the mean monthly measured weather variables of temperature, relative humidity, and mean sea level pressure in order to evaluate the effects of these respective weather variables of temperature, relative humidity, and mean sea level pressure on the signal strength from the two television stations. Each of the essential weather variables that may have effects on the result from the respective weather variable was assumed constant.

3. Results and Discussion

In order to determine their influence and mathematical relationship, the results of the mean monthly measured signal strength from the two television stations (NDTV and NTA Yenagoa) located in Yenagoa, Southern Nigeria, along with each of the mean monthly measured temperature, relative humidity, and mean sea level pressure were statistically analyzed. For the whole year 2022, the monthly mean measurements of the signal strength from the two stations are provided in Table 1, together with the monthly mean observations of temperature, relative humidity, and mean sea level pressure. For the time period under consideration, the average signal strength from NDTV and NTA Yenagoa was 16.81 dBm and 18.79 dBm respectively. While the average sea level pressure, temperature, and relative humidity were 1012.40 mbar, 25.20°C and 77.43% respectively.

Table 1 Monthly Mean Measurements of Signal Strength and Weather Variables for 2022

Month	Mean Signal Strength (dBm)		Temperature (°C)	Relative Humidity (%)	Mean Sea Level Pressure (mbar)
	NDTV	NTA Yenagoa			
January	18.80	20.55	26.80	51.50	1012.50
February	19.40	21.25	28.20	49.20	1012.10
March	17.30	19.35	26.40	68.70	1011.80
April	16.25	18.50	25.20	80.30	1011.90
May	15.65	18.00	24.50	85.4	1012.30
June	15.05	17.40	24.00	96.1	1013.10
July	14.80	17.06	23.10	98.5	1013.50
August	14.60	16.46	22.60	93.30	1013.65
September	15.42	17.60	24.8	91.2	1012.30
October	18.22	20.10	26.30	82.5	1012.20
November	17.92	19.50	25.9	75.10	1011.70
December	18.30	19.73	24.60	57.30	1011.90
Average	16.81	18.79	25.20	77.43	1012.40

For the time under discussion (2022), the signal strength fluctuations from both NDTV (UHF) and NTA Yenagoa (VHF), which were obtained from the mean monthly data, are given in Fig. 2. The values were found to be higher in the months of January, February, March, October, November, and December, which also happen to be the months with the least amount of precipitation and the lowest relative humidity levels. In contrast, the values were found to be lower in the months of April, May, June, July, August, September, and October, which also happen to be the months with the most precipitation and the highest relative humidity levels.

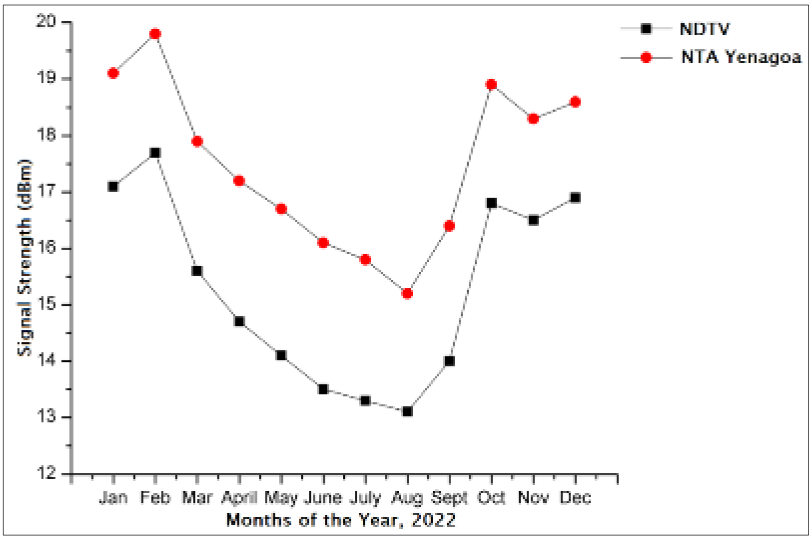

Figure 2 Monthly Variation of Signal Strength

Figures 3, 4, and 5 correspondingly depict the link between the UHF and VHF television stations' signal strengths and the corresponding meteorological variables (mean sea level pressure, temperature and relative humidity).The variation pattern for the signals from both the UHF and VHF television stations with the mean sea level pressure were not that defined, as can be seen from Fig. 3. This could be explained by the fact that the mean sea level pressure also has a significant impact on atmospheric activities [14, 16, 21].

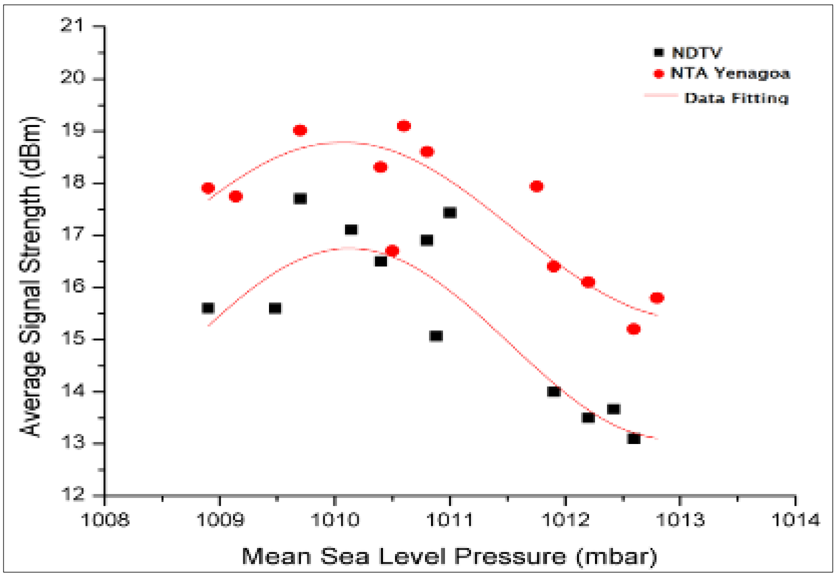

Figure 3 Average Signal Strength and Mean Sea Level Pressure

The signal strength from both the UHF and VHF television stations was observed in Fig. 4, and it was found that it increased with rising temperature and decreased with falling temperature, indicating that the signals from both the UHF and VHF television stations were directly proportional to the temperature. This could be explained by the fact that temperature is one of the most important weather variables and affects most, other weather variables [3, 15, 18, 19].

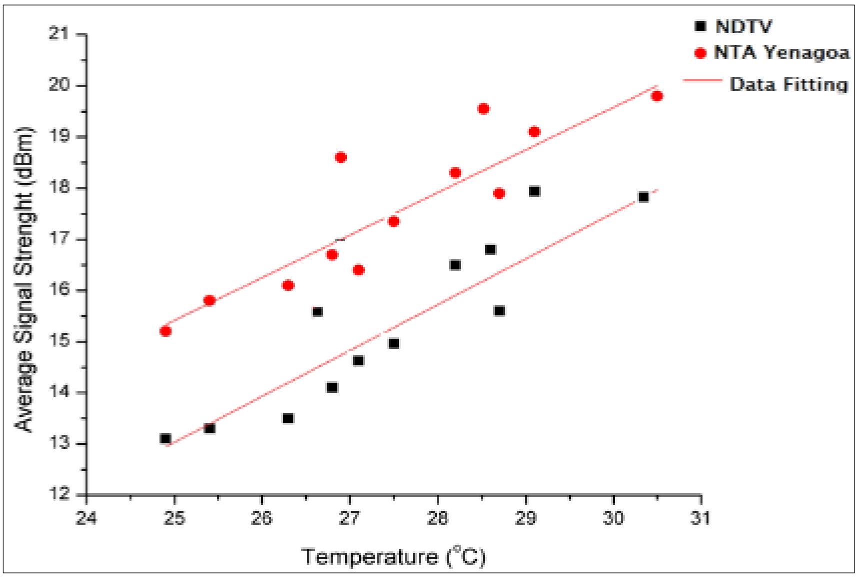

Figure 4 Average Sginal Strength and Temperature

The signals from both the UHF and VHF television stations were seen to decrease with increasing relative humidity and increase with decreasing relative humidity in Fig. 5. This indicated that the signals from both the UHF and VHF television stations had an inverse relationship with the relative humidity; this relationship could be explained by the fact that the relative humidity has a direct relationship with precipitation, which has the potential to have a significant impact on signals [17, 21].

This outcome is consistent with the works of [21, 24], whose experimental findings demonstrate a substantial association between Received Signal Strength Indicator (RSSI) and relative humidity, however there is a drop when the temperature is close to 0°C.

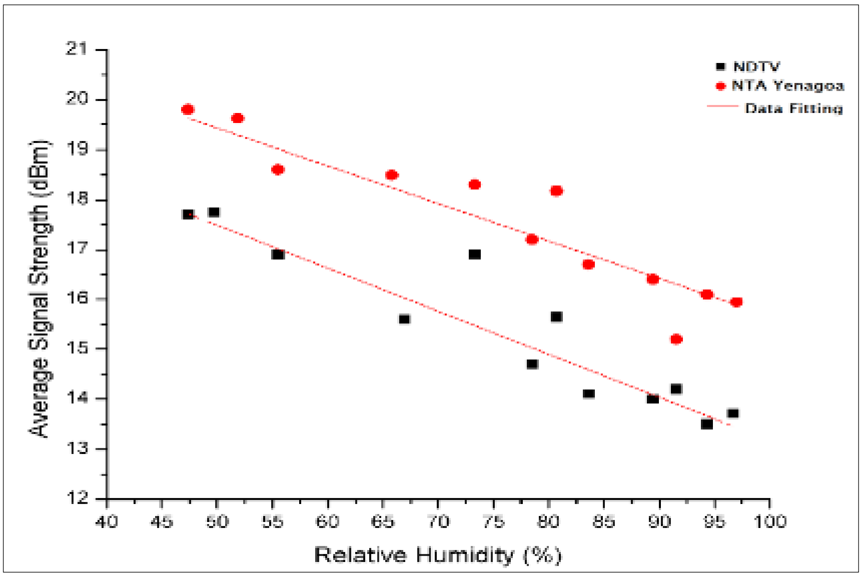

Figure 5 Average Signal Strength and Relative Humidity

4. Conclusion

In this study, the signal strength from two television stations operating in Yenagoa, Southern Nigeria—NDTV on UHF and NTA-Yenagoa on VHF—as well as some crucial weather variables—atmospheric pressure, temperature, and relative humidity—is measured and evaluated. The results and inferences drawn from this study will undoubtedly be beneficial in supporting and directing the management of radio communication networks for the purpose of planning and improvement.

Compliance of ethical standard

Acknowledgement

I sincerely appreciate the management and staff of Niger Delta Television (NDTV) and NTA-Yenagoa for their maximum cooperation during this work and for making available the required features of the investigational stations.

Disclosure of conflict of interest

I declare that there is no conflict of interest in this work.

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