Evaluation of the Effects of some Weather Variables on UHF and VHF Receivers within Benin City, South-South Region of Nigeria

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Abstract. The effects of some essential meteorological variables such as temperature, relative humidity and mean sea level pressure on the Ultra High Frequency (UHF) radio signals from Edo Broadcasting Service (EBS) transmitting at 743.25 MHz UHF and Very High Frequency (VHF) radio signals from Nigerian Television Authority (NTA) transmitting at 189.25 MHz VHF both in in Benin City, Edo State, South-South region of Nigeria located within 6°20’17″N and 5°37’32″E was evaluated in this study. The measurements of the radio signal strength from EBS television station and radio signal strength from NTA television station were done using the Digital Community-Access/Cable Television (CATV) analyser, while a self-implemented weather monitoring device was used for the measurement of the weather variables simultaneously at an equidistant position within the City. The measurements were carried out continuously for every six hours (between 12am-1am, 6am-7am, 12pm-1pm and 6pm-7pm local time respectively) all through the year, 2018. From the obtained results, it was observed that the radio signals from both the UHF and VHF television stations were directly proportional to the temperature, inversely proportional to the relative humidity and no defined pattern of proportionality with the mean sea level pressure. Inferentially, the radio signals from the UHF television station were seen to be mostly affected by these weather variables and these effects were more pronounced during the months with high relative humidity compared with the months with lower relative humidity. However, a postulation that would still be subjected to further verification has been proposed from these results. It is believed that these results and proposed postulation would definitely be helpful in guiding and assisting the management of radio communication systems for planning and other purposes.

Keywords: Television; UHF; VHF; Radio signal; Weather variables; Atmosphere

1. Introduction
Weather variables especially temperature, relative humidity and mean sea level pressure together with some other parameters like the different constituents that made up the atmosphere that occur as a result of weather variability, have significant effects on the electromagnetic waves that are propagated mostly in the lower atmosphere [1-5]. Weather variability made the refractive index of the air in the lower atmosphere to modify from one location to the other [1, 4-7]. This change could be as a result of internal variability which is due to natural internal processes within the climate system or external variability which is due to variations in natural or anthropogenic external factors [8]. The heterogeneous spatial distribution of the refractive index in the atmosphere which makes the path of the electromagnetic waves to curve have controversial effects like; multipath fading and interference, attenuation due to diffraction on the terrain obstacles also known as radio holes [3-5, 9-10]. The regions of the atmosphere where radio signals go through during the transmission process from the radio transmitters to the radio receivers which is mostly influenced by propagation pattern is very important in the management and planning processes in radio communication systems [3]. Radio links in any radio signal communication system are somehow always exposed to changes in the meteorological variability, which may result to severe degeneration in their system performance [3, 5,
9, 11]. Hence, it is very important to explore these factors that influence the radio link quality in these radio signal communication systems so as to manage and take the necessary measures and adaptation options for its mitigation and management [3].

It is on record that some researchers in the past few decades have contributed greatly in their various research works in analysing the effects of some of these weather variables on radio signals, to this end, some useful postulations have been achieved, that have helped in improving the quality of services of these radio communication systems [3, 9, 11-17]. From existing literatures at our disposal, such researches on the effects of weather variables on UHF and VHF receivers for tropical climate in some developing countries, most region of Nigeria to be specific are not that prominent [3].

In this study the measurements and evaluation of the radio signal strength from two television stations (EBS television station transmitting at 743.25 MHz UHF and NTA television station transmitting at 189.25MHz VHF) and some weather variables (temperature, relative humidity and mean sea level pressure) were done using the Digital Community-Access/Cable Television (CATV) analyser and a self-implemented weather monitoring device simultaneously at an equidistant position within the ancient city of Benin, Edo State, South-South, Nigeria, in order to comparatively ascertain the effects of these weather variables on the signal strength from these television stations. The measurements were carried out continuously for every six hours; between 12am-1am, 6am-7am, 12pm-1pm and 6pm-7pm local time respectively all through the year, 2018. This study is aimed at evaluating the effects of these essential weather variables (temperature, atmospheric pressure and relative humidity) on these two television stations, so as to know the current trend and how it can be used comprehensively for radio link margins and or link budgets in this region for planning and management purposes in radio communication systems.

2. Materials and Methods

2.1 Area of Study
The ancient city of Benin, Edo State, South-South, Nigeria is located within 6°20’17″N and 5°37’32″E. These coordinates are given in the latest version of the World Geodetic System (WGS 84) coordinate reference system, which is used in mapping and navigation, including the Global Positioning System (GPS) satellite navigation system and the canonical form of latitude and longitude representation uses (°), (′) and (") for degrees, minutes and seconds respectively [3]. This city is situated about 40 km north of the Benin River and 320 km by road east of Lagos and with an approximate elevation of 88 m (288 ft) above sea level. It has an approximate population of about 1,125,058 making it one of the biggest and most ancient cities within the South-South region of Nigeria. The city uses the West Africa time zone [18].

2.2 Methods of Measurements
Statistical data from three essential weather variables (temperature, atmospheric pressure and relative humidity) and the radio signal strength from the two television stations (EBS television station transmitting at 743.25 MHz UHF and NTA television station transmitting at 189.25MHz VHF) which were collected via the measurements that was carried out continuously for every six hours between 12am-1am, 6am-7am, 12pm-1pm and 6pm-7pm local time respectively from January – December, 2018.

The measurements of the signal strength from the two television stations was carried using the Digital Community-Access/Cable Television (CATV) analyser/receiver having about thirty channels operating on spectrum 46 – 870 MHz, which was connected to a domestic receiver antenna placed on about 4 m height above sea level. While, the measurements of the weather variables were carried out using a self-implemented weather monitoring device for the aforementioned time simultaneously.

This weather monitoring device was constructed and implemented in such a way that it can be used remotely and displayed the readings 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 can as well be sent to computer via a programmed micro SD card or/and through the serial port.
(the Arduino SD Card Module). The device is implemented in such a way that the user may decide how often the weather variables could be logged, measured, recorded, stored and displayed. The obtained weather variables are display on LCD for the respective meteorological values. Furthermore, the weather data for each day are saved on the micro SD card in Microsoft Excel format on a separate file with each file created with a file name that may corresponds to the exact date and time when the weather variable was obtained. The user also has the option to terminate the weather variables acquisition process at any time by interrupting the routine. See Ukhurebor et al., [19] for details on the construction and implementation of the weather monitoring device including its validity.

The atmospheric pressure readings was reduced to the mean sea level pressure so as to make the readings comparable using Eqn. 1 [20]:

$$P_{(sml)} = P \times \left[1 - \frac{0.0065 \times h}{T + 0.0065 \times h \times 273.15}\right]^{-5.257} = 0.03414 \times \frac{Ph}{(273.15 + T)}$$

Since distance can have a significant influence on the signal strength of any radio communication system, as such in the course of the measurements process, we took into consideration the distance from the measurement position to transmission station [3]; so these measurements were carried out at an equidistant position between the two television stations within the ancient city of Benin, which was suited out via Google map.

2.3 Methods of Evaluation

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 station (EBS and NTA television), each of the essential weather variables that may have effects on the result from the respective weather variable were assumed constant, and we only made use of the mean monthly measured signal strength in addition to the mean monthly measured weather variables of temperature, relative humidity and mean sea level pressure for the evaluation of this research which were done procedurally.

3. Results and Discussion

The results of the mean monthly measured signal strength from the two television stations (EBS and NTA television both in Benin City, Edo State, Nigeria) with each of the mean monthly measured temperature, relative humidity and mean sea level pressure were evaluated statistically in order to establish their influence and mathematical relationship.

In Table 1 the monthly mean measurements of the signal strength from the two stations together with the monthly mean measured temperature, relative humidity and mean sea level pressure, all through the year 2018 are shown. The average signal strength for the period under consideration was 15.30 dBm and 17.50 dBm from EBS and NTA respectively. While, the mean temperature, relative humidity and mean sea level pressure was $27.50 \, ^{\circ}C$, 75.60% and 1010.90 mbar respectively.
Table 1: The Monthly Mean Measurements of the Signal Strength and Weather Variables for 2018

| Month | Mean Signal Strength from EBS (dBm) | Mean Signal Strength from NTA (dBm) | Temperature (°C) | Relative Humidity (%) | Mean Sea Level Pressure (mbar) |
|-------|------------------------------------|------------------------------------|------------------|----------------------|-------------------------------|
| Jan   | 17.10                              | 19.10                              | 29.10            | 49.70                | 1010.60                       |
| Feb   | 17.70                              | 19.80                              | 30.50            | 47.40                | 1009.70                       |
| Mar   | 15.60                              | 17.90                              | 28.70            | 66.90                | 1008.90                       |
| April | 14.70                              | 17.20                              | 27.50            | 78.50                | 1009.00                       |
| May   | 14.10                              | 16.70                              | 26.80            | 83.60                | 1010.50                       |
| June  | 13.50                              | 16.10                              | 26.30            | 94.30                | 1012.20                       |
| July  | 13.30                              | 15.80                              | 25.40            | 96.70                | 1012.80                       |
| Aug   | 13.10                              | 15.20                              | 24.90            | 91.50                | 1012.60                       |
| Sept  | 14.00                              | 16.40                              | 27.10            | 89.40                | 1011.90                       |
| Oct   | 16.80                              | 18.90                              | 28.60            | 80.70                | 1011.00                       |
| Nov   | 16.50                              | 18.30                              | 28.20            | 73.30                | 1010.40                       |
| Dec   | 16.90                              | 18.60                              | 26.90            | 55.50                | 1010.80                       |
| Average | 15.30                              | 17.50                              | 27.50            | 75.60                | 1010.90                       |

In Fig. 1 the signal strength variations from both EBS television station (UHF) and NTA television station (VHF) for the period under consideration (2018) on monthly basis which were acquired from the mean monthly records are shown. It was observed that the values were higher during the months of January, February, March, October, November and December which happens to be the months with limited precipitation and are occasioned by low relative humidity values; while, the values were lower in the months of April, May, June, July, August, September and October which happens to be the months with higher precipitation and are occasioned by very high relative humidity values.
Fig. 1: Monthly Variations of the Signal Strength

The relationship between the signal strength from both the UHF and VHF television stations with the respective weather variables (temperature, relative humidity and mean sea level pressure) are graphically shown in figures 2 - 4 respectively.

From Fig. 2, it was observed that the signals from both the UHF and VHF television stations (distance is kept constant) increases with increasing temperature and also decreases with decreasing temperature; signifying that the signals from both the UHF and VHF television stations were directly proportional to the temperature; this could be attributed to the fact that temperature as one of the most crucial weather variables which influences most if not all other weather variables [3, 18-19], and could have significant influence on atmospheric activities [21].
From Fig. 3, it was observed that the signals from both the UHF and VHF television stations decreases with increasing relative humidity and increases with decreasing relative humidity; signifying that the signals from both the UHF and VHF television stations were having inverse proportionality with the relative humidity; this could be attributed to the fact that relative humidity has direct proportionality with precipitation which could affect signals significantly [21].

This result is in conformity with the work Luomala et al., [21], where there experiment results show that there is a strong correlation between Received Signal Strength Indicator (RSSI) and relative humidity, though there would be decrease when the temperature is close to 0°C.
From Fig. 4, it was observed that the figure is having a kind of undulating pattern; signifying that the variation pattern for the signals from both the UHF and VHF television stations with the mean sea level pressure were not that defined; this could be attributed to the fact mean sea level pressure also have significant influence on atmospheric activities [21].
Fig. 4: Average Signal Strength and Mean Sea Level Pressure

We can now write mathematically on the absorption that other weather variables and some other factors including distance are kept constant that:

$$U_k = STR_h$$ (2)

Where $S$ is the signal strength, $T$ is the temperature, $R_h$ is the relative humidity and $U_k$ is the constant of proportionality. This constant of proportionality would require a proper definition because it may be a very useful parameter when dealing with the relationship between the signals and weather variables. We therefore propose a postulation; that signals from both the UHF and VHF television stations have direct proportionality with the temperature and inverse proportionality with the relative humidity, on the assumption that the other weather variables and factors are kept constant. According to Guidara [22], the effect of weather variables on radio link quality is still a subject of scientific debate. We have much contrary results from previous research studies. Nevertheless, this proposed postulation is still undergoing further verification.

4. Conclusion

This study deals with the measurements and evaluation of the signal strength from two television stations located within the heartbeat of the ancient city of Benin, Edo State, South-South region of Nigeria (EBS television station operating in UHF and NTA television station operating in VHF) together with some essential weather variables (temperature, atmospheric pressure and relative humidity). The results and proposed deduction acquired from this study would definitely be helpful in
guiding and assisting the management of radio communication systems for planning and improvement purposes. Conclusively, we would suggest that further studies should be carried out, using more meteorological variables, radio communication systems, contemporary tools and technique over a long period of time in order to having more beneficial and comprehensive results.

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