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Influence of Meteorological Variables on UHF Radio Signal: Recent Findings for EBS, Benin City, South-South, Nigeria

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ABSTRACT

In this study the influence of some meteorological variables on Ultra High Frequency (UHF) radio signals from Edo Broadcasting Service (EBS) in Benin City, South-South, Nigeria located within Latitude 6°20′17″N and Longitude 5°37′32″E was investigated. The measurements of the radio signal strength from EBS Television, transmitting at 743.25 MHz UHF and some meteorological variables (air temperature, atmospheric pressure and relative humidity) using the Digital Community-Access/Cable Television (CATV) analyzer and a self designed cost effective portable weather monitoring system were carried out simultaneously at a residential building within Benin City, in order to ascertain the influence of these meteorological variables on the signal strength. The measurements were done every eight hours (between 7am-8am, 3pm-4pm and 11pm-12am respectively) for a period of one year (2017). From the obtained results, it was inferentially observed that the radio signals was having inverse relationship with the air temperature, atmospheric pressure and the relative humidity; on the assumption that for any of the aforementioned meteorological variables, the others were observed constant. Statistically, the signal strength and these meteorological variables were having correlation values of -0.94, -0.92 and -0.96 for the air temperature, atmospheric pressure and the relative humidity respectively. These results obtained from this study should be taken into account by the management of radio communication systems for enhancement and planning purposes.

Keywords: Troposphere; Radio Signals; Air temperature; Atmospheric pressure; Relative humidity

1. INTRODUCTION

Air temperature, atmospheric pressure, relative humidity and most of the other meteorological variables have great influence on the electromagnetic waves that are propagated in the troposphere (lower atmosphere), although some other factors like the different components that made up the troposphere, also have much influence as well. But it is noteworthy that the variations in these meteorological variables are the ones actually affecting the components that made up the troposphere, which in turn have these influence on the electromagnetic waves (Korak, 2003; Agbo, *et al.,* 2013; Ukhurebor and Azi, 2018). The variations in these meteorological variables cause the refractive index of the air in the troposphere to differ from one place to another (Ayantunji, *et al.,* 2011; Okoro, *et al.,* 2012; Ukhurebor and Azi, 2018). The bending in the path of the electromagnetic waves which is as a result of the non-homogenous spatial distribution of the refractive index in the air have contentious effects like multipath fading and interference, attenuation due to diffraction on the terrain obstacles which is also called the radio holes (Ukhurebor and Azi, 2018; Alam, *et al.,* 2016; Martin and Vaclav, 2011).

The propagation pattern of radio signals from the radio transmitter to the radio receivers which is controlled by the regions of the troposphere where they go through is of great significance in the management and planning processes in radio communication systems. Radio links in any radio communication system are exposed to weather variability, which could cause severe degradation in their system performance (Alam, *et al.,* 2016; Amajama, 2016). It is therefore, imperative to explore the various factors affecting the radio link quality in these radio communication systems in order to take the necessary measures and adaptation options to alleviating and controlling its effects.

In the past few years, some researchers have tried to evaluate the impacts of some meteorological variables such as air temperature, atmospheric pressure, relative humidity, rain, wind, fog, dew point temperature, light intensity, solar irradiance, wet snow and evaporating duct on microwave frequency bands, to this end, some useful results and models have been postulated by few of these researchers, as a useful step to having more reliable signal communication systems (Alam, *et al.,* 2016; Yeeken and Michael, 2011; Amajama, 2016; Adewumi, *et al.,*, 2015; Guifu Zhang and Edward, 2001; Karmakar et al, 2011; Meng, *et al.,* 2009; Olsen and Segal, 1992; Waheed-uz-Zaman Yousuf Zai, 2010; Xiaofeng and Sixun, 2010). It is noteworthy, to the best of our knowledge from existing literatures that most of the research findings and models on the recent influence of air temperature, atmospheric pressure, relative humidity and the other meteorological variables on UHF signal propagations from television (TV) transmission stations for tropical climate in developing nations, like Nigeria are below the belt. In this study the measurement results of some meteorological variables (air temperature, atmospheric pressure and relative humidity) and the radio signal strengths from EBS TV transmission station were done every eight hours for a period of one year (January – December, 2017) simultaneously at a residential building in Benin City the capital of Edo State, South- South, Nigeria using a self designed cost effective portable weather monitoring system and the Digital Community-Access/Cable Television (CATV) analyzer respectively. The main aim of this research is to analysis the recent influence of these three meteorological variables (air temperature, atmospheric pressure and relative humidity) on the UHF signal propagation from EBS TV transmission station, so as to fashion how it can be used for effective radio link margins/link budgets in tropical rain forest regions for planning and improvement purposes in radio communication systems.

2. MATERIALS AND METHODS

Statistical data of meteorological variables (air temperature, atmospheric pressure and relative humidity) and the radio signal strengths from EBS TV station transmitting on 743.25 MHz (UHF) measurements were done for every eight hours (between 7am-8am, 3pm-4pm and 11pm-12am respectively) for a period of one year (January – December, 2017) simultaneously at a residential building in Benin City, the capital of Edo State, South- South, Nigeria which is situated around 40 km north of the Benin River and 320 km by road east of Lagos and located within Latitude 6°20′29″N and Longitude 5°37′55″E with an elevation of about 88 m (288 ft) above sea level. It has an approximate population of 1,125,058 making it one of the largest and most ancient cities in South-

South, Nigeria. The city operates on the West Africa time zone (Ukhurebor*, et al.,* 2017a). The 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.

The measurements of the signal strength was done using the Digital Community-Access/Cable Television (CATV) analyzer (receiver) with more than 20 channels, spectrum 46 – 870 MHz, connected to a domestic receiver antenna of about 5 m height; while, the measurements of the meteorological variables were done using a self designed cost effective portable weather monitoring system for the aforementioned time simultaneously. The weather monitoring device was designed in such a way that it can be used remotely and the measured meteorological variables are displayed on a user friendly Liquid Crystal Display (LCD) in numerical digital values for air temperature (ºC), atmospheric pressure (mbar), relative humidity (%) and light intensity (lux) which can be send to the computer via the programmed micro SD card or/and through the serial port; the Arduino SD card module. The user has the option of choosing how often the meteorological variables will be logged, measured, recorded, displayed and stored. The acquired meteorological variables are analyzed and the LCD displays the values respectively. In addition, the meteorological variables for each measurement are saved on the micro SD card in Excel format on a separate file with each file created with a file name that corresponds to the date and time when the meteorological variables were acquired. The users also have the option to stop the meteorological variables acquisition process at anytime by interrupting the routine. The details of the weather monitoring system design and implementation including its validity are contained in Ukhurebor *et al.*, (2017b).

To ascertain the recent influence of these respective meteorological variables on the signal strength; each of the other meteorological variables which would have effect(s) on the inference on the result of that respective meteorological variable were observed constant, and we only made use of the average monthly measured signal strength together with the average monthly measured meteorological variables of air temperature, atmospheric pressure and relative humidity for the analysis of this research.

3. RESULTS AND DISCUSSION

The results of each of the average monthly measured air temperature, atmospheric pressure and relative humidity with the average monthly measured signal strength of EBS TV station, transmitting on 743.25 MHz UHF were analyzed statistically in order to ascertain their influence and relationship.

Table 1 shows the monthly average measurements of the signal strength together with the monthly average measured air temperature, atmospheric pressure and relative humidity, all through the year 2017.

Table 1 The Monthly Average Measurements of the Signal Strength and Meteorological Variables for 2017

Month	Average Signal Strength (mdB)	Air Temperature (^{0}C)	Atmospheric Pressure (mbar)	Relative Humidity (%)
January	13.50	28.20	1001.70	42.70
February	10.50	31.80	1002.50	48.20
March	11.40	30.10	1004.60	68.70
April	12.20	29.30	1007.10	85.20
May	13.40	28.40	1005.70	92.10
June	15.90	26.30	1005.90	92.40
July	16.10	25.00	1004.70	95.30
August	15.10	26.60	1003.90	78.60
September	16.00	25.50	1005.40	78.40
October	16.20	25.70	1005.60	68.90
November	13.10	27.80	1004.70	68.20
December	15.30	26.50	1002.90	58.30
Total Average	14.06	25.28	1005.00	73.08

In Figure 1 the direction of the residential building where the CATV analyzer and the weather monitoring device was stationed away from the EBS-TV transmission station is shown; while in Figures 2, 3 and 4 the relationship between the signal strength and the air temperature, atmospheric pressure and relative humidity are graphically shown respectively.

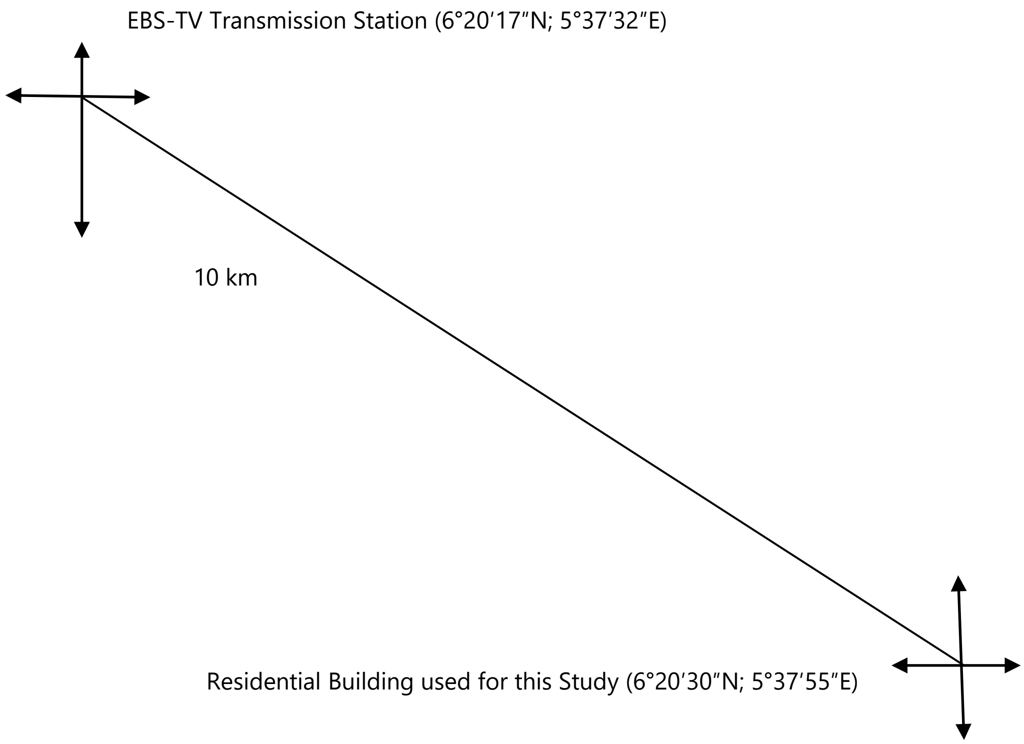

Figure 1 Diagrammatic Description of the Direction of EBS-TV Transmission Station and the Residential Building used for this Study

In Fig. 1 the direction of the residential building where the CATV analyzer and the weather monitoring device was stationed away from the EBS-TV transmission station is shown. From EBS-TV transmission station to the residential building was about 10 km. We also took into account of the fact the distance from the transmission station can also affect the signal strength.

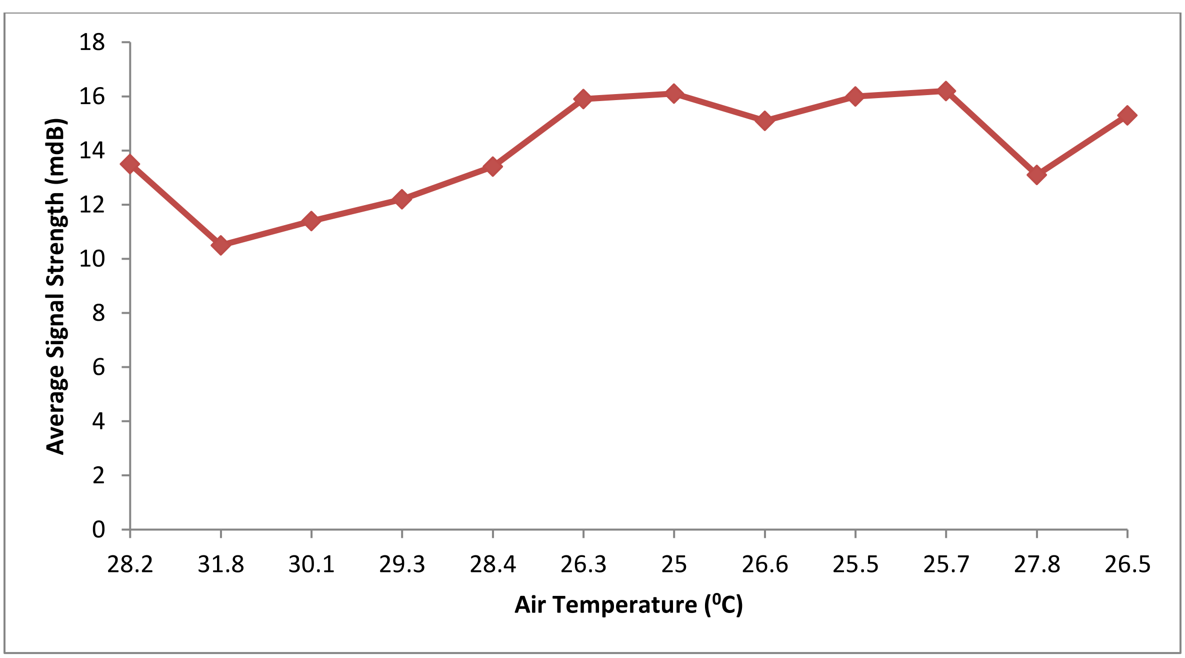

Figure 2 Graphical Representation of the Signal Strength against the Air Temperature

In Fig. 2 the graphical representation of the signal strength against the air temperature is shown. It was observed that the signal strength decreases as the air temperature increases slightly. Statistically, the correlation between the signal strength and the air temperature was having a value of -0.94. This implies that, the signal strength is inversely proportional to air temperature, on the assumption that the other meteorological variables are observed constant. The increase in air temperature causes degradation of signal strength, this is true because there is a collision between increasing raining particles of light from the sun as air temperature which is the measure of temperature at different levels of earth's atmosphere increases with the radio signals (since both waves are electromagnetic waves), this attenuates the signal strength.

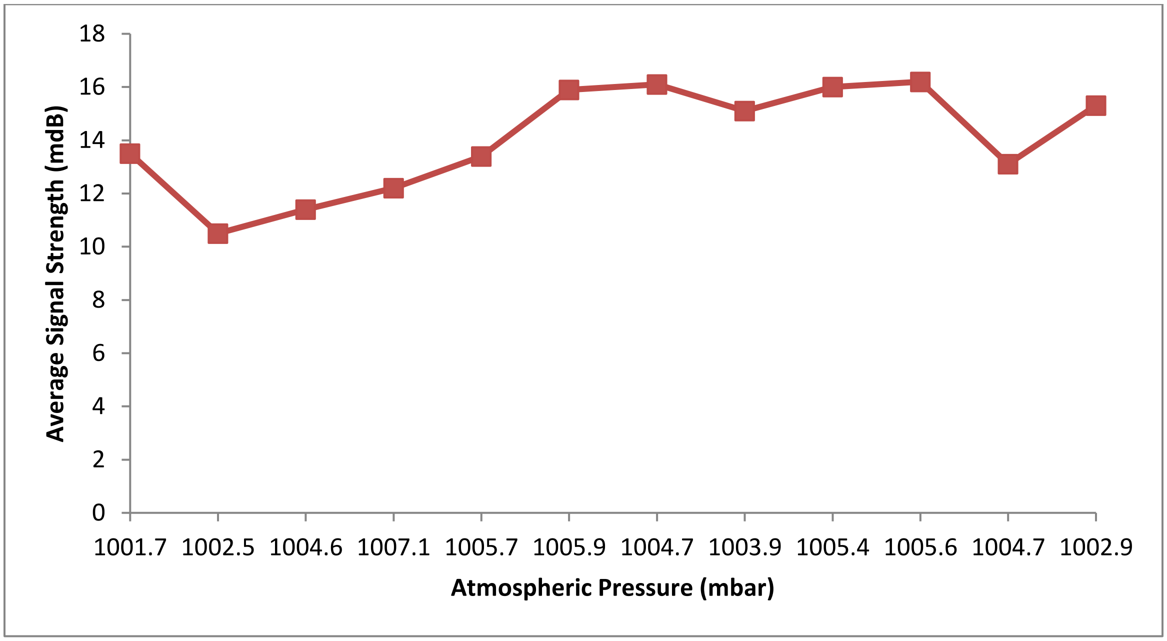

Figure 3 Graphical Representations of the Signal Strength and the Atmospheric Pressure

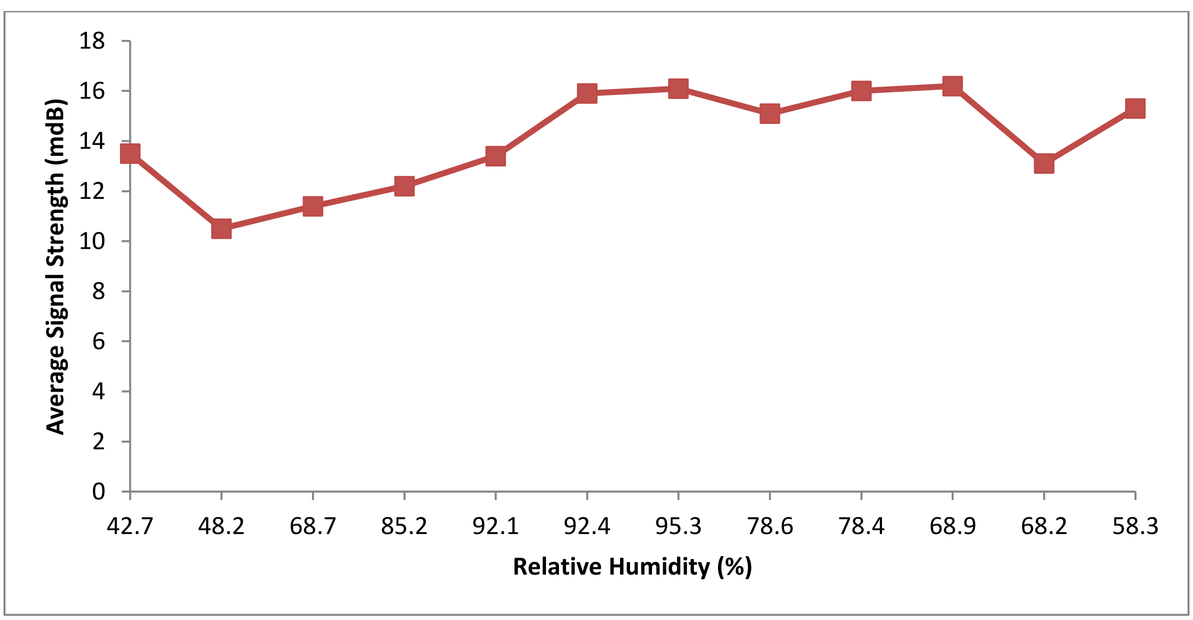

Figure 4 Graphical Representation of the Signal Strength and the Relative Humidity

In Fig. 3 the graphical representation of the signal strength against the atmospheric pressure is shown. It was observed that the signal strength decreases as the atmospheric pressure increases. Statistically, the correlation between the signal strength and the atmospheric pressure was having a value of -0.92. This implies that, the signal strength is inversely proportional to atmospheric pressure, on the assumption that the other meteorological variables are observed constant. The atmospheric pressure impacts negatively on signal strength. Atmospheric pressure which is the force exerted on unit surface area on the earth by the weight of earth's atmospheric air above its surface has a negative influence on the signal and that the signal has to overcome it as its travels through the atmospheric channel.

In Fig. 4 the graphical representation of the signal strength against the relative humidity is shown. It was observed that the signal strength decreases as the relative humidity increases. Statistically, the correlation between the signal strength and the atmospheric pressure was having a value of -0.96. On the assumption that the other meteorological variables are observed constant, the signal strength is inversely proportional to relative humidity which is the ratio of the amount of water vapor in the air at any given temperature to the maximum amount of water vapor that the air can hold. The increase in relative humidity has great impact on the signal strength negatively and this is could be as a result of the water particulate content of the atmosphere which may cause diffraction, reflection and scattering of radio waves and hence attenuation.

Inferentially from these results, we established a mathematical relationship between the measured signal strength and these measured meteorological variables (air temperature, atmospheric pressure and relative humidity).

Where we have that;

$S \propto \frac{1}{T}$ (1)

$S \propto \frac{1}{P}$ (2)

$S \propto \frac{1}{H}$ (3)

Combining and resolving Eqn. (1), (2) and (3) mathematically, we have;

$S = \frac{K}{TPH}$ (4)

$K = \boldsymbol{S} \times \boldsymbol{T} \times \boldsymbol{P} \times H$ (5)

This implies that; $S_n \times T_n \times P_n \times H_n = S_{n+1} \times T_{n+1} \times P_{n+1} \times H_{n+1}$ (6)

Where, *S, T, P, H* and *K* are the signal strength, air temperature, atmospheric pressure, relative humidity and the proportionality constant respectively. The constant *K* is an important factor that needs to be quantified and *n* is in sequence of 1, 2, 3 … nth.

The influences of these meteorological variables on the signal strength were observed higher during the months with much rainfall (rainy season), compared to the months with lesser rainfall (dry season) for the period under consideration (2017), and among these three meteorological variables used for this study; air temperature was having the highest influence on the signal strength, this affirm the fact that air temperature is the most widely measured meteorological variable because of it crucial nature and its influence on other meteorological variables (Ukhurebor*, et al.,* 2017a).

4. CONCLUSION

In this study the relationship and influence of air temperature, atmospheric pressure and relative humidity on the radio signals from EBS TV station transmitting on 743.25 MHz (UHF) in Benin City, South-South, Nigeria was analyzed. The results obtained from this study will go a long way in providing assistance for the management of radio communication systems in improving their quality of service within the studied area and beyond.

The following conclusions were inferentially reached from the results obtained:

- The air temperature, atmospheric pressure and relative humidity were inversely proportional to the signal strength during the studied period (2017).
- The influences of these meteorological variables were observed higher during the months with higher rainfall (wet season) during the studied period (2017).

- The air temperature was having the highest influence on the signal strength compared to the other two meteorological variables used for this study.
- Further studies should be carried out, using more meteorological variables and more radio signal service providers over a long period of time, in order to have more comprehensive results.

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