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EFFECT OF SOME RADIO CLIMATIC FACTORS ON DIGITAL TERRESTRIAL TELEVISION SIGNAL IN A SAHEL SAVANNAH CITY OF NIGERIA

***[1]Akinbolati, A., [2]Ajewole, M. O., and [2] Ojo J. S.**

[1]Department of Physics, Federal University Dutsin-Ma, Katsina State, Nigeria
[2]Department of Physics, Federal University of Technology, Akure, Ondo State, Nigeria

*Corresponding Author's E-mail; sanmibola2@yahoo.com, aakinbolati@fudutsinma.edu.ng

ABSTRACT

This study investigates the effect of some radio climatic factors on the Received Signal Strength (RSS) of a Digital Terrestrial Television Broadcast Station (DTTBS) in Katsina City, Nigeria. The RSS was measured at intervals along selected routes around the station using a digital signal strength meter. GPS receiver was used to log the line of sight, geographic coordinates and heights of data points from the station. The atmospheric pressure, temperature and humidity corresponding to data points were concurrently measured using a compact weather station whereas the corresponding surface radio refractivity (N_s) values were computed. Data were collected during dry (November) and wet (July) season months in the year 2017. Result shows that, N_s is inversely proportional to RSS irrespective of routes and seasons with correlation coefficients of **-0.51 and -0.57** during dry and wet season months respectively. Higher mean value of, 358.50 (N-units) was deduced during wet compared to the dry season month of 301.20 (N-units). Average atmospheric pressure of 951.92 and 949.61 (hPa) and as well as humidity values of 32.25 and 77.93 %RH were deduced during dry and wet season months respectively. Findings also show that pressure is inversely proportional to RSS. This study concludes that the specified radio climatic factors have attenuation effects (refraction, absorption and scattering) on UHF signal and should be put into consideration when planning link's design and power budgets on the UHF band.

Keywords: Digital, Terrestrial, Television, UHF, surface radio refractivity and Katsina

INTRODUCTION

Analogue and digital terrestrial transmission of signal on the Ultra High Frequency (UHF) broadcast band is by space wave which propagates on Line of Sight (LOS) from the transmitter to the receiver through the troposphere (Akinbolati *et al*., 2017). The interaction of the radio signal with both primary and secondary radio climatic factors results into attenuation of the signal strength. Examples of primary radio climatic factors are temperature, humidity, precipitation and atmospheric pressure amongst others. Surface radio refractivity, refractivity gradient and k-factor are examples of secondary radio climatic factors. Many literatures have established correlation between radio climatic factors and signal strength losses on Very High Frequency (VHF) and UHF bands in Nigeria (Oyedum and Gambo, 1994; Adewumi *et al*., 2013, Ajewole *et al*., 2014; Adediji *et al*., 2017, Akinbolati *et al.*, 2017a).

Other well-known factors that determine the quality of signal from the transmitter to the receiver on the UHF band include; transmitter output power, transmitting antenna height, transmitter-receiver distance (LOS) and elevation of the receiver above ground level. Others are; gain of the receiving antenna, the quality of the receiver (Armoogum *et al.,* 2010, Akinbolati *et al.,* 2016) and effect of terrestrial objects on the propagation path (Boithias, 1987; Kenedy and Bernard (1992). Kenedy G., Bernard, D. (1992). For stakeholders to enjoy Quality of Service (QOS) of transmitted wireless signal in the UHF band, the attenuation effect of surface radio refractivity and meteorological parameters which forms parts of the path losses should be investigated across climatic zones and factored into transmission's links' design and power budget (Akinwumi *et al.*, 2015; Akingbade and Olorunnibi, 2013)

UHF Band

Ultra-High Frequency (UHF) is the International Telecommunications Union (ITU) designation for radio frequencies in the range of 300 MHz and 3 GHz, It is also known as decimeter band as the wavelengths range from one meter to one tenth of a meter (one decimeter). Most UHF radio waves propagate mainly by LOS; they are affected by hills, large buildings, vegetation, radio climatic factors and elevation pattern (Boithias, 1987; Akinbolati *et al.,* 2016) although its transmission through the building walls is strong enough for indoor reception. They are used for television broadcasting, cell phones, satellite communication including Global Positioning System (GPS), personal radio services, Bluetooth, Wi-fi, walkie, talkie amongst others. There is no reflection from the ionosphere to UHF, since UHF transmission is limited by the visual horizon 48-64 km and often to shorter distance due to local terrain (Boithias, 1987). It allows the same frequency channels to be reused by other users in neighboring geographic areas (frequency reuse).

Surface Radio Refractivity and Radio Signal

The refractive index (n) of the troposphere is an important factor at predicting performance of terrestrial radio links. It is always close to unity while the parameter used to describe its spatial and temporal variations is generally termed the radio refractivity *N*, and defined by (ITU-R, 1995):

$$N = (n-1)\times 10^6 \tag{1}$$

Refractive index variations of the atmosphere affect radio frequencies above 30 MHz, which becomes more significant only at frequencies greater than about 100 MHz especially in the troposphere (Ayantunji et al., 2011; Oyedum and Gambo, 1994).
Radio refractivity, N, is a dimensionless quantity defined and measured in N units and can be further expressed by the relations below (Adediji and Ajewole, 2008; ITU-R, Rec. P453-9, 2003):
where, *N*, depends on meteorological parameters of pressure P (hPa), temperature T (K) and water vapour pressure, e (hPa). The surface radio refractivity (N_s) is as presented in (2):

$$N_s = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right)(N - units) \quad \text{(N-units)} \tag{2}$$

with,

$$e = \frac{He_s}{100}(hPa) \tag{3}$$

and

$$e_s = 6.11\exp\left[\frac{17.502t}{t+240.97}\right] \tag{4}$$

e_s is the maximum (or saturated) vapour pressure at the given air temperature, t (°C).

Water molecules in the atmosphere are polar; with dipole moments. Other gases are basically non polar but dipole moments are induced in their molecules only when electromagnetic waves propagate through them (Olorode and Adeniji, 2013). This reaction causes change in the radio refractive index, n, leading to reflection, polarization and scattering of the incident wave (Olorode and Adeniji, 2013) with the overall effect resulting into signal loss (Akinbolati *et al.*, 2017b). This work investigates the attenuation effects of humidity, temperature, atmospheric pressure and surface radio refractivity on digital terrestrial television base station operating on UHF channel 28, Katsina in the Sahel Savannah zone of Nigeria. No similar work has been reported in the study area which forms the motivation for this study with the view that the findings will enhance the QoS of the existing Digital Terrestrial Television (DTTV) networks in this region of Nigeria.

Research Hypothesis

This work was designed to investigate the attenuation effect (level of attenuation) of some radio climatic factors such as; temperature, pressure, humidity (primary radio climatic factors) and surface radio refractivity (secondary radio climatic factor) on transmitted digital terrestrial television signal in the Sahel Savannah parts of Nigeria using Katsina city as case study.

MATERIALS AND METHOD

This section focuses on the study area, the instruments used for field work and the step by step methods for data collection and analysis.

Study Areas and the Experimental Station

The Digital Terrestrial Television Base Station (DTTBS) of Star Times Television, along Jibia road, Katsina was used as the source of signal (case study). Katsina is the capital city of Katsina State located in the North Western parts of Nigeria. The climate is Sahel Savannah; the city has a population of about 318,459 according to 2006 Nigerian population census. The amount of rainfall in this area is always less than 1000 mm per annum in only about four months (July- October) in a year. The peak of the wet season is July/August every year (Ati, 2016). Table 1 presents the transmission parameters of the experimental station.

Table 1: Transmission Characteristic of the Experimental DTTBS

S/N	Parameter	Value /definition
1	Base station's location	Lat. $13^0 01' 50''$ N, Long. $7^0 32' 50''$ E
2	Base station transmitted power (kW)	1.80
3	Base station's frequency (MHz)/ Channel	530 / 28
4	Height of transmitting mast (m)	200
5	Height of receiving antenna (m)	3.0

Instrumentation and Methods

Measurement of RSS of the DTTBS located along Jibya road Katsina was carried out radially from the base station along three different routes using Star Times terrestrial Yagi receiver antenna mounted on a 3.0 m height. The output was connected to a digital Satlink (WS-6936) signal meter for the RSS values to be recorded. Figure 1 presents the google map of the routes where measurements were carried out. The LOS from the base station was monitored during the drive test using the GPS, which equally measures the location's longitude, latitude, and the elevation. A wireless compact weather station (N96FY) was used concurrently for the measurement of surface weather parameters such as; temperature, pressure and humidity of data points. The research crew usually stops at an interval of 1 km LOS for measurement to be taken, up to a maximum of 20 km for each route. Data were collected during dry (November) and wet (July) season months in the year 2017. In summary, eight primary data were measured at each point while the surface radio refractivity (N_s) values corresponding to data locations were computed using equations (1) - (4) based on the surface weather parameters obtained. Measurements were carried out for three consecutive days in each season (each day per route) with about 120 data sets collected for both dry and wet seasons' months in all the routes. Daily data were sorted and the mean values used for analysis. MATLAB was used to generate the plots that depict the relationship between the parameters and RSS with respect to the LOS separation distance from DTTBS while correlation coefficient and Analysis of Variance (ANOVA) were used for the statistical analysis.

Transmission parameters of the DTTBS were relatively constant throughout the period of measurement as confirmed by the records of transmission in the station.

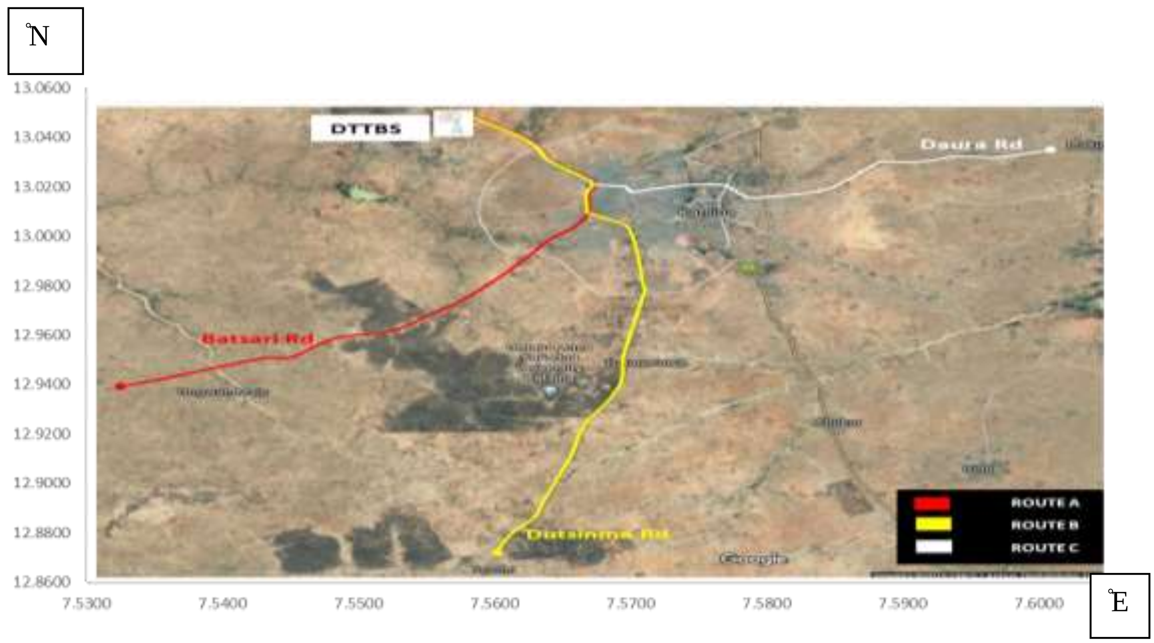

Figure 1: Google Map Showing Routes of Measurements in Katsina city (Akinbolati et al., 2020)

RESULT AND DISCUSSIONS

This section presents the findings of the analysis on the effect of the specified radio climatic factors on RSS of the digital terrestrial television.

The effect of surface radio refractivity (N_s) on RSS over the study area

Figures 2 and 3 depict typical influence of surface radio refractivity on RSS during dry and wet season months respectively. The pattern of the results revealed the influence of surface radio refractivity on the received signal strength of DTTV.

From Figure 2 , at higher values of N_s , between 295 and 315 N-units within LOS of 0-5.0 km, the signal strength was poor compared to the signal strength recorded within the same distance at lower refractivity values 270-290 N-units. The lower the surface radio refractivity, the better the signal strength recorded. The trend was observed generally irrespective of the routes and seasons. Mean, N_s , values of 301.20 and 358.50 N-units were obtained during dry and wet season months respectively. Statistical correlation coefficient of -0.51 and -0.57 were obtained between N_s and RSS during dry and wet season months respectively over the study areas; this correlation coefficient is significant and it reveals that surface radio refractivity is inversely proportional to RSS. In addition, higher values of N_s were recorded during wet compared to the dry season months. The implication is that RSS will experience higher signal loss during wet compared to dry season months

Effect of Humidity on RSS

Figures 4 and 5 depict the relationship between humidity and RSS with respect to LOS separation distance from DTTBS during dry and wet season months respectively. The results revealed that, at higher value of humidity and at the near field of the DTTV signal, RSS is at the peak for all the routes. This might be attributed to near field and may not necessarily be the effect of humidity. The other possibility is that, when humidity is low, air moisture reduces, which may lead to enhanced activity of few aerosols such as dust and haze resulting to attenuation of signal through absorption and scattering of transmitted signal. Mean humidity values of **32.35** and **77.93 % RH** were obtained during dry and wet season months respectively.

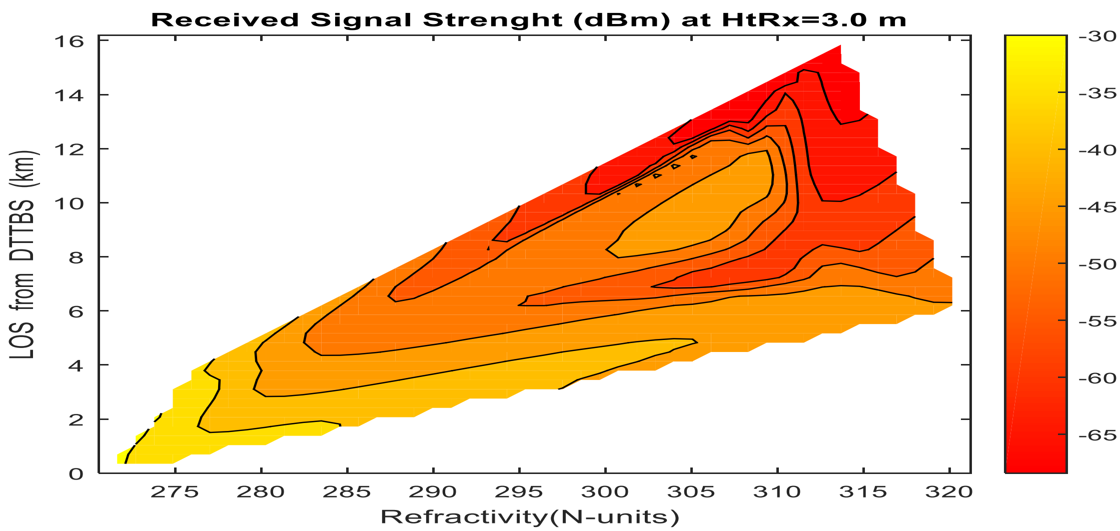

Figure 2: Effect of Surface Radio Refractivity on RSS in Katsina during Dry Season Months.

HtRx: Height of Receiver Antenna.

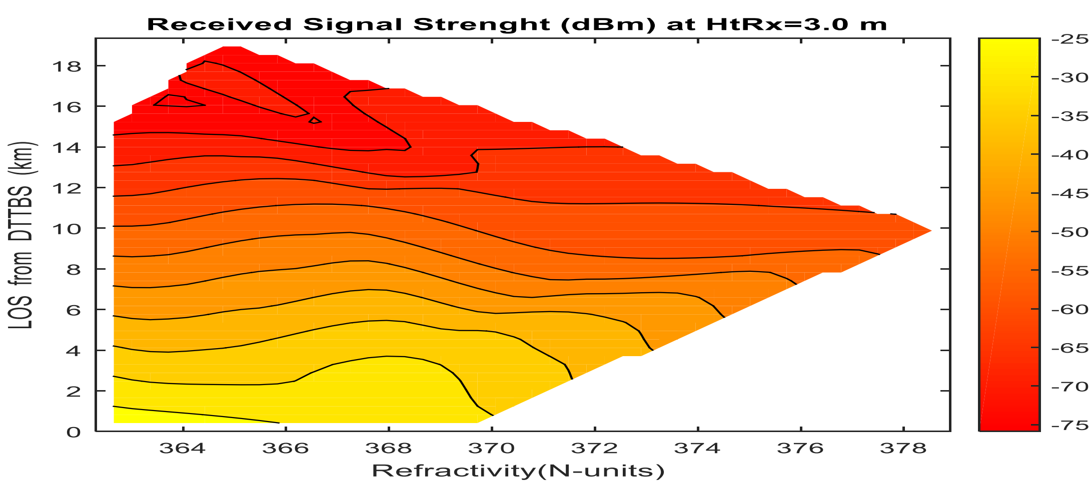

Figure 3: Effect of Surface Radio Refractivity on RSS in Katsina during Wet Season Months'.

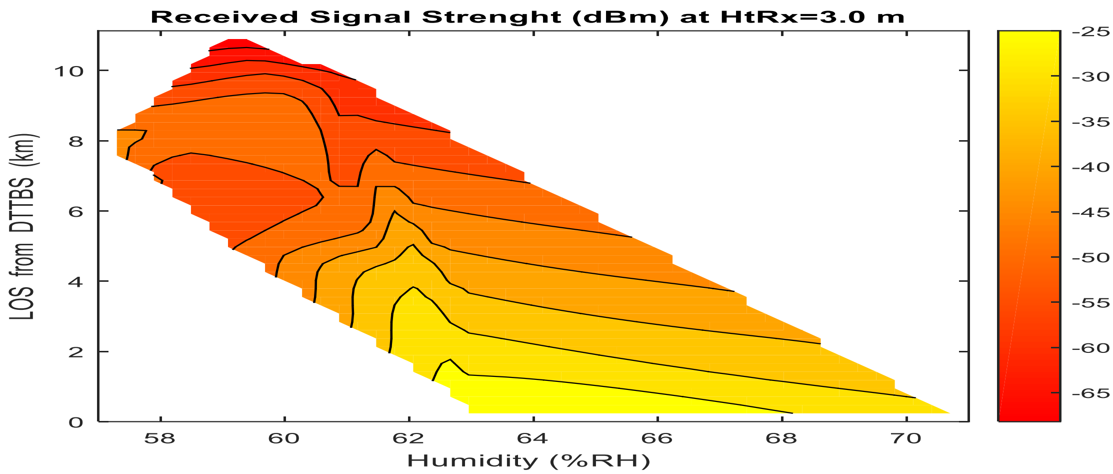

Figure 4: Effect of Humidity on RSS in Katsina during Dry Season Months

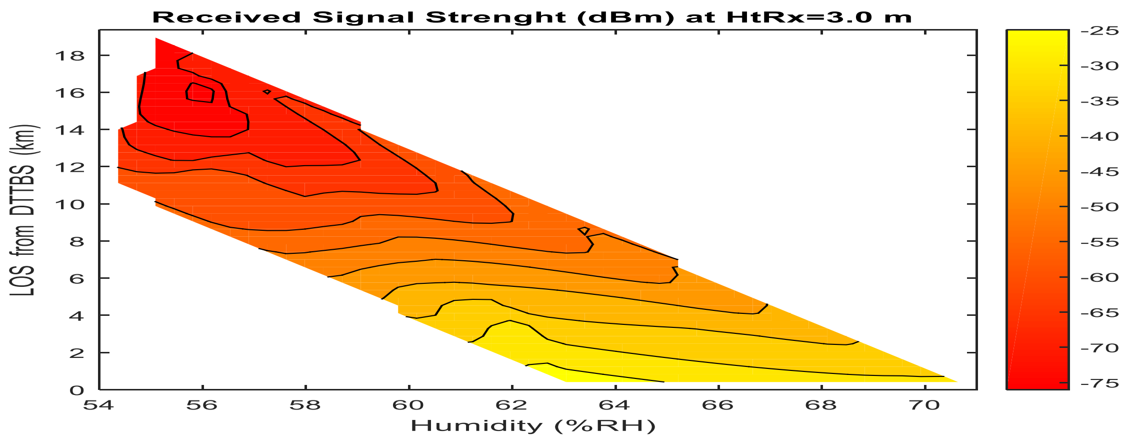

Figure 5: Effect of Humidity on RSS in Katsina during Wet Season Months

Effect of Temperature on RSS

Figures 6 and 7 respectively present typical relationship between temperature and RSS with respect to LOS separation distance from DTTBS during dry and wet season months. It was also observed particularly at distances closer to the transmitter base that, as temperature increases, RSS decreases irrespective of the routes and seasons. This again could be attributed to the near field effect of the DTTV signal and may not necessarily mean that lower temperature enhances RSS. Though for the discrete method of data collection adopted in this work, it can be said that as temperature increases, RSS reduces. Mean values of **33.37and 31.54℃** were recorded for dry and wet season months respectively.

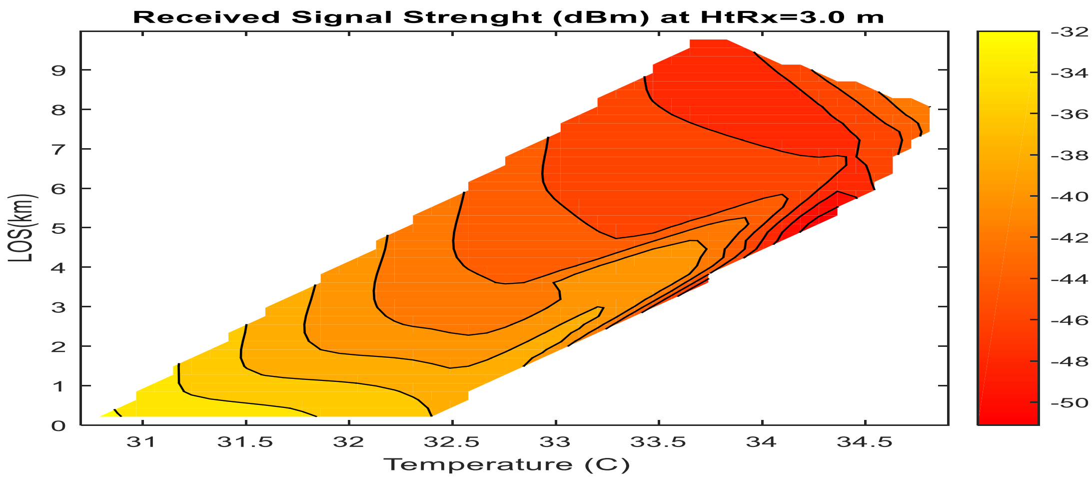

Figure 6: Effect of Temperature on RSS in Katsina during Dry Season Months

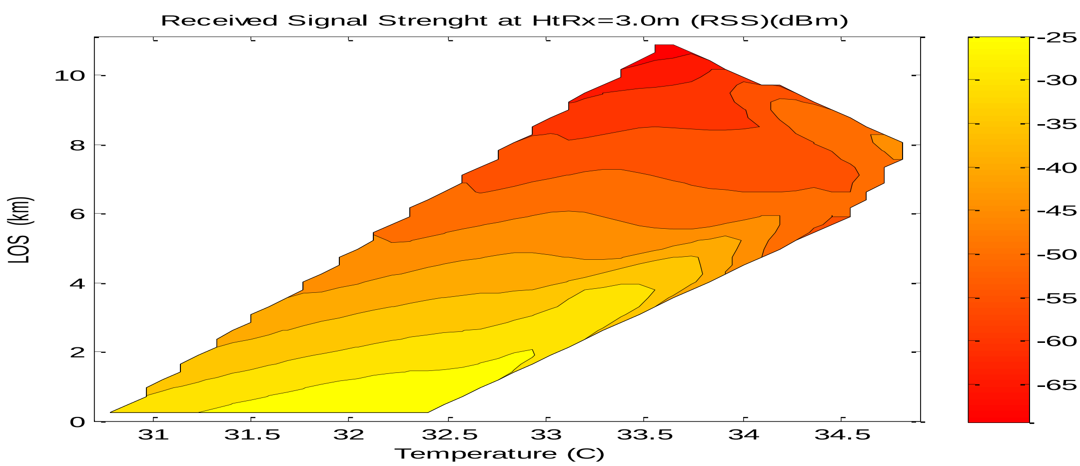

Figure 7: Effect of Temperature on RSS in Katsina during Wet Season Months

Effect of Atmospheric Pressure on RSS

Figures 8 and 9 present the typical effect of atmospheric pressure on RSS during dry and wet season months respectively in Katsina. As observed from the figures, especially within 0-5 km LOS from base station, better signal strengths were obtained between the pressure range of 940 and 950 hPa. However, as LOS increases and air pressure increases, the signal degrades in strength especially at the far field. It is clearly shown from this study that Mean pressure values of **951.92** and **949.61 hPa** were obtained during dry and wet season months' respectively.

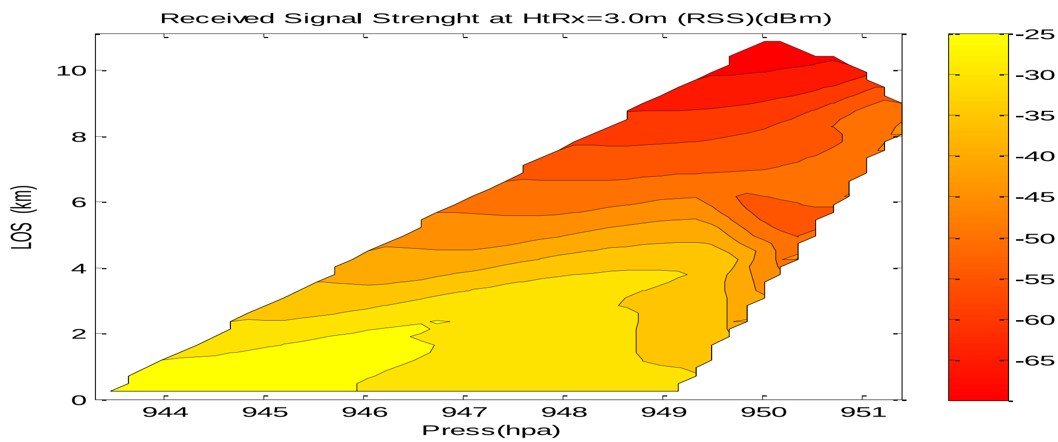

Figure 8: Effect of Pressure on RSS in Katsina during Dry Season Months

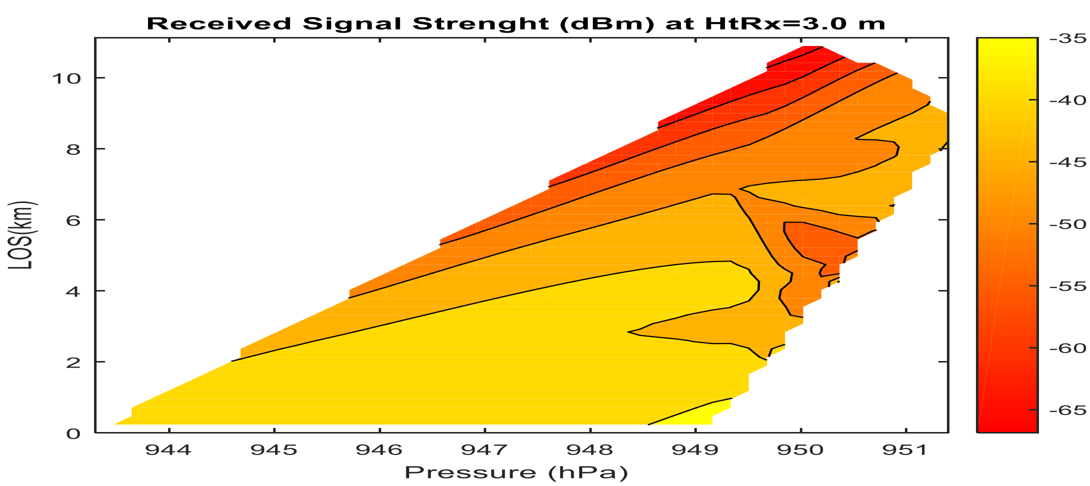

Figure 9: Effect of Pressure on RSS in Katsina during Wet Season Months

CONCLUSION

From the results; lower signal strengths were received at higher values of surface radio refractivity (N_s) irrespective of the seasons. The lower the surface radio refractivity, the better the signal strength recorded. Higher mean value of N_s, was deduced during wet compared to dry season months with statistical correlation coefficients of **-0.51 and -0.57** obtained between N_s and RSS during dry and wet season months respectively. The implication is that digital terrestrial television will encounter more attenuation due to surface radio refractivity, N_s, during wet compared to dry season months. In addition, mean values of **301.20** and **358.50** (N-units) were obtained during dry and wet season months respectively. Findings also show that; the higher the atmospheric pressure (especially at the far field) the lower the RSS. Mean values of **951.92** and **949.61 hPa** were obtained during dry and wet season months respectively. In addition, the higher the humidity the higher the signal strength especially at distances closer to the transmitter, this may be attributed to the near field effect. The other possibility is that, when humidity is low, air moisture reduces which may lead to enhanced activity of few aerosols such as dust and haze resulting to attenuation of signal through absorption and scattering of transmitted signal. Mean humidity values of **32.35** and **77.93 % RH** were obtained during dry and wet season months respectively. Furthermore, as temperature increases, RSS decreases in strength irrespective of the routes and seasons, this again could be attributed to the near field effect. Mean values of **33.37 and 31.54℃** were recorded for dry and wet season months respectively. The overall effect of pressure, temperature and humidity on RSS is better understood using the correlation coefficient obtained between RSS and surface radio refractivity since the latter is derived from the parameters. This study therefore reveals that the specified radio climatic factors have attenuation effect on UHF signal and should be put into consideration when planning link's design and power budget over the study area. The attenuation effect could be attributed to refraction effect of surface radio refractivity with absorption and scattering effects traceable to the specified radio climatic factors.

RECOMMENDATION

The management of the DTTBS and other similar service providers should make deliberate efforts at compensating for signal losses resulting from the effect of the specified radio climatic factors especially during wet season so as to prevent coverage failure and ensure QoS on the UHF band over the study area.

Suggestion for further work

Further study that will critically look at the effect of humidity, precipitation and temperature on UHF radio signal using a location-based stationary method of data collection is suggested.

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