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The Influences of Meteorological Parameters on Digital Terrestrial Television (DTT) Signal in the Tropics

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ABSTRACT

The medium of propagation for Digital Terrestrial Television (DTT) is the troposphere, where most weather phenomena occur. Thus the need to study the effect of meteorological parameters on DTT signal has become necessary in Nigeria now that DTT will soon replace the existing analog transmission. This study therefore investigates the influences of meteorological parameters of temperature, atmospheric pressure, humidity, amount of rainfall or precipitation. Also investigated, is the influence of surface radio refractivity on the Received Signal Strength (RSS) of a Digital Terrestrial Broadcast Station (DTTBS) in Akure metropolis, South West Nigeria. The Received Signal Strength (RSS) of the base station was measured at intervals of 1km along three selected routes around the station using a digital Satlink signal meter model WS-6936 with a DTT UHF receiving antenna connected. A GPS receiver (Garmin Map 78s) was used to monitor the line of sight with the station as reference and was equally used to log data geographic coordinates and heights. For the measurement of meteorological parameters of data locations, a USB Mobile Weather Station model N96FY was used whereas the surface refractivity values were calculated using the atmospheric parameters obtained. Data were collected during dry and wet seasons for comparative studies. Two sets of Signal Strength values were obtained corresponding to two receiver antenna heights of 1.5 m and 3.0 m. Analyses were carried out on the obtained data using necessary soft ware. Result showed that higher values of surface refractivity degrade DTT signal while lower values enhance it. This was observed for both dry and wet seasons, though higher average value of surface refractivity was recorded during wet seasons compared to the dry seasons, meaning that DTT signal surfers' more attenuation effect of surface refractivity during the rainy season compared to dry seasons. A correlation coefficient of **-0.26** was determined for DTT Signal and RSS. In addition, the higher the rainfall or precipitation values the lower the signal strength recorded and vice versa. A high negative correlation coefficient of **-0.80** and **-0.82** were determined between precipitation and Received Signal Strength (RSS) for both dry and wet seasons respectively. Result further revealed that higher values of humidity do not necessarily lead to attenuation of DTT signal rather lower values enhance its attenuation. Furthermore as atmospheric pressure increases, RSS decreases even at the near field this was the trend for both seasons, in other words, high atmospheric pressure attenuates DTT Signal. However, the effect of temperature was found to be insignificant on DTT signal.

KEY WORDS

Meteorological parameters, surface refractivity, Digital Terrestrial Television (DTT), Received Signal Strength (RSS) and Correlation Coefficient

1. INTRODUCTION

Over the years, terrestrial television broadcasting has been on the analogue transmission and reception technology until the last few years that Digital Terrestrial Television (DTT) technology was proposed by the International Telecommunications Union (ITU). This was due to the quest to maximize the UHF band by releasing the upper UHF for other services and still ensure access to quality of service. The medium of propagation for both analogue and digital terrestrial television is the troposphere, where most weather phenomena occur [1].

It has therefore become expedient to carry out researches on the influence of key meteorological parameters in the troposphere on digital terrestrial television signal strength. No comprehensive work had been done on weather effects on digital terrestrial television signal in Nigeria. This may be tolerated in analogue television broadcasting; however, this cannot be tolerated on Digital Terrestrial Television (DTT) which is already in place in few places and will soon replace the existing analogue terrestrial broadcasting all over Nigeria.

This work was conceived to investigate the variability in the values of the received signal strength of DTT signal and the possible influence of meteorological parameters in the troposphere on the signal using some Nigerian Cities in different climatic zones as case studies. The report for Akure, a sub urban city in the tropical rain forest of Nigeria is presented in this work. This work is apt now so as to come out with noble results that will enhance the Quality of Service (QoS) of the few existing DTT networks in Nigeria and to guide in the establishment of new Digital Terrestrial Base Station (DTTBS) network across the Country now that Nigeria will soon switch over fully from analogue to digital terrestrial television transmission.

Television broadcasting is a key factor in the socio-economic development of any developing nation, especially in Nigeria due to its educative, entertaining, and informative and research oriented programs [2].

1.1 Theoretical background

All terrestrial analogue television stations in Nigeria transmit on the very high frequency (30-300 MHz) and the lower part of the ultra-high frequency (460-790 MHz) bands. The mode of propagation in these bands is by direct wave (line of sight) and the medium is through the troposphere.

The troposphere is the lowest part of the atmosphere whose average height ranges from 0-20 km in the tropics, 0-17 km in the mid latitude and 0-7km in the polar region above the surface of the earth [3]. Most weather phenomena occur in the troposphere, which makes the study of its effect on terrestrial television broadcast of great interest to radio scientists and engineers. The propagation of VHF and UHF signals is by space wave in the troposphere. VHF and UHF signal travel on line of sight from the transmitting antenna to its destination and thus are affected by weather parameters, terrain and terrestrial objects [4] Figure 1, presents the diagram of the atmosphere showing the troposphere and other layers.

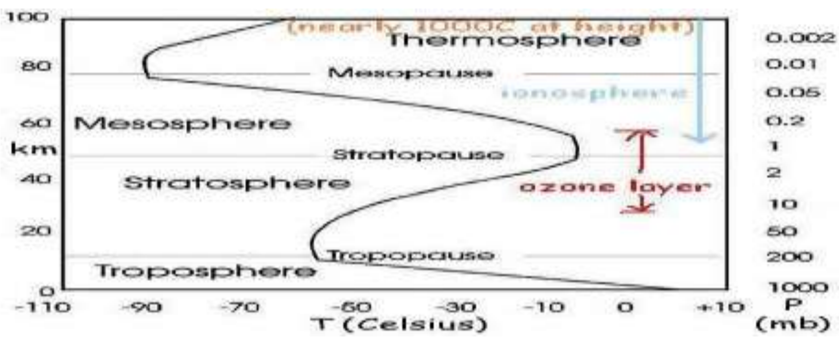

Fig. 1: Structure of the atmosphere showing different layers with their corresponding pressure levels and temperature values.

1.1.1 Meteorological Parameters, Surface Radio Refractivity and Radio Signal

Meteorological Parameters are described and quantified by the variables of earth's atmosphere in terms of temperature, air pressure, water vapor or humidity and mass flow. Weather is the state of the atmosphere at any given point in time, to the degree of hotness or coldness, wet or dry, calm or stormy, clear or cloudy. Most weather phenomena occur in the lowest level of the atmosphere which is the troposphere.

The refractive index of the troposphere is an important factor at predicting performance of terrestrial radio links. 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 [4]

Radio refractivity N is a measure of deviation of refractive index n of air from unity which is scaled up in parts per million to obtain more amenable figures. Thus N is a dimensionless quantity defined and measured in N units. N is given by the relations below;

$$N = (n - 1) \times 10^6 \qquad (1)$$

where N depends on meteorological parameters of pressure P (hPa), temperature T (K) and water vapour pressure, e (hPa) as presented in (2)

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

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

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

where e_s = maximum (or saturated) vapour pressure at the given air temperature, t (℃)

Generally, P and e decrease rapidly with height whereas T decreases slowly with height. [4, 5]

Surface radio refractivity N_s, has a high correlation with radio field strength values while the surface refractivity gradient which depends on N_s, determines the refractivity condition of the atmosphere which may result in a normal, sub-refractive, super refractive or ducting layer, each of which has important influences on propagation of VHF, UHF and microwaves in the atmosphere. [4, 6]

1.2. Study Areas and the Experimental Station

A Digital Terrestrial Broadcast Station (DTTBS) belonging to the NTA-Star Times Station in Akure, in the tropical rainforest zone of Nigeria was chosen as a case study for this climatic zone. Akure is the Capital City of Ondo State with about 500,000 people [7] residing within the metropolis comprising of Akure South and Akure North Local Council Areas. Table 1 indicates the details about the DTTBS.

Table 1: Transmission Characteristic of the experimental DTTBS Station

S/N	Parameter	Value /definition
1	Base station's location	Lat. 7°15' 08" N, Long. 5°07' 53" E
2	Base station's transmitted power (kW)	2.50
3	Base station's frequency(MHz)/ Channel	722/ 52
4	Height of transmitting mast AGL (m)	250
5	Height of receiving antenna (m)	1.5, and 3.0 (Variable)

2 INSTRUMENTATION AND METHODS

2.1 Instrumentation

A digital Satlink WS-6936 model field strength meter (Figure 3) was used for the DTT signal strength measurement by connecting the terrestrial input signal received by the Star Times DTT UHF receiving antenna attached to a variable antenna stand (Figure 2). Whereas a Global Positioning System receiver (GPS Map 78s personal navigator) was used for the measurement of elevation, geographic coordinates and the line of sight of the various data locations from the base station. Also, a USB wireless mobile weather forecaster model N96FY (Figure 4) was used to measure the meteorological parameters of Temperature, Pressure and Humidity. Others are Rainfall or Precipitation, Wind Speed and the time of measurement corresponding to each data locations along the selected routes around the base station. A field vehicle was used for the field campaign along the routes of measurement

2.2 Data Collection and Handling

Measurement of the Received Signal Strength (RSS) of the Digital Terrestrial Television Base Station, (DTBBS) in Oke Isikan Akure, was carried out radially from the base Station along three different routes in the State using a Star Times DTT receiving antenna connected to a digital Satlink WS-6936 signal meter. Two sets of data were obtained for the RSS at two antenna receiver heights of 1.5 m and 3.0 m for each datum location. This is to give room for comparison in the strength of signal received for the two heights. The station's transmitting antenna was logged and used as the reference point by the GPS receiver for all the routes. The line of sight from the base station was monitored during the drive using the GPS, which equally measures the location's longitude, latitude, and the elevation. A USB wireless mobile weather forecaster model N96FY was used for the measurement of the surface weather parameters of Temperature, Pressure, Humidity, Wind Speed, and Precipitation of data points. A field vehicle was used as a means of movement along the routes during the field work. The research crew usually stops at an interval of 1km Line of Sight (LoS) for measurement to be taken and at each point of data collection, all the equipment would be set for the readings to be taken. The exercise usually takes about 20minutes for each point before moving to another point (usually 1 km LoS). About sixteen data points were taken for each of the three radial routes around the transmitter. Detail of the routes categorization is as presented in Table 2.1. Data were collected for both dry and wet seasons for comparative studies in the study area.

In summary, the Received Signal Strength (RSS) values, geographic coordinates, elevation above ground level as well as the line of sight of the various data locations were recorded. Also recorded were the meteorological parameters of Temperature, Pressure, Humidity, wind speed, and rainfall or precipitation for necessary analysis. Transmission parameters of the (DTBBS) were relatively constant throughout the period of measurement as confirmed by the records of transmission in the station. Figure 5 captures a scene of data measurement in action.

Table 2.1: Route definition for the field work

Route	Direction/ Definition
A	DTTBS in Akure towards Arakale-Oda Town (0-15 km LoS)
B	DTTBS in Akure towards - Igoba- Ita Ogbolu (0-15 km LoS)
C	DTTBS in Akure towards – Ilaramokin - Igbara Oke (0-12 km LoS)


Fig.2: Star times DTT UHF receiving antenna used for reception

Fig.3: Digital Satlink Signal Strength Meter

Fig.4a: Weather station model N96FY

Fig.4b: USB Mobile Weather console or receiver

Fig.5: RSS measurement at 3.0m receiver antenna height

3.0 RESULTS AND DISCUSSIONS

Determination of the effect of radio climatic factors on broadcasting signal is a fundamental task at predicting coverage areas and television network. [2, 8]. This section discusses the influences of meteorological parameters on the signal strength of terrestrial digital television.

3.1 Influences of primary Meteorological Parameters on DTT Signal during dry seasons

In this sub section, the possible effect of meteorological parameters of Temperature, Atmospheric Pressure, Humidity and rainfall or precipitation on DTT RSS were analyzed using Mat lab software. Also analyzed using the same software is the possible influence of Surface Radio Refractivity N, (a key factor in radio communication) on the DTT RSS. This quantity was derived using the values of temperature, atmospheric pressure and humidity as expressed in equations (1, 3). Each parameter was analyzed for two received signal strength when using 1.5m and 3.0 m receiver antenna heights (RxHt) along the routes of measurement for both dry and wet seasons of data collection. The results obtained for routes A, B and C for a particular season are similar, so one similar route from each season had been selected for the purpose of results and discussions as presented below.

3.1.1 Influence of humidity on the received DTT Signal Strength

Figures 6a and 6b depict the relationship between humidity and RSS with respect to line of sight. It is observed that at higher values of humidity and at the near field of the DTT transmitter; RSS is at the highest values for this route. High humidity does not lead to significant attenuation of the signal. However, at the far field, (around 6-14 km LoS from DTTBS), the signal depreciated. On the other hand, it was observed, that, at lower values of humidity even at the near field, the signal received was poor. This implies that lower humidity enhances attenuation of signal. This is possible, because at lower humidity, the atmosphere (air) becomes drier leading to enhanced activities of the particles in the air. These particles are responsible for attenuation of signal through scattering and absorption leading to reduced signal strength.

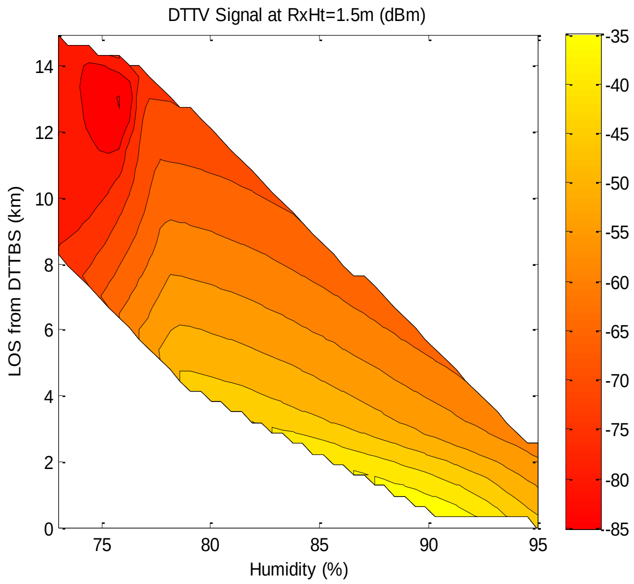

Fig.6a: Influence of humidity on the received DTT signal with respect to LoS from DTTBS at RxHt=1.5 m

Key: Digital Terrestrial Television (DTT)

Digital Terrestrial Television Base Station (DTTBS)

Line of Sight (LoS)

Antenna Receiver Height (RxHt)

Received Signal Strength (RSS)

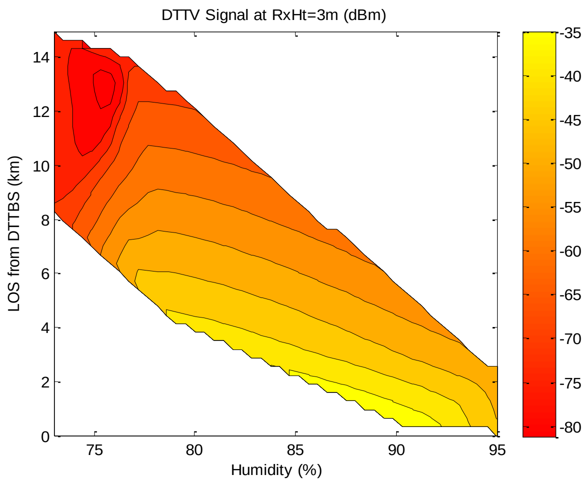

Fig.6b: Influence of humidity on the received DTTV signal with respect to LOS from DTTBS at RxHt=3.0 m

3.1.2 Influence of Surface Temperature

Figures 7a and 7b describe the influence of temperature on RSS. As temperature increases signal strength decreases. This could be possibly explained that as temperature increases, air depth also increases. This is similar to the effect of line of sight.

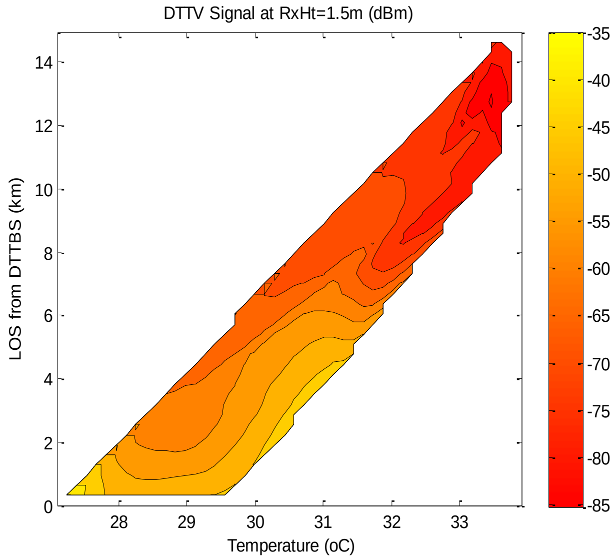

Fig. 7a: Influence of temperature on DTT signal with respect to LoS from DTTBS at RxHt=1.5 m

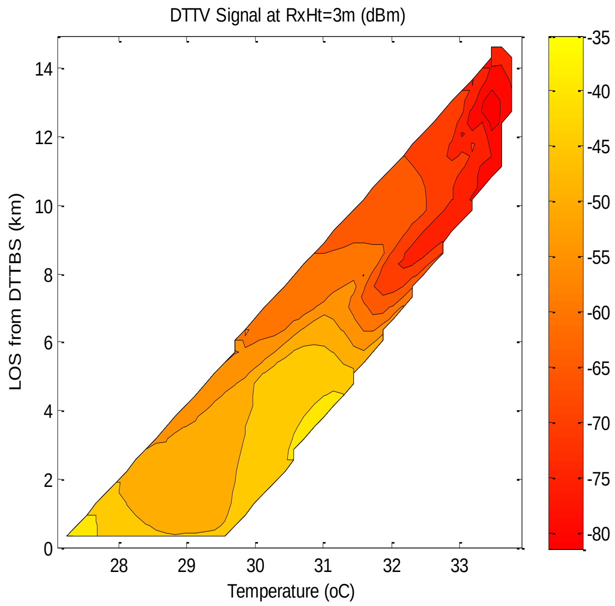

Fig. 7b: Influence of temperature on DTT signal with respect to LoS from DTTBS at RxHt=3.0 m

3.1.3 Influence of Atmospheric pressure

Atmospheric pressure as observed in figures 8a and 8b does not have a negative influence on the signal especially at the near field. At the near field (0-5 km) and within the pressure range of 962 kPa and 967.5 kPa, RSS was strongest. However, as LOS increases and air pressure increases, the signal surfers' degradation majorly due to inverse square law and the increase in atmospheric pressure also supports the degradation.

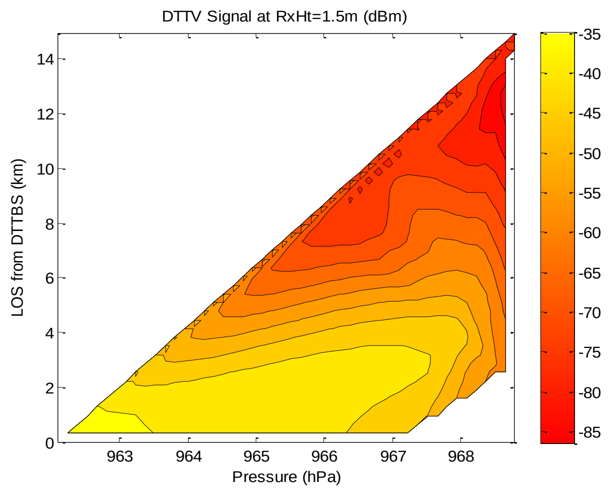

Fig. 8a: Influence of atmospheric pressure on DTT signal with respect to LOS from DTTBS at RxHt=3.0 m

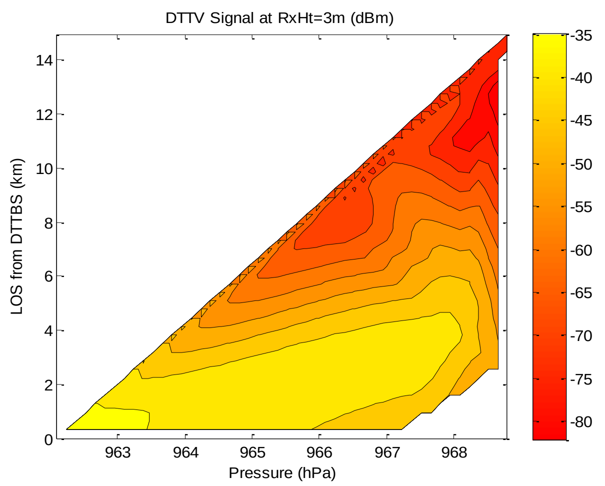

Fig. 8b: Influence of atmospheric pressure on DTT signal with respect to LoS from DTTBS at RxHt=3.0 m

3.1.4 Influence of precipitation

Influence of rainfall on DTTV signal as observed from figures 9a and 9b shows that better signal strenghts were recorded at lower values compared to higher values for both receiving antenna heights of 1.5m and 3.0m. The implication of this is that, precipitation has a negative influence on DTT signal strenght which is possible through absorption and scattering effects on signal strength.

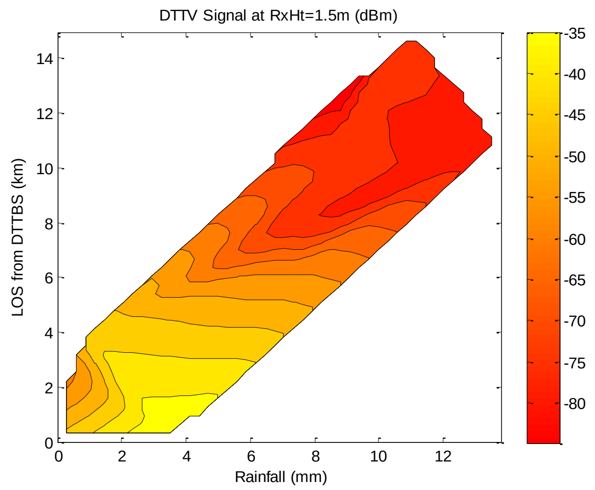

Fig.9a: Influence of precipitation on DTT signal at receiving antenna height of 1.5 m

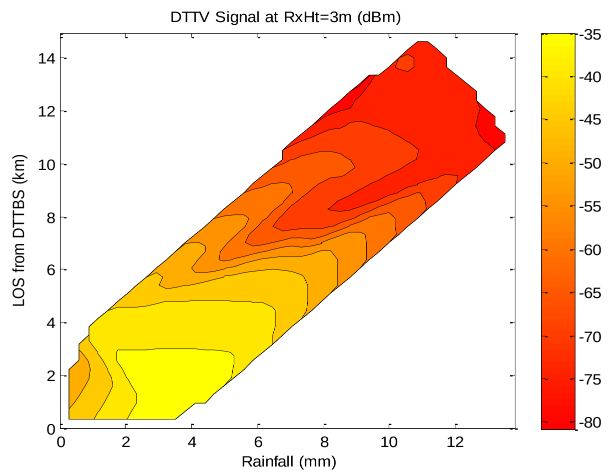

Fig.9b: Influence of Rainfall on DTT signal at receiving antenna height of 3.0 m

3.2 Influence of Surface Refractivity on DTT Received Signal Strength (RSS) for Route A, During Dry Seasons

The influence of surface radio refractivity derived from measured data in the study locations are depicted in figures 10a and 10b respectively for the two antenna heights under consideration. The figures clearly reveal the significant influence of surface refractivity on the received DTT signal. At higher values of N_s, between 396 to 405 N-units even at the near field of the signal (0-3.5 km) where a good signal is expected to be received, the signal strength measured was poor compared to the signal strength recorded within the same distance (0-3.5 km) at lower refractivity values (385-395 N/units). Thus, this study clearly reveals that increase in the values of surface refractivity N, (above 395 N-units) of the atmosphere in this region- the tropical rain forest of Nigeria leads to attenuation of DTT signal. Secondly, better range of signal (–35 dBm to –40 dBm) was recorded till about 4.5 km line of sight from the station at a higher receiving antenna height of 3m compared to the same signal strength range that was recorded till about 2.5 km line of sight at receiving antenna height of 1.5 km.

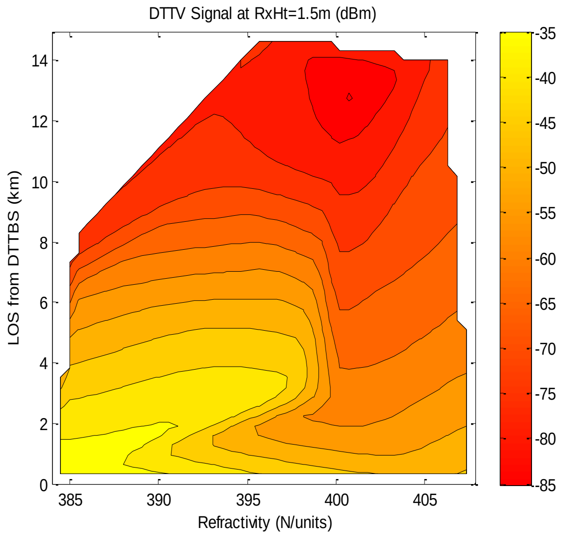

Fig.10a: Relationship between surface refractivity and DTT signal at receiving antenna height of 1.5 m

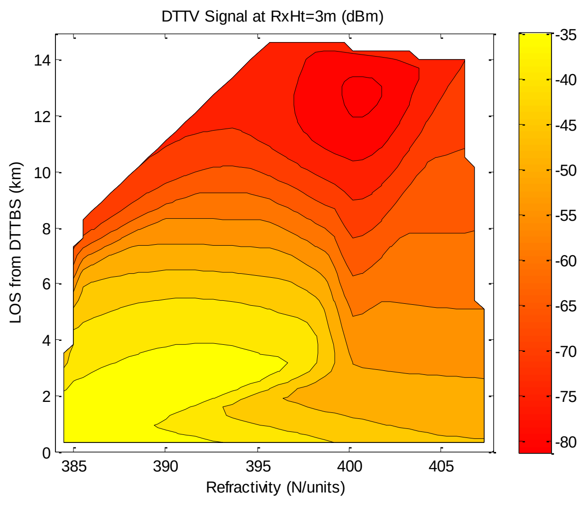

Fig.10b: Relationship between surface refractivity and DTT signal at receiving antenna height of 3.0 m

3.3 Influences of Meteorological Parameters on Received Signal Strength (RSS) during Wet Seasons

3.3.1 Influence of Humidity

From figures 11a and 11b, it is observed that higher values of humidity enhance RSS as it was observed during the dry period. On the other hand, it was observed, that, at lower values of humidity even at the near field, the signal received was poor. By implication, lower humidity enhances attenuation of signal. This is possible, because at lower humidity, the atmosphere (air) becomes drier leading to enhanced activities of the particles in the air. These particles are responsible for attenuation of signal through scattering and absorption leading to reduced RSS [9].

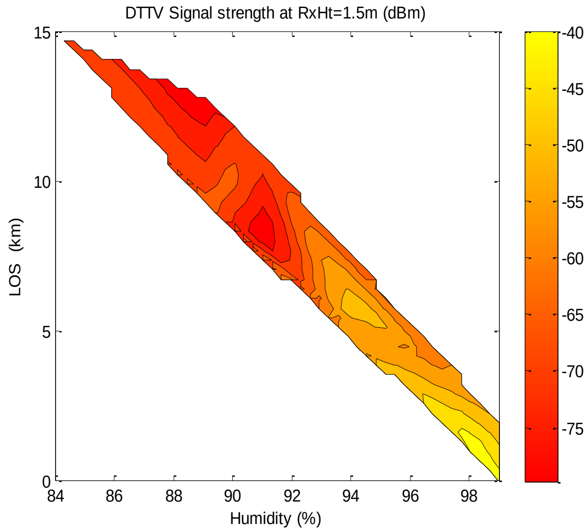

Fig. 11a: Relationship between humidity and signal strength received at receiving antenna height of 1.5 m

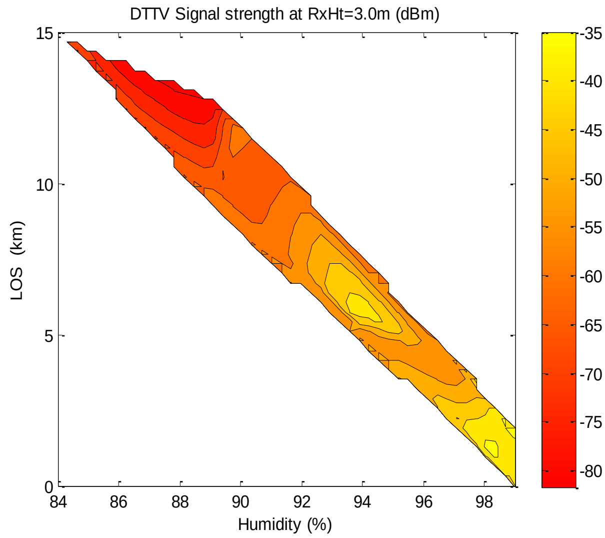

Fig. 11b: Relationship between humidity and signal strength received at receiving antenna height of 3.0 m

3.3.2 Influence of Temperature on DTT signal

From figures 12a and 12b, as temperature increases signal strength decreases. This could be possibly explained that as temperature increases, air depth also increases, meaning that the signal would have to travel longer distances, thereby leading to reduced signal strength.

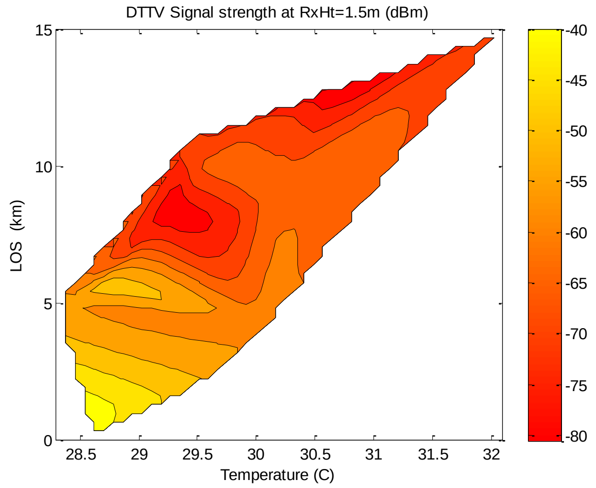

Fig.12a: Relationship between temperature and RSS at receiving antenna height of 1.5 m

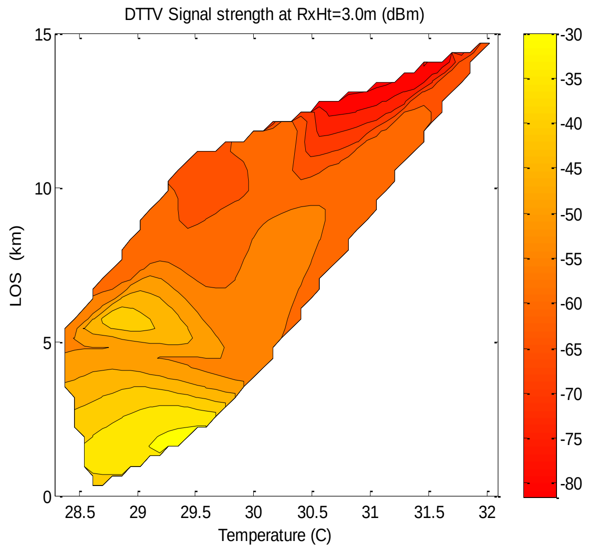

Fig. 12b: Relationship between temperature and RSS at receiving antenna height of 3.0 m

3.3.3 Influence of Atmospheric Pressure

Atmospheric pressure as observed in figures 13a and 13b seems not to have a negative influence on the signal especially at the near field. Lower atmospheric pressure is a friend to good signal reception while higher value is a foe as observed in the figures.

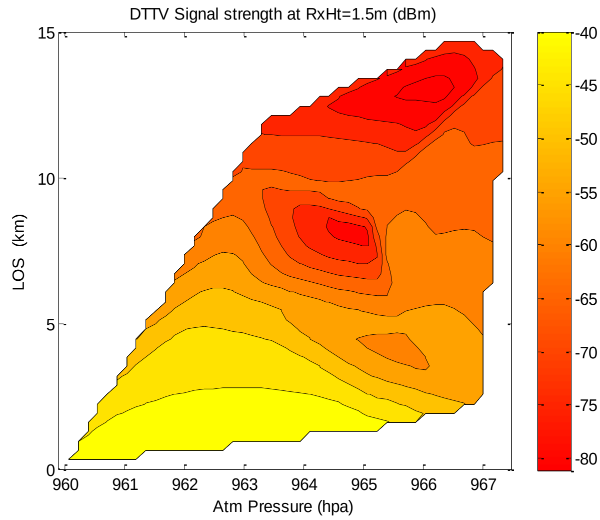

Fig. 13a: Relationship between atmospheric pressure and RSS at receiving antenna height of 1.5 m

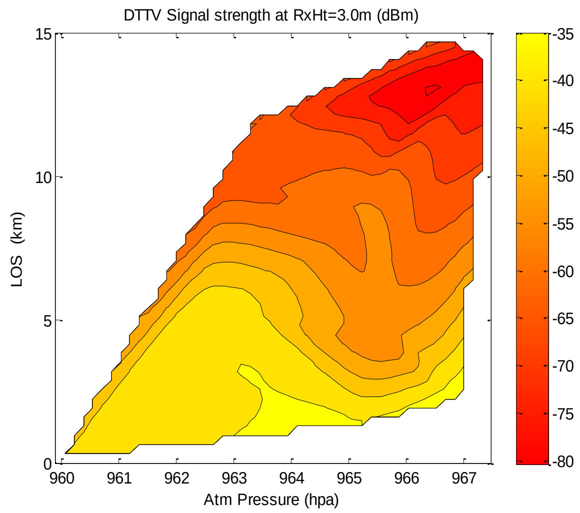

Fig. 13b: Relationship between atmospheric pressure and RSS at receiving antenna height of 3.0 m

3.3.4 Influence of rainfall or Precipitation

Figures 14a and 14b clearly show the relationship between precipitation and RSS. At lower values, better signal strenghts were recorded compared to higher values for both receiving antenna heights of 1.5m and 3.0m. This is understood as precipitation is a major attenuation factor in radio communications especially at high frequencies [6, 10, 11].

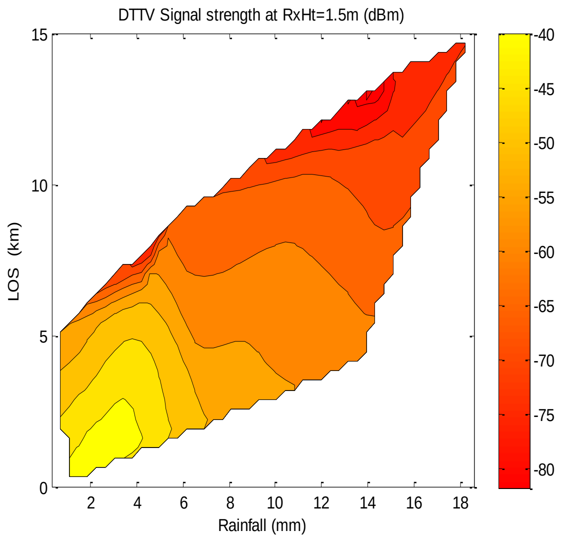

Fig. 14a: Relationship between precipitation and signal strength received at receiving antenna height of 1.5 m

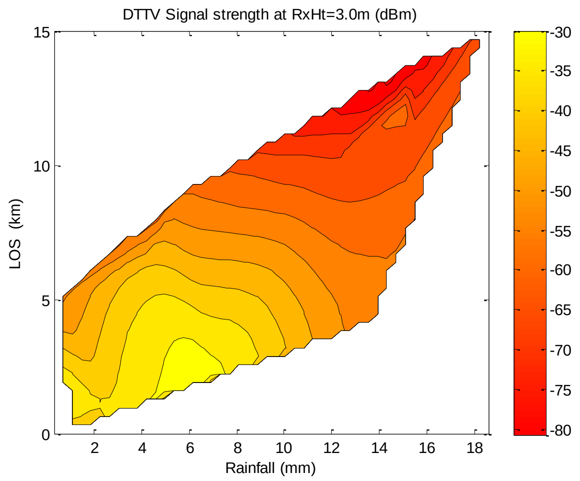

Fig. 14b: Relationship between precipitation and signal strength received at receiving antenna height of 3.0 m

3.4 The influence of Surface Radio Refractivity on Received Signal Strength (RSS) during the Rainy Season.

The influence of surface radio refractivity derived from measured data in the study locations are depicted in figures 15a and 15b respectively for the two antenna heights under consideration. It is clearly revealed from these figures that the higher the values of refractivity 415 N-units and above, even at the near field of around 0-2.5 km the signal recorded was poor. This further shows that higher refractivity values attenuate DTTV signals as experienced during the dry seasons. Another observation is that average refractivity value of 404.65 N-units recorded during this rainy season is higher than that of dry season- which is 395.93. Thus the attenuation effect of refractivity during this season is slightly higher than that of the dry seasons.

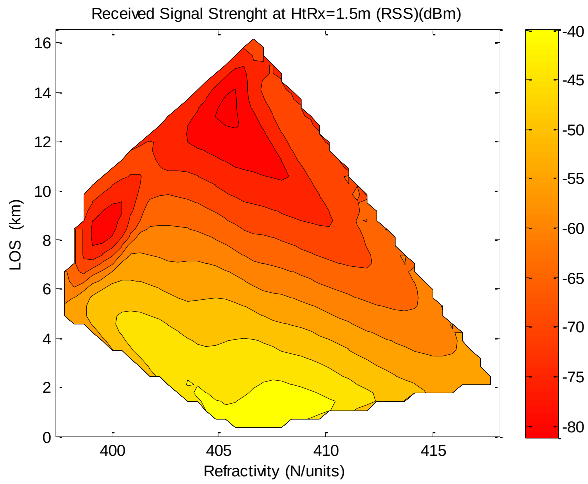

Fig. 15a: Relationship between surface refractivity and RSS at receiving antenna height of 1.5 m for wet season

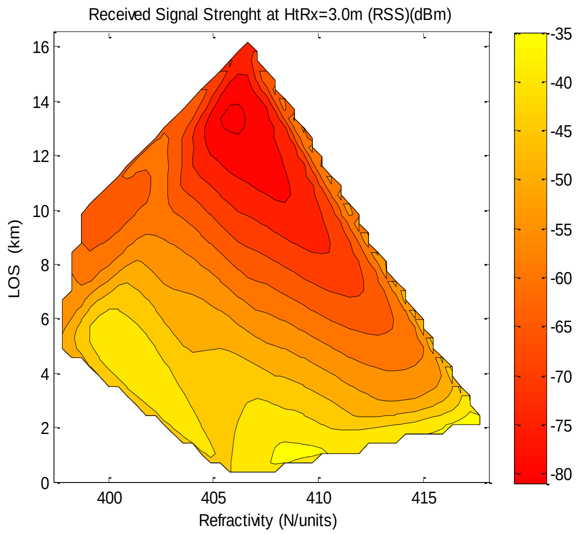

Fig. 15b: Relationship between surface refractivity and RSS at receiving antenna height of 3.0 m for wet season

4.0 CONCLUSION

This study has successfully investigated the influences of both primary (temperature, humidity, atmospheric pressure and rainfall or precipitation) and secondary (Surface Radio Refractivity, N_s,) radio meteorological factors on DTT signal for two major seasons within Akure metropolis, South West, Nigeria. Some of the major findings are presented below;

The work reveals the significant influence of Surface Radio Refractivity, N_s on DTT RSS for the two seasons. Higher , N_s value, promotes attenuation of signal even at the near field as deduced from figures 10a, 10b, 15a and 15b. Average values of **395.93 N-units** and **404.63 N-units** were recorded for dry season and wet season respectively. The implication is that DTT signal surfers more attenuation due to refractivity influence during the rainy season compared to dry seasons. Although, a low negative correlation coefficient of **-0.26** was determined between RSS and N_s, the effect is significant. Also the higher the rainfall or precipitation values, the lower the signal strength recorded. A high negative correlation coefficient of **-0.82** and **-0.80** were determined between precipitation values and Received Signal Strength (RSS) for both dry and wet seasons respectively. This clearly reveals that as the values of rainfall or precipitation increases, RSS decreases and vice versa. Furthermore, the Influence of humidity on RSS was also determined. Higher values of humidity do not necessarily lead to attenuation of DTT signal rather lower values enhance attenuation.. In addition, as atmospheric pressure increases, RSS decreases even at the near field for both seasons under consideration. In other words, high atmospheric pressure attenuates DTT Signal. The overall result of this study will be useful for DTT subscribers in the study areas and other similar cities in the tropics who are encouraged to mount receiving antenna height of not less than 3 m for them to enjoy Quality of Reception (QoR) especially during the rainy seasons and at distances beyond 8 km from DTTBS (the fringe coverage range). Whereas it will serve as a guide for DTT Service providers in the choice of their transmission parameters especially the output power at ensuring QoS at all seasons in the study areas to minimize coverage failures. Finally, these findings will be of great assistance to the government in policy making with regards to DTT industry in the study areas. Further studies are recommended in which the authors have taken up as a task.

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