Modeling digital terrestrial television signal strength with atmospheric parameters and noise temperature: a case study of North-Central Nigeria

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Abstract. The modeling of DTTV signal strength (AIT, NTA, ETV and Channels TV) in Abuja and Unity TV, Jos, Plateau State, with atmospheric parameters (temperature, pressure, relative humidity, wind speed and rainfall) as well as noise temperature, from April 2019 to December 2020 have been carried out using the atmospheric parameters measured with an automatic weather station and noise temperature measured with a non-contact infra-red thermometer, with TV signal strength measured with a CATV signal strength meter from 5.00 am – 9.00 pm daily, at 30 minutes interval. The results show that atmospheric temperature (58%), noise temperature (60%) and atmospheric pressure (100%) affect the Received Signal Strength (RSS) negatively, while the wind speed (60%), relative humidity (80%), and rainfall (100%) affect the signal strength positively. The RSS measured in Jos on altitude 1,400m was higher than that in Abuja on altitude 470m which may likely be due to an increase in altitude resulting in a decrease in atmospheric pressure and air density which implies less signal attenuation. It can be inferred that atmospheric parameters and noise temperature have a great impact on the RSS in the study areas. Consequently, the higher signal received in the rainy season compared to the dry season may be due to less dust in the atmosphere as well as the enhanced digitalized television signal and its robustness to interference and signal attenuation compared to the analogue signal. The developed models have low RMSE values; hence will be able to predict the influence of atmospheric parameters on TV RSS in the areas. Generally, the result will be useful to the Nigeria Broadcasting Commission to improve the quality of the signal transmission of digital television broadcasting for the future digital switchover in other parts of the country especially on the choice of antennas on their transmitters. The findings will also be useful to spectrum users such as mobile telecommunication, wireless internet, and radio broadcasting in managing and improving the quality of their services.

Keywords: Altitude, Attenuation, Digital Television, Pressure, Temperature.

1. Introduction

Digital terrestrial television (DTTV) is the type of television broadcasting which makes use of Yagi-Uda antenna to receive television signal from transceiver. The quality of terrestrial television signal received by viewers is of great interest to stakeholders in the world of broadcasting [1] but this quality is also affected by noise in different forms.
external factors such as atmospheric parameters, as the condition of the atmosphere can lead to loss of signal \[3\] as well as alteration of the horizon of radio signal \[4 - 5\].

The geographical locations as well as the topography of the television signal receiver either affect the strength or the quality of the signal reception, thus, according to \[6 - 7\] the higher the locations of the receiver, the better the received signal strength. Abuja and Jos are the only two cities in Nigeria that have been fully digitalized on television broadcasting while other states are in the process of digital switchover. As a result of the dependence of the signal strength on some factors including the atmospheric conditions \[6\] which vary across Nigeria, there is a need to model atmospheric parameters with the received signal strength at these pilot cities (Abuja and Jos). The aim of this study is to assess the relationship between some atmospheric parameters and noise temperature on DTTV signal strength in Abuja and Jos. It will help for the actualization of good quality of signal for the Digital Terrestrial Broadcasting (DTB) in Nigeria by the Nigeria Broadcasting Commission (NBC) across the entire country.

2. Materials and Method

Abuja is located between latitude 8.25° and 9.20° N, and longitude 6.45° and 7.39° E, and at an altitude of about 470 m above sea level. It has Guinea Savanna vegetation, with a rainy season from April to September and the dry season from October to March, with annual rainfall of about 1,389 mm. The average monthly temperature is between 23.9 – 25.7° C. Jos lies between latitude 8.92° and 10.18° N, and longitude 8.35° and 9.50° E and at an altitude of about 1400 m above sea level. It has Guinea Savanna vegetation, with a rainy season from April to September and the dry season from October to March. It has an annual rainfall of about 1,324 mm and an average monthly temperature range of 21 – 25° C. Jos has Guinea Savanna vegetation. The two locations were chosen because they are the only locations that have been fully digitalized Television broadcasting in Nigeria.

The experimental set-ups in both Abuja and Jos consist of an automatic weather station, CATV signal strength meters, a non-contact infrared thermometer, and Yagi-Uda antennas as the only antenna for terrestrial TV signal reception. The automatic weather station measures all the selected atmospheric parameters, the CATV signal meter measures the RSS, and the non-contact infrared thermometer measures the noise temperature from the antenna. The selected TV stations are African Independent Television, Abuja (AIT-535.2 MHz), Nigeria Television Authority, Abuja (NTA-567.25 MHz), Channels television, Abuja (Channels - 615.25 MHz) and Entertainment Television, South Africa (ETV - 564 MHz) in Abuja while the signal strength of Unity TV (786 MHz) was measured in Jos, and at the same time with that of Abuja. Measurements were recorded every 30 minutes from 5.00 am till 9.00pm daily from April 2019 to December 2020. The direction of the Yagi-uda antennas in both Abuja and Jos, remained fixed throughout the study period. Continuous routines were carried out every three (3) months to replace the battery and other necessary cleanings. Each measurement was averaged daily for all the months. Regression analysis was used to develop some models (equations) for each television channel using each of the atmospheric parameters and noise temperature with RSS of each station, which can be used to determine the influence of that component on the RSS of the television channels in the study areas at any time.

3. Results and Discussion

Figures 1(a -e) show the plots for the 2-year averaged monthly RSS of the television stations. Generally, the results show that the signal strengths of the five stations varied monthly, and were higher in a rainy season than in the dry season.

Year 2019 recorded maximum average signal strength of AIT to be 38.33 dBμV in July while the minimum average signal strength of 32.27 dBμV was recorded in November. NTA recorded a maximum and minimum average signal strength of 29.49 dBμV and 27.32 dBμV for the months of July and December respectively. Other stations show a similar trend, although with maximum and minimum values of RSS occurring in different months.

Year 2020 depicted the maximum average signal strength of AIT to be 36.6 dBμV which was recorded in April while August presented minimum average signal strength of 31.88 dBμV. Months of August and November in the case of NTA recorded 28.51 dBμV and 26.9 dBμV as the maximum and minimum signal strength. Other TV stations also show similar monthly variations with maximum and minimum values of RSS occurring in different months.
It was also shown from the results that even in the dry season, the signal strength during the Harmattan period (especially December) in Abuja and Jos was higher than when there was no Harmattan; more so, the RSS in Abuja have lower values than the RSS in Jos.

In order to assess the effects of the measured parameters on the RSS, the average of the data of 2019 and 2020 was taken and the relationship is shown by the regression analysis shown in Figures 2 to 6. The results show that atmospheric parameters, as well as noise or antenna temperature, have effects on the signal strength in the two study areas – Abuja and Jos. Correlation between the atmospheric parameters and the RSS over the 2-year of study is presented in Table 1.
Figure 2: Regression relations between AIT RSS and (a) atmospheric temperature (b) atmospheric pressure (c) relative humidity (d) wind speed (e) noise temperature and (f) rainfall over 2 years.

Figure 3: Regression relations between NTA signal strength and (a) atmospheric temperature (b) atmospheric pressure (c) relative humidity (d) wind speed (e) noise temperature and (f) rainfall over 2 years.
Figure 4: Regression relations between Channels TV signal strength and (a) atmospheric temperature (b) atmospheric pressure (c) relative humidity (d) wind speed (e) noise temperature and (f) rainfall over 2 years.
Figure 5: Regression relations between ETV signal strength and (a) atmospheric temperature (b) atmospheric pressure (c) relative humidity (d) wind speed (e) noise temperature and (f) rainfall over 2 years.
As presented in Table 1; the correlation coefficients have shown that; atmospheric temperature is inversely related with AIT and ETV, but directly related with NTA, Unity TV, and Channels television; thus having 58% (sum of negative coefficients) negative effects on signal strength. Relative Humidity increased with an increase in AIT, Channels TV, and ETV RSS but inversely related with NTA and Unity TV. This means that relative humidity has about 60% positive effect on the signal strengths in the two areas. Since temperature is directly related to Channels TV signals, it is expected that relative humidity will be inversely related to Channels TV signals. This is not so in this case probably because of other factors which might have made the correlation coefficients for channels television to be as low as just 6.4% and 5.5% respectively for temperature and relative humidity respectively. Noise temperature has about 60% negative effect on the signal strength as it has a negative relationship with AIT, Channels TV, and ETV RSS but inversely related with NTA and Unity TV. This means that atmospheric temperature and noise temperatures will to a large extent result to a decrease in signal strength when higher, and vice versa. This might be due to the increase in temperature leading to an increase in the kinetic energy of the particles in the atmosphere, hence the
faster bombarding of the particles with the signals causing refraction or multipath of the signals. This is in confirmation with the work of [9] in which the signal strength observed was found to be inversely related to air temperature and atmospheric pressure. The increase in atmospheric pressure resulted in a decrease in RSS because an increase in pressure causes an increase in air density, and an increase in air density is a result of more particles of gas within a particular area, thus more air particles bombarding the signal resulting in fading. The wind speed, though has positive effects on the signal strengths, its effect is so minimal. Wind speed results in less accumulation of particles in a particular location thereby reducing the air density, enabling the retention of the original power or energy of the signal transmitted. The increase in relative humidity to a large extent affects the signal strength positively because increase it helps to reduce the temperature, which in turn reduces the movement or vibration of atmospheric particles that may have led to signal fading.

In the case of rainfall, unlike many other works in which rainfall was observed to have had negative effects on signal strength, the result of this work has shown that signal strength increases with an increase in rainfall in the study areas. That is why the average maximum signal strength in all the five DTTV stations in the two study locations was observed during the period of a rainy season or lower temperature.

The high signal strength observed in the rainy season might be due to the fact that the television broadcasting is fully digitized as well as less dust particles in the atmosphere, hence the tendency of the good quality signal and robustness to interference and signal attenuation, even during rainfall.

In addition, the signal strength of Unity TV measured in Jos, Plateau state was higher than the signal strength of the four stations (AIT, NTA, Channels, and ETV) measured in Abuja. This can be attributed to the high altitude of Jos, which favors lower pressure and in turn which encourages an increase in signal strength. This higher signal measured in Jos which is at a higher altitude of 1,400 m compared to that of Abuja (470m) is also because higher altitude reduces the range between a satellite in space and line of sight to the transceiver, hence reducing the signal fading, and this is in conformity with the works of [6] and [8].

The accuracy of the models developed from the data was accessed using the Root Mean Square Error (RMSE). The result as shown in Table 2 shows that the RMSE values of all the stations are in the range of < 0.7 except for the case of Unity TV Jos Plateau state which is above 2. The reason for the higher value of RMSE in Jos is because the recorded signal strength in Jos is higher than the signal strength recorded from each of the four TV stations measured in Abuja. In other words, the higher the values of the data measured, the more the RMSE values. This is also shown in AIT and ETV which have higher values of RMSE than NTA and Channels that have lower values of signal strength compared with AIT and ETV.

Table 2: RMSE

|        | Temperature | Pressure | Relative Humidity | Wind speed | Noise Temp | Rainfall |
|--------|-------------|----------|-------------------|------------|------------|----------|
| AIT    | 0.494       | 0.575    | 0.517             | 0.516      | 0.511      | 0.530    |
| NTA    | 0.190       | 0.288    | 0.167             | 0.181      | 0.181      | 0.362    |
| Channels | 0.218     | 0.293    | 0.223             | 0.191      | 0.217      | 0.217    |
| ETV    | 0.609       | 0.633    | 0.63              | 0.633      | 0.491      | 0.632    |
| Unity TV | 2.612      | 2.616    | 2.636             | 2.658      | 2.621      | 2.638    |

4. Conclusion
The assessment of the relationship between atmospheric parameters as well as antenna temperature and the DTTV signal strength of some television stations in Abuja and Jos, Plateau State from April 2019 to December 2020 has
been carried out. It can be observed from the results that the signal strength of the five stations in the study areas increases with an increase in rainfall, relative humidity, and wind speed, but decrease with increase atmospheric temperature, pressure, and noise temperature.

The good quality signal and robustness to interference and signal attenuation by digital signal made the signals not be seriously affected negatively by rainfall. More so, it can be observed that the developed model equations can be used to study the influence of each of these parameters on the RSS in the areas.

The result of this work will be useful to Satellite link designers, satellite and mobile communication experts as well as Nigeria Broadcasting Commission to improve the quality of the signal transmission of DTB in the future for digital switchover in other parts of the country especially on the choice of antennas on their transmitters in the high-temperature area.

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