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Effects of F2 Layer Ionospheric Variations On Radio Waves in Nigeria Using Ionospheric Parameters

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ABSTRACT: *The F2 layer of the ionosphere is very important to radio wave propagation around the globe. Radio waves propagated into the ionosphere get reflected, refracted or absorbed by the ionosphere. The refraction and reflection of the radio waves back to the Earth plays a major role in radio wave transmission. This paper investigates the role of the ionospheric F2 layer on radio propagation. The median absolute deviation was employed in the analysis. Results show that the ionosphere plays a major part in radio communication in Nigeria. Also, differences exist in the quality of radio wave propagation between wet season and dry season. This may likely be due to differences in the quantity of ionization and the interaction between the Earth's magnetic field and the plasma. It is, therefore, necessary that the behaviour of F2 layer of the ionosphere be properly studied for a better understanding of radio communication using the ionosphere*.

KEYWORDS: Communication, F2 layer, ionosphere, radio wave, transmission

INTRODUCTION

The earth's atmosphere is a gaseous region where several activities are going on and it is stratified. The troposphere is the part of the atmosphere closest to the ground. The second layer, third and fourth layers are the stratosphere, mesosphere, thermosphere and exosphere respectively. The ionosphere which extends from the 50 – 500km altitude (i.e. from the stratosphere up to the thermosphere), is a region ionized by solar radiation to the extent that it contains electrons and free ions in sufficient quantities that it affects radio communications.

Radio waves can be absorbed, scattered, bent, refracted or reflected back to earth by the ionosphere thereby allowing long-distance communication. The ionosphere is, also stratified into D, E and F layer with F layer further classified into F1 and F2 due to plasma response to dynamic processes in the geomagnetic field. The aim of this study is to investigate the effects of F2 layer ionospheric variation on radio communications in Nigeria using ionospheric parameters. Specifically, this work will focus on the contribution of F2 layer to radio communication in Nigeria during rainy and dry seasons.

Galuk et al. (2019) reported that radio wave scattering at low frequency caused by non-uniformity in the lower ionosphere (between 70 and 80km altitudes) and which depends on the radius of propagation had two poles: a monopole that radiates symmetrically and a dipole having a cosine radiation pattern. There are maximum distortions that decreases with distance during the daytime near ionospheric radio-wave propagation paths (Zheng et al., 2022), significant anomalies in extremely low frequency (Hayakawa et al., 2020) and inverse relation between absorption by short wave and frequency/elevation angle (Ma et al., 2021) have been seen in radio wave propagation. Extremely low frequency (ELF) wave scattering and seismagnetic disturbance are the prime suspects in these distortions and anomalies. Absorption is highest during at noon and lowest during winter. Cervera et al. (2021) is of the idea that both the disturbed and undisturbed ionosphere affect radio wave propagation in the high frequency (HF) range.

Space weather affects radio wave propagation (Kryukovsky et al., 2021). For instance, sporadic E aids its propagation (Cameron et al., 2022) and typhoon's action increases atmospheric wave activity by altering the periods and reflection region height of radio waves (Chernogor et al., 2021). Also, Very low frequency (VLF) waves penetrate the ionosphere (Zhao et al. 2019) propagating in the magnetosphere to its conjugate hemisphere as ducted or non-ducted whistlers. Abrupt changes in the electromagnetic field trigger Earth's energy release during storms and this has effect on satellite orbital drag (Oliverira et al., 2019; Sobolev, 2020). An unexpected intense positive ionospheric response during a minor magnetic storm was reported by Rajesh et al. (2021) while during earthquake Satti et al. (2022) found pre- and post-seismic anomalies for 60 days before and after each shock.

Sources of Data

The electron density profiles data for 2020 and 2021, COSMIC-2 missions were obtained from University Corporation for Atmospheric Research (https://data.cosmic.ucar.edu/gnss-ro/). Data obtained over Abuja 8.99^{o}N, 7.38^{o}E were used for the study.

Theory and Method of Data Analysis

The median absolute deviation (MAD) expressed in equation (1) was computed as to determine deviations from the median values.

$$MAD = median\ (|Y_i - \bar{Y}|) \qquad 1$$

where Y_i are elements in the distribution, and $\bar{Y}$ is median of the distribution.

This median processing of the NmF2 and HmF2 variability is more robust than the mean processing because it eliminates the disproportionate influence of outlying points on the results (Olive et al. 2008).

Matlab software was used for statistical analyses of all of the data. The seasonal and HmF2 and diurnal variabilities of TEC were computed by considering median values of the hourly

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measurements collected over the seasons. Three months were chosen for each season. For dry season, December, January and February were selected while June, July and August were chosen for the wet/rainy season. The selections were done such that the months chosen correspond to winter months for dry season and summer months for rainy season. This enabled us compare our results with what obtain in the temperate regions of the world. The median absolute deviation (MAD) expressed in equation (1) was computed as a measure of the typical deviations from the median values. Then graphs of NmF_2, HMF_2 against time and altitude against electron density were plotted.

Results and Discussion

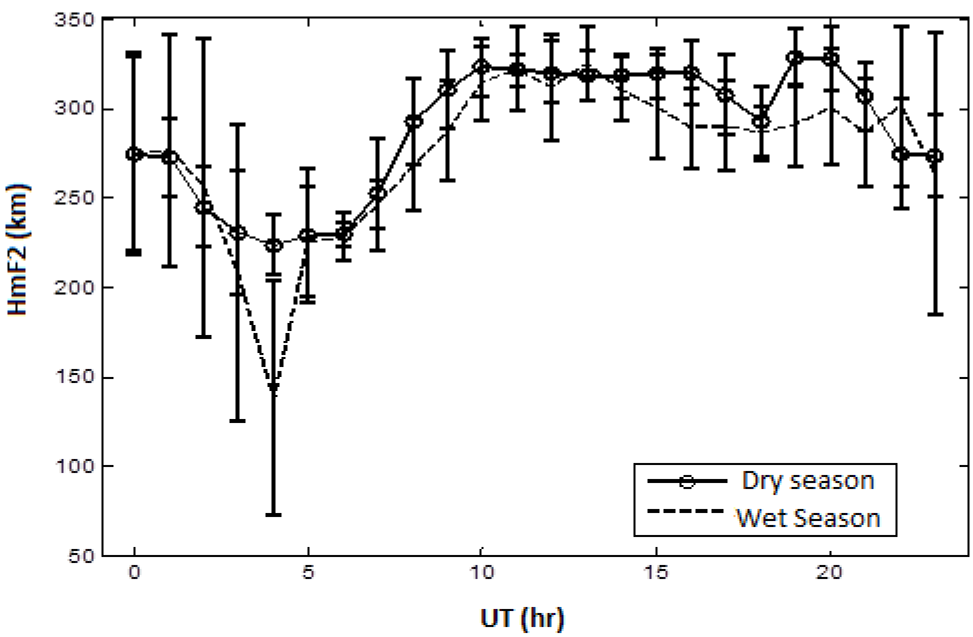

Figure 1: Seasonal variation of the height of the electron density (hmF2) against time

From Figure 1, we discovered that the peak height of electron density was recorded around 320km in the nighttime during dry season/Harmattan; this is anomalous behaviour while the peak electron density height during wet season was slightly above 300km at 10-13 UT. Harmattan is the dry dusty wind blowing across the sub-Saharan Africa in the months of October, November, December, January and February. Morning hour results show an exponential decrease in electron collision frequency with height, to about 150 km, and above that height the collision frequency decreases more slowly with height due to electron-ion collisions in wet season. This agrees with the work of Davies (1990) who found similar trends during summer. During daytime the collision frequency increases in winter; this could be as a result winter anomaly.

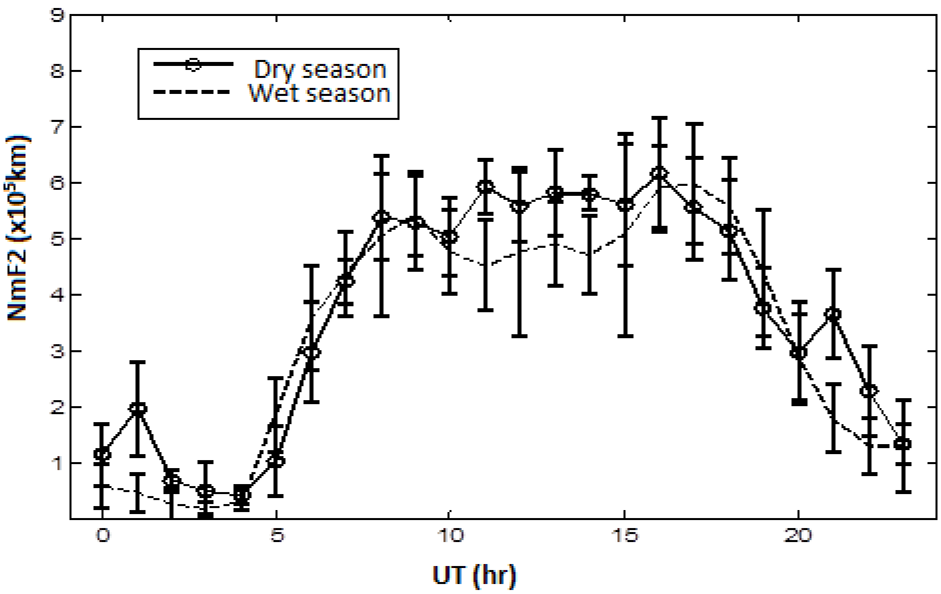

Figure 2 typical seasonal variation of the electron density against time

From Figure 2 above, the electron density peaks around 10-15 UT during dry season while the maximum electron density peak during wet season was at 16-18 UT. Also observed that the electron content in the dry season is greater than the electron concentration in the wet season. This means that the ionosphere reflects more radio waves and absorbs less during dry season than during wet season. During the day, solar radiation strikes the atmosphere more obliquely, so the intensity of radiation and the electron density production increases towards the equator. There were deviations from solar-controlled behaviour caused by anomaly experienced in winter/dry season, in this case in the critical frequency f_oF_2 (proportional to the square root of the peak electron density, N_mF_2) varies regularly with the solar zenith angle χ as it does in the well-known Chapman layer (Brown 2019) more than as expected in summer season. Winter anomaly is a phenomenon that is predominant in mid-latitude during daytime N_mF_2 (or f_oF_2) it can also be found in the equator as equatorial anomalies greater in winter than in summer at approximately the same solar activity level (Torr and Torr, 1973; Zou *et al.* 2000). Burns *et al.* (2012, 2014).

ANALYSIS OF DIURNAL VARIATION

In measuring electron density of the ionosphere, we usually refer to total electron content (TEC) in which a trans-ionospheric ray path vertically above the location of the receiver (i.e. at a deviation of 90^o) is used. A case study of the year 2021, a year of solar maximum, using the data from Cosmic-2 was used to explain the effect of solar radiation on telecommunication as a function of electron density of the ionosphere. The plot of altitude against electron density (N/cm^3) is shown below.

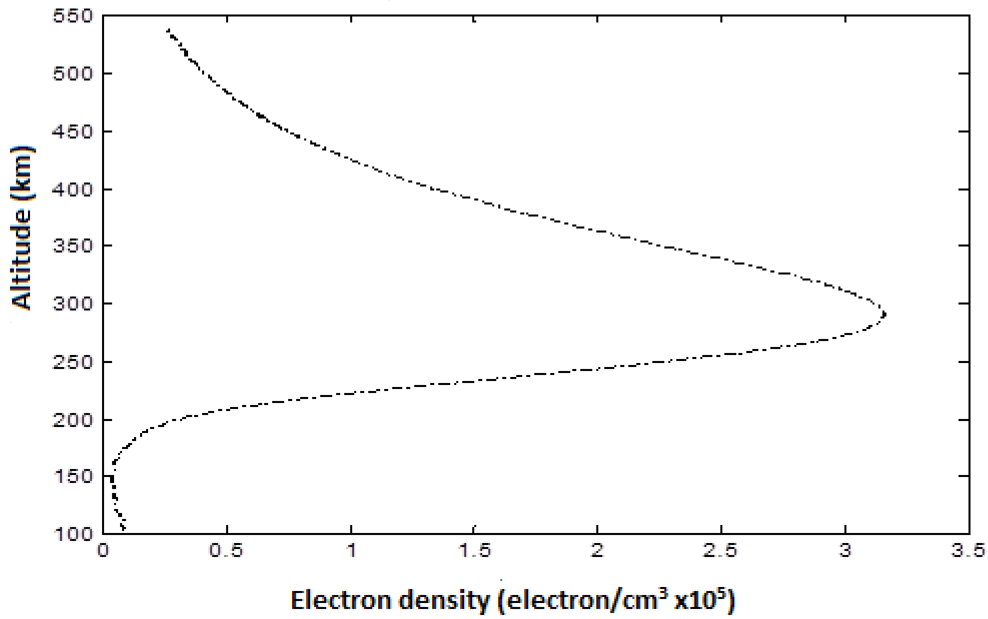

Figure 3: Typical variation of altitude with the electron density

There is general trend is characterized by a peak value appearing around (250-350 km) at the equator. The equator receives the highest amount of solar radiations in any day and as such is expected to have more ionization. The result is consistent with the results of Osueke (2022). There is a sudden drop in electron density which is attributed to the spread in electron over a height range during this period.

CONCLUSION

From this research work, it is evident that the ionosphere plays a very major role in radio communication. The influence of radio wave which brings about radio wave through distance places cannot be neglected. The ionosphere is part of the atmosphere that contains charged particles or ions. The ionosphere is a new world to which radio research and radio operations have given us access to propagate signals into space at various time of the day. The ionized layer of the atmosphere makes long distance radio communication possible. Radio waves can be reflected from F_2 layer due to charged particles in this medium by interaction of particles. There was significant differences in the seasonal variation between wet season and dry season. In the F_2 region, electromagnetic drift (E **x** B), caused by interaction of ionized particles with the Earth's magnetic field (B) and electric fields (E) in the ionosphere, is important because it accounts for ionization moving across magnetic field lines. The relationship between the direction of the geomagnetic field and the direction of the neutral winds and electrodynamic drifts plays a major role in the structure of the F_2 layer. It is the plasma response to the dynamic processes in the presence of the geomagnetic field that gives rise to the observed geographical and temporal variations in the F_2 layer. However, from our result the maximum density generally occurs well after local noon, sometimes in the evening. The height of the maximum ranges from 250 to 350 km at our study area and the height of the maximum electron density are higher at night than in the daytime.

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