The Effect of Solar Wind-Magnetosphere parameters interactions on Radio wave Transmission in Minna

[1,a] **P. E. Agbo, Ph.D**   and [1,b] **O. N. Okoro, M.Sc**

[1]Department of Industrial Physics, Ebonyi State University, Abakaliki, Nigeria

E-mail: [a]ekumaagbo@gmail.com , [b]bathonjoku@yahoo.com

Abstract

The effect of solar wind-magnetosphere parameters interactions on radio wave transmission was investigated using hourly records of solar wind-magnetosphere interplanetary parameters activities in 2008 at Minna North central, Nigeria (Latitude 9° 36' 50" N and Longitude 6° 33' 24" E). Of all the parameters studied within the hours of the year, it was observed that relative humidity (H) temperature (T) and proton density (PD) are the major causes of radio wave transmission effect in Minna during propagation of radio signal. The correlation analysis of radio refractivity with the solar wind-magnetosphere interplanetary parameters showed that relative humidity (H) has correlation coefficient of 0.985, proton density (PD) has correlation coefficient of 0.452, temperature (T)) has correlation coefficient of 0.392, pressure (P) has correlation coefficient of 0.274 and Dst index) has correlation coefficient of 0.011 respectively.

Keywords: Solar wind, Magnetosphere, interplanetary parameters, radio wave, correlation coefficient, refractive index, temperature

The refractive index of the atmosphere is an important factor in predicting performance of terrestrial radio wave transmission. Refractive index variations of the atmosphere affect radio frequencies above 30 MHz, although these effects become significant only at frequencies above 100MHz especially in the lower atmosphere. The radio refractive index n of the atmosphere changes slightly from unity due to the polarisability of the constituent molecules by the incident electromagnetic field and the atmospheric parameters at certain frequency bands in different layers of the atmosphere.(Bean et al, 1996)

Marconi demonstrated the feasibility of intercontinental wireless communications with his successful transmissions from Poldhu Station, Cornwall, to St. John's, Newfoundland, in December 1901. Marconi's achievement (for which he shared the Nobel Prize in Physics with Karl Ferdinand Braun in 1909) was only possible because of the high altitude reflecting layer, the ionosphere, which reflected the wireless signals because wireless remained the only method for cross oceanic voice (in contrast to telegraph).

Electromagnetic coupling is perhaps the most process linking the magnetosphere-ionosphere and thermosphere at high latitudes. The coupling arises as a result of the interaction of the magnetized solar wind with the Earth's geomagnetic field. When the supersonic solar wind first encounters the geomagnetic field, a free-standing bow shock is formed that deflects the solar wind (Adimula et al, 2006) around the Earth in a region called the magnetosheath. The subsequent interaction of the magnetosheath flow with the geomagnetic field leads to the formation of the magnetopause, which is a relatively thin boundary layer that acts to separate the solar wind's magnetic field from the geomagnetic field. The separation is accomplished via magnetopause current system. However, the shielding is not perfect, and a portion of the solar wind's magnetic field (also known as the interplanetary magnetic field) penetrates the magnetopause and connects with the geomagnetic field. Until the laying of the first trans- Atlantic telecommunications cable, TAT-1 (Newfoundland to Scotland) in 1958, any physical changes in the radio wave-reflecting layer (even before it was "discovered") were critical to the success (or failure) of reliable transmissions.

The same magnetosphere-ionosphere electrical currents that could produce "spontaneous" electrical currents within the Earth (and thus within the wires of the electrical telegraph) could also affect the reception and fidelity of the transmitted long-distance wireless signals. Indeed, Marconi (1928) commented on this phenomenon when he noted that "times of bad fading of radio signals, practically always coincide with the appearance of large sunspots and intense aurora-boreali usually accompanied by magnetic storms" These are the same periods when cables and land lines experience difficulties or are thrown out of action. The effective operating distance of this system increased as the equipment was improved, and in 1901, Marconi succeeded in sending the letter S across the Atlantic Ocean using Morse code. Marconi's famous experiment showed the way toward worldwide communication, but it also raised a serious scientific dilemma. Up to this point, it had been assumed that electromagnetic radiation traveled in straight lines in a manner similar to light waves. If this were true, the maximum possible communication distance would be determined by the geometry of the path.

The beginning of radio telephony (the transmission of music and speech) began in 1906 with the work of Reginald. Radios that combine transmitters and receivers are now widely used for communications. Cellular telephones, despite the name, are another popular form of radio used for communication.

Long distance propagation of radio waves depends on an invisible layer of charged particles, which envelops the Earth. The layer of charged particles known as the ionosphere has been in existence for millions of years and it is the layer of the atmosphere that radio transmission takes place.

The relationship between disturbed long wavelength radio transmissions and individual incidents of magnetosperic interplanetary activities were first identified in 1923 (Anderson, 1928). The technical literature of the early wireless era showed clearly that solar-originating disturbances were serious factor that determine the efficiency of telecommunications during the first decades of the twentieth century. Communications engineers pursued a number of methodologies to alleviate or mitigate the factor.

The increasing demand for data communications and connectivity has resulted in the development of innovative methods to satisfy current and emerging communication requirements. The path on which data travels from its source to its destination is described as a communications link.

The primary sources of interference that effect wireless communication systems are electromagnetic in nature and can result in the magnetic and radio frequency disruption or intermittent failure of electronic, communication and information systems.The subdivision of the atmosphere is shown in Fig. 1. Radio wave propagation varies as it travels through different layers of the atmosphere.

The effects of solar radiation on telecommunications were studied by Ezekoye, et al (2007). In their study, they observed that solar radiations and other solar activities affect the total electron content of the ionosphere and also affect various radio frequencies used during radio signal transmission. Also, Chaman, et al (2003), studied performance of free space optical communication using M-array receivers at atmospheric condition. He stated that atmospheric turbulence is caused by both spatial and temporal random fluctuations of refractive index due to temperature, pressure, and solar wind parameter variations along the optical propagation path within the channel. Adediji, et al (2008), studied vertical profile gradient in Akure South-West Nigeria. He observed that radio propagation conditions have varying degree of occurrence with sub-refractive conditions. Ayantunji et al (2001) studied diurnal and seasonal variation of surface refractivity in Nigeria. However, this communication is aimed at investigating the effect of solar wind-magnetosphere parameter interaction during radio transmission using statistical data of atmospheric parameters in Minna.

Theoretical Analysis

The atmosphere of the Earth may be divided into several distinct layers, as shown in figure 1. Long distance propagation of radio waves depends on an invisible layer of charged particles of magnetosphere-ionosphere which envelops the Earth.

Transmission of radio wave follows a definite pattern through which the radio signal travels from transmitter to the receiver in the atmosphere. This transmission of radio signal is determined by the

changes in the refractive index of air in the atmosphere resulting in the interactions of solar wind-magnetospheric interplanetary parameters at different layer of the atmosphere within the seasons of the year. The refractive index of air determines the efficiency of radio signal propagation in the atmosphere. But since refractive index of the atmosphere is very close to unity (about 1.0003), it is measured by a quantity called radio refractivity (N). Radio refractivity (N) according to ITU-R (2003) is therefore related to refractive index (n) by the following formula:

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

The quantity N depends on the variations of interplanetary parameters in atmosphere during various activities of the solar system. Thus, as a function of interplanetary parameters;

$$N = 77.6 \frac{P}{T} + 3.37 \ x \frac{10^5 e}{T^2} \tag{2}$$

where

$$e = \frac{H}{100} e_s \tag{3}$$

e_s is the saturated vapour pressure at the given atmospheric temperature t^oC, and   can be calculated from the following:

$$e_s = 6.11 \exp[\frac{17.5(T - 273.16)}{T - 35.87}] \tag{4}$$

 Where in equations 3 and 4,

P = atmospheric pressure (hPa)

e_s = water vapour pressure (hPa)

T = absolute temperature (K)

Equation (4) may be employed for the propagation of radio frequencies up to 100GHz (Willoughby et al, 2002).

In general, P and e decrease rapidly with height while T decreases slowly with height (ITU-R, 2003).

Radio waves (or radio frequency waves) are electromagnetic waves having frequency range from a few Hertz up to 10^8 Hz. These waves, which are used in telecommunications such as television, radio broadcasting, telephone, aeronautic and maritime, etc., are generated by electronics devices, mainly oscillating circuits. As radio waves travel away from their point of origin, they become attenuated due the interactions of the solar wind-magnetospheric interplanetary parameters which results in the spreading out of the signal and because of energy lost by scattering and absorption in different layers of the atmosphere. The amount of this attenuation depends on the frequency of the wave, the time of the day, and the season of the year, as well as the character of the earth's surface.

Material and Method

The data used for this work covered a period of one year starting from January to December, 2008. The data are in two forms. First one is meteorological parameters which are raw recorded hourly data of temperature, humidity and pressure. These data were provided by the Centre for Basic Space Science (CBSS) Nsukka, Nigeria. The second type of data is the interplanetary magnetic data obtained from OMINI website (www.ominiweb.com). This data consists of hourly value of solar wind interplanetary parameters (proton density and Dst index).

Results and Discussion

The average hourly record of solar wind-magnetosphere interplanetary parameters data were observed and recorded in Minna with Latitude 9° 36' 50" N and Longitude 6° 33' 24" E for the year 2008 on each day within the Months. The work covered all the days and months of the year, but the Month of February was chosen as a representative month for the rest of the other months in year 2008.

The plots of figure 2-7 depict the variations of relative humidity (%), temperature (^{o}C), pressure (hPa), radio refractivity (N-unit), proton density (Ncm^3) and Dst index (nT). It is clearly seen from figure 2 and figures 5 that variation of relative humidity with time and variation of radio refractivity with time and variation of radio refractivity with time followed the same trend line throughout the hours of study with maxima at 900hr and 2100hr respectively. In the same way, the variation of proton density (fig. 6) has almost similar trend line which shifted from the early hours of the day till the late hours of the day with the maxima amplitude occurring at 600hr and 1000hr during the day. These observations review the high dependency of radio refractivity with humidity and proton density in the atmosphere during radio wave propagation.

In figure 3, 4 and 7, it is observed that the trend lines of variations of the plots exhibit a different pattern as compared to that of figure 5. It is clearly seen that variation of temperature with time (fig 3) rises from the early hours of the day till it reached maximum amplitude at 600hr.

In figure 8-12, to allow the clear view of the relationship between radio refractivity and solar wind-magnetosphere parameters, correlation
Analysis of radio refractivity and solar wind parameters were studied**.** The analysis indicated that relative humidity

(H), temperature (T), pressure (P), proton density (PD) and Dst index correlation coefficient are respectively 0.985, 0.274, 0.391, 0.452 and 0.452.

from there it decreased progressively till the late hours of the day. The variation of pressure with time seems to exhibit two cycles within the hours of the day with its maximum amplitude at the 2400hr. But the variation of Dsx occurs in a negative direction with the maximum amplitude at 1600hr.It is clear that relative humidity and proton density have high correlation coefficients which are in agreement with fig. 2, 5 and 6 showing the variations of atmospheric parameters with time during the hours of the day. The high humidity and proton density show the high dependency of radio refractivity with the atmospheric parameters during radio transmission in Minna.

In the plots also, it is observed that figs. 8, 9 and 12 have positive gradients of $\frac{dN}{dH} = 1.592, \frac{dN}{dp} = 1.473, \frac{dn}{dDst} = 0.032$ While Figs. 10 and 11 have negative gradients of $\frac{dN}{dT} = -1.361$ and $\frac{dN}{dP_D} = -1.949$.

These values are in agreement with equation (2) which indicated that radio refractivity is directly proportional to pressure and inversely proportional to temperature (i.e. $N \propto P$ and $N \propto \frac{1}{T}$) respectively.

Conclusion

In conclusion, the results of the analysis showed that radio wave transmission which is the function of radio refractivity in the atmosphere is sorely dependent on the solar wind-magnetosphere parameters interactions in study area. This dependency is clearly shown in the variation of radio refractivity plots and solar wind-magnetosphere parameters with time as well as the correlation of radio refractivity against solar wind-magnetosphere parameters. The results equally indicated that relative humidity has the greatest effect on radio transmission at Minna in 2008.

Acknowledgement

References

1. Adediji A.T and M.O. Ajewole 2008.Vertical profile of radio Refractivity in Akure South-West Nigeria, Progress In Electromagnetics Research C,   Vol.4. 157-168.

2.   Anderson, C. N., Correlation of radio Transmission and solar activity, Proc. I. R. E., **16**, 297, 1928.

3. Anderson, C. N., Notes on the effects of solar disturbances on transatlantic radio transmissions, Proc. I. R. E., **17**, 1528, 1929.

4. Adebanjo, T. I., (1977). A semi-Empirical radio refractive index Variation over Nigeria," Bull. Nig. Inst. Phys., Vol. 2, No. 2, pp 69-78.

5. Adimula, I.A. and A.A. Willoughby.   2008. "Temperature and Precipitation Relation in the Sub-Sahel". Nigeria Journal of Physics. 20(2):291-297.

6. Bean, B.R. and E.J. Dutton. 1966. Radio Meteorology. National Bureau of Standards Monograph 92.

7.   Ayantunji B. G. and P. N. Okeke ,2011. Diurnal and seasonal variation of surface Refractivity over Nigeria, Progress in Electromagnetics Research B, Vol. 30, 201-222

8. Gordon, G. D., and W. L. Morgan, 1993. Principals of Communications Satellites, John Wiley, New York,   178-192,

9. Marconi, G., Radio communication,1928, Proc. IRE, **16**, 40, 1928.

10. Zilinskas M., S. Tamosiunas, M. Tamosiunaite, and M. Tamosniene 2011. Yearly, Seasonal and Daily Variations of Radio Refractivity, Physical Aspects of Microwave and

    Radar Applications Vol. 119, pp 2-3.