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The Comparative Study of the Impact of Refractivity in Enugu, South Eastern Nigeria (A Case Study of Enugu State University of Science and Technology)

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Abstract: *This work investigates the impact of radio refractivity over Enugu, South Eastern Nigeria using atmospheric parameters of temperature, pressure and relative humidity collected from August 2017 to July 2018 respectively, we downloaded our data from Automated Weather Station and Signal Strength Meter in the Department of Industrial Physics Enugu State University of Science and Technology using Davis weather station vantage pro 2 positioned close to the ground surface. The data were logged at 30 minutes' interval continuously for each day during the period. Hourly, daily and monthly averages of radio refractivity during dry and wet seasons were calculated from the data obtained. The result indicated that the radio refractivity during the wet season is greater than the dry season. This is as a result of variation in atmospheric parameters such as relative humidity, pressure and temperature, which cause the radio refractivity to vary at different times of the day; while the pressure variation seems to be insignificant. However, results of the refractivity show that the propagation conditions have varying degree of occurrence with super-refractivity conditions observed to be prevalent throughout the one-year period. The months of December and January have the lowest value of refractivity and June and July have the lowest vale of refractivity.*

Keywords: *Radio refractivity; Atmospheric parameters; Troposphere.*

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I. Introduction

Signal propagation in the troposphere is affected by many factors caused by the variations of meteorological parameters such as humidity, temperature and pressure. The radio signal can be reflected, refracted, scattered and absorbed by different atmospheric constituents (Chinelo and Chukwunike, 2016). A radio wave propagating through the earth atmosphere will experience path bending due to inhomogeneous spatial distribution of the refractive index of air, which causes adverse effects such as multipath fading and interference. These effects significantly impair radio communication, aero - space, environmental monitoring, disaster forecasting e.t.c (Bawa *et al*., 2015). The part of the atmosphere most closely related to human life is the troposphere: It is the lowest layer of the earth's atmosphere and site for all weather on earth (Akpootu and Illiyasu, 2017). Refractivity is one of the factors, which influence the transmission of radio signals operating within the troposphere. The troposphere extends from the earth's surface to an altitude of about 10 km at the earth's poles and 17 km at the equator (Hall, 1979). At the lower part of the earth called the troposphere, the tropospheric refraction is due to the fluctuations of weather parameters like temperature, pressure and relative humidity (Agunlejika and Raji, 2010). The troposphere is, however bounded on the top by a layer of air called the tropopause, which separates the troposphere from the stratosphere and at the bottom by the surface of the earth; it contains approximately 77% of the atmosphere's mass and 99% of its water vapor and aerosols.

Since temperature decreases with altitude in the troposphere, warm air near the surface of the earth can rapidly rise, replacing the cold dense air at the upper part of the atmosphere (John, 2005). This will set up convection current in the air molecules of the troposphere. Such vertical movement or convection current creates clouds and ultimately rain from moisture within the air and gives rise to the weather condition we experience. However, the degree of atmospheric effect on radio signals depends mainly upon the frequency, power of the signal and on the state of the troposphere through which the radio waves propagates. The characterization of tropospheric variability has great significance to radio communications, aerospace, environmental monitoring, disaster forecasting etc, for instance worse propagation condition may lead to increased fading on communication links and consequently decreased power levels at the receiver (Chinelo and Chukwunike, 2016). Quality of propagation of radio waves between the transmitter and receiver mostly depends on performance and reliability of the links (Serdege and Ivanous, 2007). In addition, a radio propagation model is required to be used for the evaluation of signal level variation that occurs at various locations of interest over different times of the year. An important element of such type of propagation model is the variation of radio refractivity in the troposphere (Gao *et al.*, 2008).

According to (Serdege and Ivanovs, 2007), radio wave systems could become unavailable due to seasonal variation of refractive index. The structure of the radio refractive index, n at the lower part of the atmosphere is an important parameter in planning of the communication links. It is defined as a ratio of the radio wave propagation velocity in free space to its velocity in a specified medium (Freeman, 2007). Radio – wave propagation is determined by changes in the refractive index of air in the troposphere (Adediji and Ajewole, 2008). Changes in the value of the radio refractive index in the troposphere can curve the path of the propagating radio wave. The atmospheric radio refractive index depends on air temperature, humidity, atmospheric pressure and water vapor pressure. Even small changes in any of these variables can make a significant influence on radio-wave propagation, because radio signals can be refracted over the whole signal path (Priestley and Hill, 1985). Refractive index is not constant in the atmosphere and its space-time distribution results in scattering, sub-refraction, super-refraction, ducting and absorption phenomena (Adeyemi, 2008). The variation of refractive index is due to various phenomena affecting the propagation of radio signal, which for instance include refraction, bending, ducting and scintillation, range and elevation errors in radar acquisition and radio station interference (Freeman,2007; Grabner and Kvicera,2003; Jan and Ewa,2009; Maitham and Asrar,2003; Tom, 2006). The variation of refractive index as well as specific attenuation of micro/radio wave may be estimated indirectly with the measurement of temperature, pressure and relative humidity. The establishment of a radio refractive index database is necessary because the knowledge of radio refractive index is always required when measurements are made in air (Guanjun and Shukai, 2000; Nel *et al.*, 1988). Several research work on radio refractivity for different regions and climates using measured local meteorological data have been investigated in Nigeria and other parts of the world Adediji and Ajewole (2008), Agbo, (2011) Ajileye, (2015), Ajileye *et al.*, (2014); Ayantunji (2011), Ekpe, (2010); Emmanuel , (2013), Grabner and Kvicera, (2005); Isikwue and Kwen, (2013); Luhunga Mutayoba, (2014); Usman, (2015); Zilinskas and Tamosiunas, (2011). The results of their works show that the local climate has an appreciable influence on the radio refractivity and hence on the transmitted radio signals.

Therefore, accurate knowledge of radio refractivity within the atmosphere is very significant for radio engineers to accurately predict electromagnetic radio propagation. For example, in radar applications it is widely known that gradients in the radio refractivity of the atmosphere can create ducts which guide radio propagation to very long distances or create holes in radio coverage through which objects may travel undetected (Caglar *et al.*, 2006; Naveen *et al.*, 2011). For characterizing a radio channel, surface (ground level) and elevated refractivity data are often required; and in particular, the surface refractivity is very useful for prediction of some propagation effects on terrestrial links. Local coverage and statistics of refractivity, such as refractivity gradient, provide the most useful indication of the likely occurrence of refractivity-related effects required for prediction methods. Moreover, this research is important to all Radio Broadcasting Services as well as Television Stations across the country or state because, it will enable radio engineers to accurately determine the quality of UHF, VHF, and SHF signals for proper design of their communication stations. Refractive index is small at the earth's surface and as a result, it becomes convenient to use refractivity, N when modeling variation of refractive index in the atmosphere. Refractivity, N is related to refractive index, n by (Ekpe *et al.*,2009).

$$N = (n-1) \times 10^5 \quad \ldots\ldots 1$$

In terms of meteorological parameters, the refractivity is expressed as

$$N = 77.6\frac{P}{T} + 3.75 \times 10^5 \frac{e}{T^2} - \frac{77.6}{T[P+4810\left(\frac{e}{T}\right)]} \quad \ldots\ldots 2$$

where P is the pressure (hPa), T is the temperature in Kelvin and e is the water vapour pressure determined by

$$e = \left(\frac{R.h}{100}\right)e_s \quad \ldots\ldots 3$$

and

$$e_s = 6.11 exp(17.5t/t+240.97 \quad \ldots\ldots 4$$

where e_s is the saturated vapour pressure, t is temperature in degree Celsius, R.h is relative humidity expressed in percentage (%). The variation of the refractive index with height has a considerable influence on radio wave within the frequency range of 30MHz and above. Bending of radio signals as they propagate through the troposphere can cause a lot of problem in systems such as the accuracy of tracking radio source (such as stars) with radio telescope, tracking of satellites (such as GPS satellite), missile range *etc*. As radio wave propagates in the troposphere the vertical gradient of the refractive index induces a bending of its path which remains every point of space constrained within the vertical plane (Ayantunji *et al.,* 2011). The lower atmosphere scatters electromagnetic radiation over a vast range, including radio waves; this effect is known as tropospheric scatter, or troposcatter.

In this study, we intend to statistically investigate the impact of the surface radio refractivity variations in Enugu State, South Eastern Nigeria using the data obtained from ESUT Weather Station.

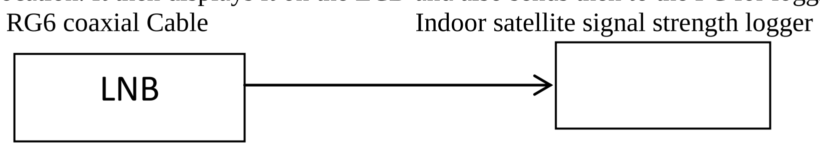
II. Materials

All the data used in this research was downloaded from the Automated Weather Station and Signal Strength Meter in Industrial Physics Department ESUT.

Figure 1. Automated Weather Station**.**

The satellite dish is focused on ASTRA1R 15.2^0E located at the geostationary orbit or Clark orbit. The dish concentrates the signal at Low Noise Block (LNB). The LNB is a universal type receiving 10.7 GHz – 12.6GHz (Ku Band), it then down converts it to signal between 950 MHZ – 2150MHz. this is called **down conversion** and the reason for the conversion is because the 10.7GHz – 12.6GHz signal cannot be transmitted through coaxial cable (because of attenuation). Therefore, a lower frequency was chosen for the transmission into the internal unit via cable.

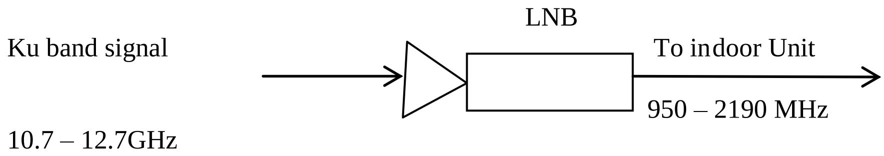
Indoor unit connects with the Outdoor instrument box and then receives the network signal strength and location. It then displays it on the LCD and also sends then to the PC for logging



The indoor system consists of the following:

i. Power supply phantom power to the LNB. LNB is an amplifier system and needs power to operate, the power is sent to it from the indoor system via the coaxial cable. It also sends its own signal to the indoor unit via the same cable.
ii. RF power detector to detect the power of the signal coming to the LNB in dBm.
iii. Processor connects with the power detector and sends the detected power to the PC.

The logger software on the PC was written with visual studio 12.0 and it accepts connection from the two-instrumentation system displays them as graphs.



Instrument Box contains the followings;
i. GSM modems for network signals
ii. GPS module
iii. 2.4 GHz transceiver to translate processed signal into the indoor Network signal analyser.
iv. The GSM modules converted the GSM network around depending on the (SIM card used) and capture the network strength.
v.The GPS detects the longitude and latitude of the location. A central processor then collates these into and then sends then to the indoor unit via a 2.4 GHz transceiver.

III. Methods

We downloaded the three atmospheric parameters and find the average which were arranged on a tabular form and the measurements were taken simultaneously at 2 minutes interval for 24 hours in one year. The graphs of the measured refractivity against time were plotted using Microsoft Excel to determine the lowest and the peak values of the refractivity variations. This in turn shows the nature of surface radio refractivity during wet and dry season.

IV. Results

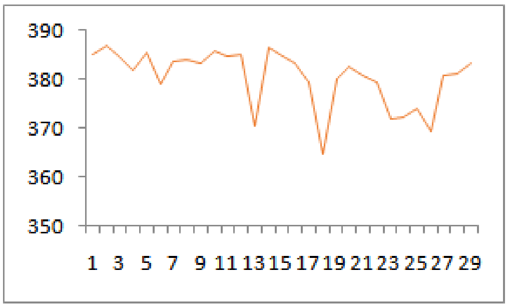


Figure 2. Daily mean variation of surface radio refractivity over Enugu for the month of August 2017 in wet season.

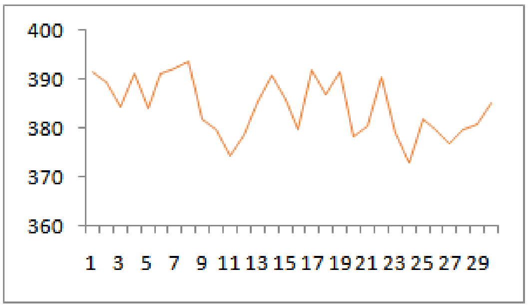


Figure 3. Daily mean variation of surface radio refractivity over Enugu for the month of September 2017, in wet season.

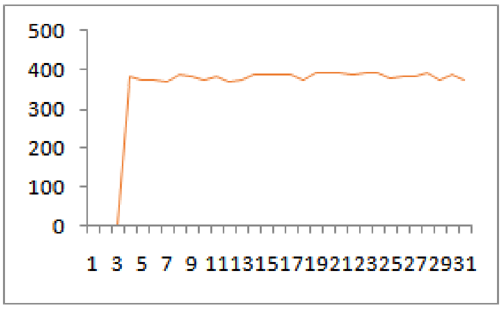


Figure 4. Daily mean variation of surface radio refractivity over Enugu for the month of October 2017, in dry season.

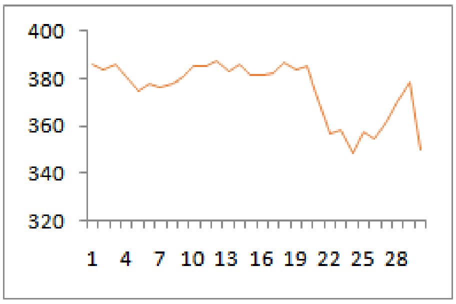


Figure 5. Daily mean variation of surface radio refractivity over Enugu for the month of November 2017, in dry season

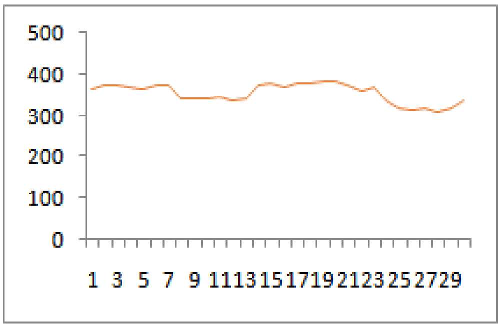


Figure 6. Daily mean variation of surface radio refractivity over Enugu for the month of December 2107 in dry season.

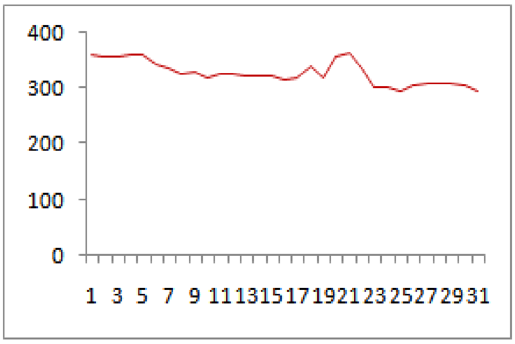


Figure 7. Daily mean variation of surface radio refractivity over Enugu for the month of January 2018, in dry season.

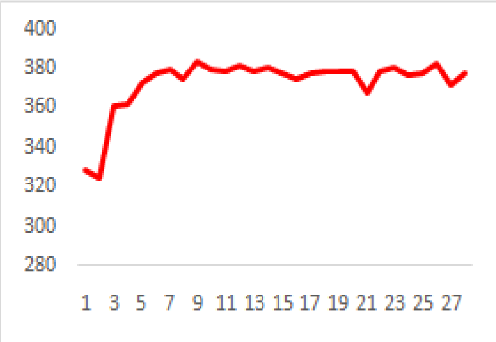


Figure 8.Daily mean variation of surface radio refractivity over Enugu for the month of February 2018, in dry season.

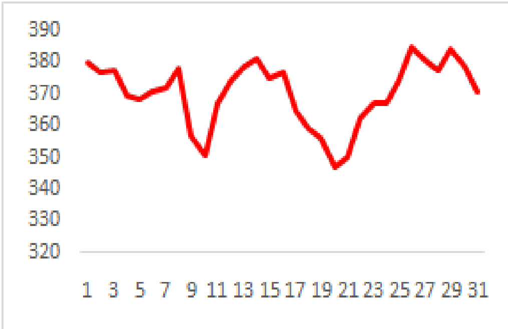


Figure 9. Daily mean variation of surface radio refractivity over Enugu for the month of March 2018, in dry season.

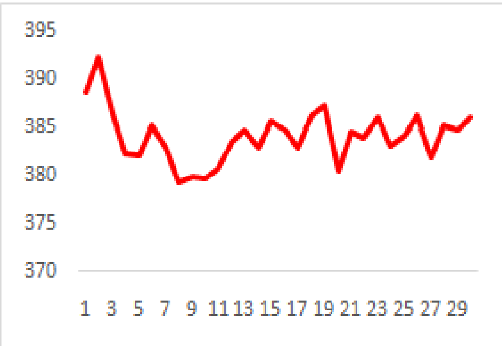


Figure 10. Daily mean variation of surface radio refractivity over Enugu for the month of April 2018, in wet season.

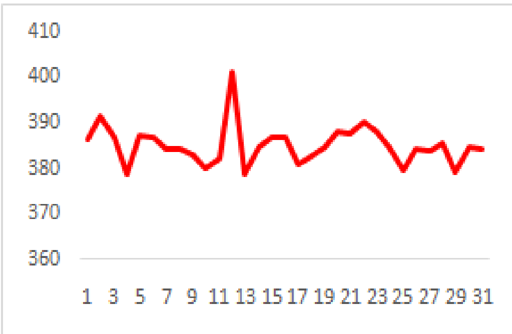


Figure 11. Daily mean variation of surface radio refractivity over Enugu for the month of May 2018, in dry season.

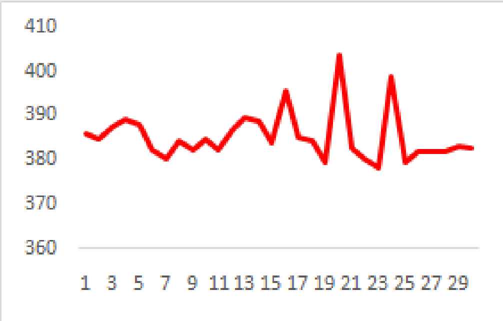


Figure 12.Daily mean variation of surface radio refractivity over Enugu for the month of June 2018, in wet season.

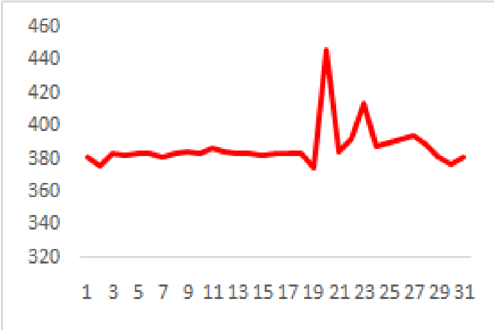


Figure 13.Daily mean variation of surface radio refractivity over Enugu for the month of July 2018, in wet season.

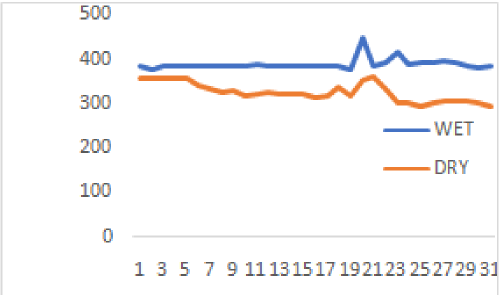


Figure 14. Mean daily variations of surface radio refractivity for the maximum wet and dry season months;

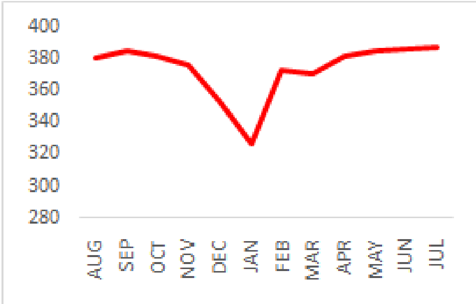


Figure 15. Seasonal variations of surface radio refractivity in Enugu for the period of one year; August 2017 to July 2018.

V. Discussions

From the measured values for pressure, temperature and relative humidity; vapour pressure, saturation vapour pressure and refractivity were then determined. The result obtained from the average of every representative wet and dry season months is presented in figures 2 to 15. The values were observed to be generally high during the rainy season. The high values are due to high air humidity (very close to 100%) observed in this part of Nigeria during this period, this is because the city of Enugu is under the influence of a large quantity of moisture-laden tropical maritime air resulting from continuous migration of inter-tropical discontinuity (ITD) with the sun. Generally, when the dry and dust – laden north - east winds become dominant in December, the dry Harmattan season sets in, resulting in lower values of refractivity as can be seen in the figures.

Figure 2 shows the refractivity of a typical wet season month, August. From the 1st day to the 11th day, there was unstable variation of surface refractivity with high values. This value falls gradually form about the 12th day to the 20th day, as a result of August break and rose back again with an unstable variation. Figure 3 shows the refractivity variation during the month of September, this is the period when the dry season is about to set in but we still experienced high refractivity variation due to high rainfall thereby affecting radio communications within the region. Figures 4,5 and 6 shows refractivity of typical dry season months, October, November and December. As the dry season sets in, the degree and values of refractivity variation reduces gradually. During the month of October, the refractivity values reduces small because wet season is gradually coming to an end, the values and graph sketch does not show much variation in the month of November and becomes more significant in the month of December where u will observe that the graph sketch is gradually looking like a straight line because harmattan sets in. Figure 7 shows the surface refractivity of a typical representative dry season month, January. Surface refractivity values drops gradually from the 1st day with a value of 358 N-unit to a value of 357 N-unit on the 2nd day. It maintained a steady variation of refractivity values to the 3rd day and then rose gradually on the 4th and 5th day to 359 and 360 N - unit respectively. The value drops again at the value of 345 N - unit on the 6th and was gradually falling until it gets to the value of 313 N-unit on the 17th day to a maximum value of 362 N - unit on the 21st as a result of higher moisture content and lower temperature. Then the values drop again from the 22rd day to the 31st day with a minimum value of 295 N-unit on the 31st day, due to high solar insolation and reduced humid content in the atmosphere during this time. Figure 8 shows the surface refractivity of a typical dry season month, February. The surface radio refractivity value is low but rises gradually from the 1st day to about the 3rd day and maintained a low value of refractivity variation. This is because wet season is gradually setting in. Figures 9, 10, 11 and 12 show the surface refractivity of wet season months, March, April, May and July. From the month of March wet season sets in, refractivity values increase and the variation becomes high. This high variation becomes applicable to all the wet season months because rainfall affects refractivity also has a lot of impact on radio signal and radio communication. Figure 13 shows an abrupt rise of surface refractivity of a typical wet season month, July. From the 1st day of July which is 381 N-unit, the refractivity values drop gradually to the 7th day with an unstable variation with a value of 380 N-unit. It rises again and maintained an unstable variation to the 15th day with a value of 381 N-unit. From about the 16th to the 18th day, it maintained a stable variation, it drops gradually on the 19th day with a value of 374 N-unit. It rises to a maximum value of 446 N - unit on the 20th day. Then from the21st day to the 31st day of July, there was an unstable variation of refractivity values. July is a typical wet season in Enugu and as such is expected high surface refractivity values. Figure 14 shows the diurnal surface refractivity for both dry and wet season months. With this figure for both wet and dry season months, it is observed that refractivity during the wet season is generally higher during the wet season than during the dry season. Figure 15 shows the seasonal variation of surface refractivity for both wet and dry season, from the period of August 2017 to July 2018. The wet season is from March to October while the dry season is November to February. It is observed that the refractivity is high during the wet season (Mar-Oct) and is low during the dry season (Nov-Feb)

VI. Conclusion.

The analysis of this work has shown that the surface refractivity for the period of one year over Enugu showed seasonal variations with high values in the rainy season and low values in the dry season. The variation of radio refractivity with meteorological parameters of atmospheric pressure, relative humidity and temperature for a period of 1-year has been investigated. Figure 15 summarizes all the months under review and shows that we have high refractivity variations in the rainy season and low refractivity variations in dry. The results indicated that an average value of 386.8523 N-units and an average value of 326.7976 N-units were observed during the rainy and dry seasons respectively. This shows obviously that radio refractivity during the rainy season is greater than the dry season for the study area. The maximum and minimum values of radio refractivity were observed in the months of July and January. In this study we used January as dry season and July as rainy session. The variation of radio refractivity with atmospheric pressure indicates that both radio refractivity and atmospheric pressure are greater during the rainy season than in the dry season. Similar observations were observed for relative humidity. The dry term contributes 67.98% to the total value of the radio refractivity while the wet term contributes to the 33.2 % variation.

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