Predicting radio refractivity using a stochastic model: Preliminary Studies

Samuel T. Ogunjo [1] and Moses O. Ajewole[1]*

[1]Department of Physics, Federal University of Technology, Akure, PMB 704, Akure, Ondo State, Nigeria.
stogunjo@futa.edu.ng; oludare.ajewole@futa.edu.ng

Abstract

The radio refractivity is a very important phenomena in communication. This paper attempts to model the radio refractivity over a tropical station (Akure, Southwestern Nigeria) with the aim of predicting future values. Atmospheric variables (temperature, pressure and relative humidity) were obtained over a year using a Davis Pro weather station. Differencing of the data was carried out to ensure stationarity. Suitable lags were obtained using the Box-Jenkins approach. Based on the model parameters, predictions were made. The predictions were found to be good for a period of about 6 days into the future.

1. Introduction

The radio refractivity (N-units) of air at a point can be expressed as

$$N = \frac{77.6}{T} + 3.75\times10^{5}\frac{e}{T^{2}} \tag{1}$$

where P is the atmospheric pressure in hPa, T is the temperature in Kelvin and e is the vapour pressure in hPa (cite [1]). From equation (1), local meteorological conditions are seen to affect radio wave propagation. According to Adeyemi [2], the wet term, $3.75\times10^{5}e/T^{2}$ is responsible for the variation of radio refractivity within the troposphere. Radio refractivity can give an insight into the behavioural pattern of the signal being propagated which may then influence the design of the equipments suitable for use in the tropics.

Several literatures abound on the study of radio refractivity for various regions of the world [3 - 5]. Agbo et al., [6] introduced the use of neural network for the study of refractivity profile for Markudi, Nigeria. Based on the results, the use of neural networks was proposed for the estimation of refractivity profile in the area. Ogunjo et al., [7] used tools from nonlinear dynamics to investigate chaos in radio refractivity data from Akure, Nigeria. It was concluded that the data was nonlinear and chaotic with limited prediction horizon. To the best of our knowledge, no research has been done on the prediction of radio refractivity into the future, hence the need for this research work. Future values of radio refractivity, however limited, will be extremely useful for radio planning and power budget. An approach to such prediction will be to predict individual atmospheric parameters in the computation of radio refractivity. However, prediction of individual atmospheric parameters has its own associated error, hence, the predicted value of the refractivity will contain a larger error.

2. Methodology

The data used in this study was obtained from an ongoing experiment by the Communications Research Group, The Federal University of Technology, Akure. A Davis 6162 Wireless Vantage Pro2 equipped with the Integrated Sensor Suite (ISS), a solar panel (with an alternative battery source) and the wireless console. The console is connected to a computer, through which the stored data are downloaded. The equipment is located about 26 km by road from the campus of the Federal University of Technology, Akure (FUTA) and about 11.5km on line of sight from Akure. The ISS houses the sensor for pressure, temperature, relative humidity, UV index and dose, solar radiation among others. The fixed measuring method by a high tower is employed for the measurement with the ISSs positioned on the ground surface and at different heights (50m, 100m, 150m and 200m) on the tower. The data were obtained at a height of 150m covering 24 hours each day at a time interval of 30 minutes. Daily averages were computed and used in this study for a period of eighteen months (January 2010 till June, 2012). The time series of the data is shown in Figure 1.

978-1-4673-5225-3/14/$31.00 ©2014 IEEE

When the value of a series at a current time period is a function of its immediate previous value plus some error, the underlying generating mechanism is said to be an autoregressive process (AR) with order p. Moving averages (MA) are time series that are regarded as an unevenly weighted effects of a random shock series [8]. Both AR and MA can be used to generate a time series of the order q which can model a given stationary time series. Series that have both autoregressive and moving average characteristics are known as ARMA(p,q) processes (Equation 2 shows the general form of an ARMA process). The right hand side denotes tne MA(q) process while the left hand side is the AR(p).

$$Y_t - \phi_1 Y_{t-1} - \cdots - \phi_p Y_{t-p} = \varepsilon_t + b_1 \varepsilon_{t-1} + \cdots + b_q \varepsilon_{t-q} \tag{2}$$

If the time series is differenced to make it stationary, the resulting model is termed Autoregressive Integrated Moving Average model of order (p,d,q) where d is the order of differencing necessary to make the series stationary. To obtain the proper lag for the model, the method of Box Jenkins (using autocorrelation and partial autocorrelation) is used. The result was confirmed using the Augmented Dickey-Fuller Test.

3. Result and Discussion

The time series of the data used in this study is shown in Figure 1. The series is seen to be non-stationary. This is further confirmed by the linearly decaying autocorrelation function (Figure 2). Hence, the time series is differenced to make it stationary (Figure 1). Both the autocorrelation and partial autocorrelation figure (2) of the differenced time series can be seen to decay rapidly, which indicates an ARIMA process. The cut off in the partial autocorrelation after lag 5 indicates an autoregressive process of order five. Based on the parameters, an ARIMA(5,1,10) model is proposed. Using this model, predictions were made for 11 days (Figure 3). It was observed that the predicted values were within the forecast intervals. Using this model for forecasting beyond this number of days resulted in larger errors.

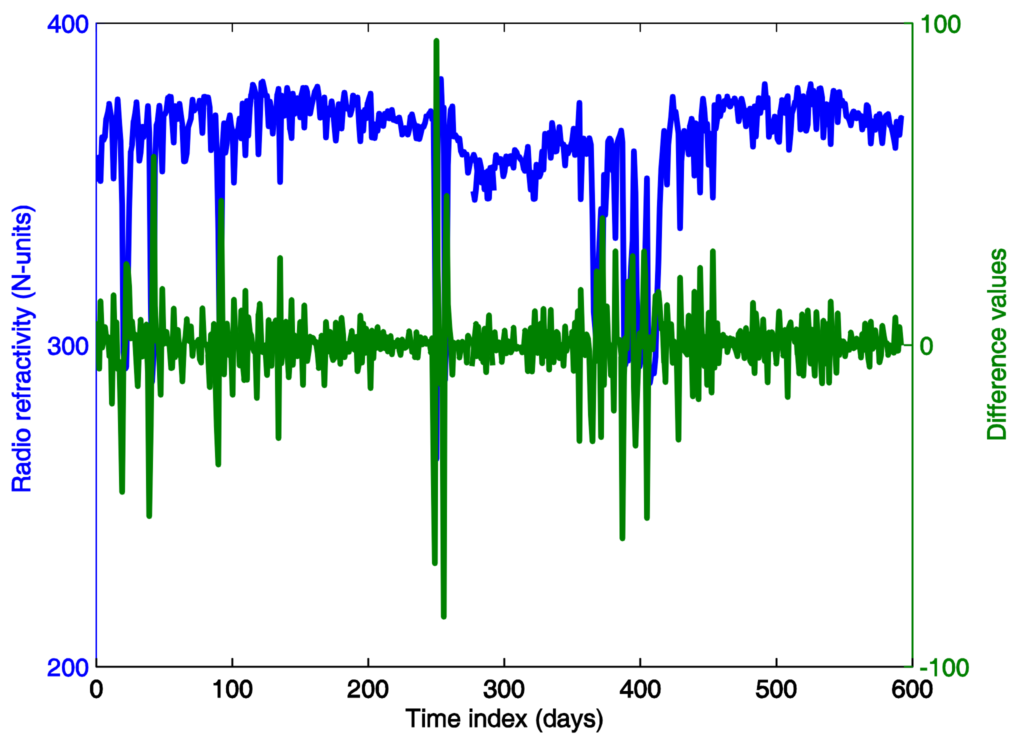

Figure 1: Time series data of radio refractivity (blue) during the period under study and the differenced time series (green)

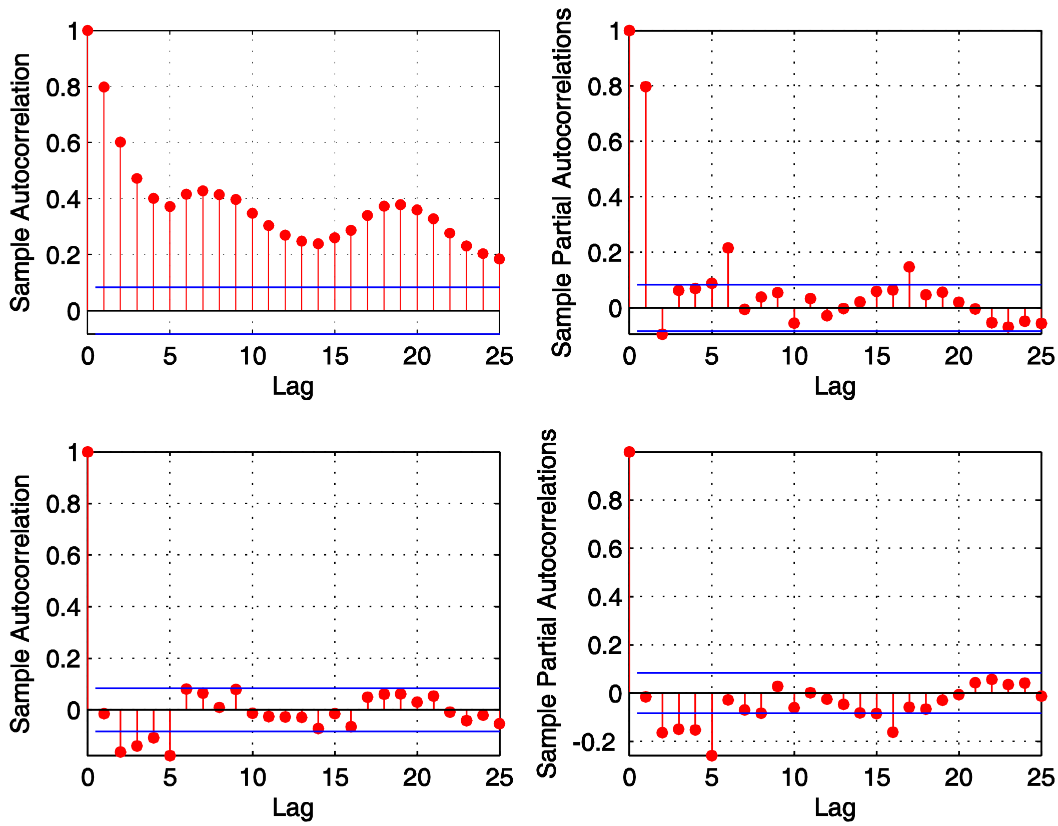

Figure 2: Sample autocorrelation function of original time series (top left) and differenced time series (bottom left) . Sample Partial Autocorrelation function of original time series (top right) and differenced time series (bottom right). The blue line indicates the confidence interval.

4. Conclusion

In this study, radio refractivity values over a tropical location, Akure Nigeria has been investigated. Based on the need to have future values of refractivity for better network budget and management, an ARIMA(5,1,10) has been proposed and tested. Preliminary results indicated good agreement between predicted and computed values. We hereby proposed further investigation to enhance the prediction horizon of the model. ARIMA models for hourly, daily and monthly prediction can also be examined.

5. Acknowledgments

The authors are grateful to Dr. J. S. Ojo and Dr. T. Adediji for their help in obtaining the data used in this study. Furthermore, the support of the Department of Physics is also acknowledged.

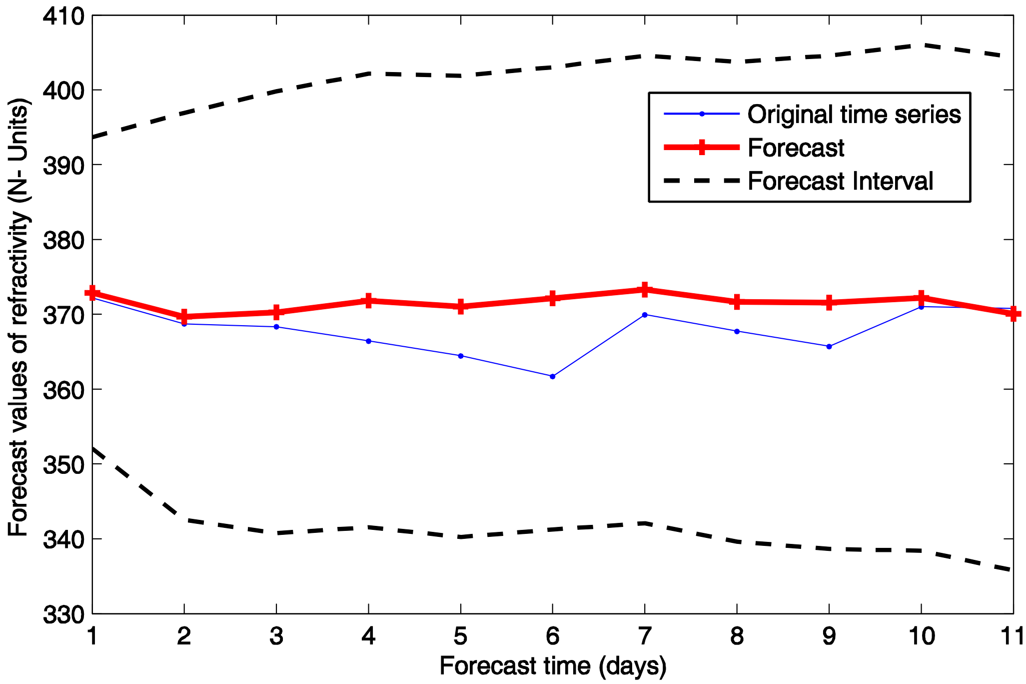

Figure 3: Forecast values based on an ARIMA(5,1,10) model.

6. References

1. A. T. Adediji and M. O. Ajewole, "Vertical Profile of Radio Refractivity Gradient in Akure South-West Nigeria," *Progress in Electromagnetics Research C,* **4**, 2008, pp. 157-168.

2. B. Adeyemi, "Surface water vapour density and tropospheric radio refractivity linkage over three stations in Nigeria" *Journal of Atmospheric and Solar-Terrestrial Physics* **68,** April 2006, pp. 1105-1115.

3. S. E. Falodun and L. B. Kolawole, "Studies of Super Refractivity and Ducting of Radiowaves in Nigeria" *Nigeria Journal of Pure and Applied Physics*, **1**, 2000, pp. 1-5.

4. S. E. Falodun and M. O. Ajewole, "Radio refractivity index in the lowest 100m layer of the troposphere in Akure, South Western Nigeria" *Journal of Atmospheric and Solar-Terrestrial Physics*, **68**, 2006, pp. 236-243.

5. A. A. Willoughby, T. O. Aro, and I. E. Owolabi, "Seasonal Variations of Radio Refractivity Gradients in Nigeria" *Journal of Atmospheric and Solar-Terrestrial Physics*, **64**, 2002, pp. 417-425.

6. G. A. Agbo, G. F. Ibeh, D. U. Onah, A. E. Umahi, E. Nnaji and F. C. Ugwuonah, "Application of Neural Network in Atmospheric Refractivity Profile at Markurdi," International Conference on Information, Business and Education (ICIBIT, 2013) Atlantis Press.

7. S. T. Ogunjo, J. S. Ojo, A. T. Adediji, K. D. Adedayo, and J. B. Dada. Chaos in radio refractivity over Akure, South-Western Nigeria. Book of Proceedings of the 5th Annual Conference of the Nigerian Union of Radio Science (NURS), 2013 pp. 56 - 63.

8.. R. Yaffee and M. McGee, "Introduction to Time Series Analysis and Forecasting with Applications of SAS and SPSS," New York, Academic Press, 1999.