Correlation and Regression Analyses of Refractivity with Metrological Parameters in Jos

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*Abstract:-***The paper studies the variation pattern of refractivity on land with the three major metrological parameters. The measured refractivity was compared with measured temperature, pressure and relative humidity at 100m height. The data were collected at interval of 30minutes for the whole day. Exponential, linear, power series, logarithmic and polynomial regressions were used to analysed the data and predict the refractivity in a day over the eight months in Jos of Nigeria. Correlation analyses were also used base on the predicted regression equations for two months each represents early dry season, late dry season, early rainy season and late rainy season. The study shows that refractivity increases with pressure and relative humidity while decreasing with temperature. The best regression equation of refractivity with pressure, temperature and relative humidity is polynomial equation. The correlation of pressure, temperature and relative humidity ranges from 0.2067-0.7291, 0.2242-0.9061 and 0.6741-0.9686. The correlations in early rainy and dry seasons for humidity and temperature and late rainy for pressure have highest value. Other regression equations for humidity and temperature have better performance and worst in pressure.**

Keywords: **Refractivity, Meteorological parameters, Regression equations, Correlation analyses, radio signal, tropospheric layer**

I. INTRODUCTION

For proper planning of terrestrial and earth space communication links, it is necessary to have appropriate knowledge of effect of refractivity on radio signal. Refraction of electromagnetic signal along its propagation is caused by variation of refractivity of the medium with height and from place to place (Serdega et al., 2007&Agbo, 2011). The variation of meteorological parameters with time and period caused variation of refractivity of a place over a period of time. In most tropical countries like Nigeria, pressure, temperature and Relative humidity varies from early hour of the day to late hour of the day and also with seasons. There are basically two types of seasons; the dry season and rainy season. The dry season is characterising with low humidity, low rainfall, high temperature, and son on while rain season is characterised with high rainfall, high humidity, and moderate temperature and so on (Valma et al., 2010).

However, temperature, pressure and relative humidity also varies with the time of the day and also with height and varies from place to place. These parameters have effect on atmospheric refractivity of a place. These caused the signal either to experience sub refractivity; vacuum refractivity; Normal or standard refractivity; super refractivity; or ducting depending on the refractivity gradient (Okoro & Agbo, 2012). Hence, there is need to study the variation of these meteorological parameters in other to determine the type of refractivity that occur in a place.

In general, atmospheric pressure and water vapour pressure decrease rapidly with height in an exponential form while temperature decreases slowly with height. For the purpose of this study a linear decreasing rate with height is considered for the first 1km of tropospheric height (Falodun & Ajewole, 2006). The horizontal variation od refractivity is negligible in lower troposphere compare to the large scale vertical variation when dealing with a particular location but when moving from the coastal region in the extreme south to semi-arid region in the extreme north, horizontal variation of refractivity is very significant because of the high different in climatic variation (Guanjun & Shukai, 2000 &Gao et al., 2010).

This research utilizes both experimental results obtained from measurement of atmospheric refractivity and computational methods to simulate correlation and regression analyses of refractivity with metrological parameters in Jos. The equations that relate the refractivity with the meteorological parameters were proposed using different empirical equations and the correlation and regression analyses were done (Freeman, 2007). All the data used were collected from NIMET, Nigeria for the year 2014. The paper is organised as follows. The atmospheric refractivity equations are described in section 2, comparison of computational and experimental results were compared in section 3. The statistical results were discussed in section 4. Finally, conclusion is in section 5.

II. METHODS

The data were collected at a height of 100m above the ground. The refractivity, temperature, pressure and relative humidity were measured using refract meter and probe Rs 92.SGP Finnish company VAISALA with was equipped with barometer, thermometer and hygrometer. The balloon was attached to the probe filled with helium gas. The data were collected at an interval of 30minutes for 3-5minutes and average values were computed to represent the whole month. This was done for every January to December but eight months are selected to represent early dry season; November and December, late dry season; January and February, Early rainy season; April and May, and late rainy season; August and September.

Exponential regression, linear regression, power series regression, polynomial regressionand logarithmic regression with their Correlation analyses were investigated to know the best equation to represent or predict the refractivity when one of the metrological parameters is known.

Exponential equation is represented as follows:

$$refractivity, y = K_1 \exp^{\alpha x}$$

Where, K_1 is the exponential constant which represents minimum or maximum refractivity depends on α. For α > 0 is minimum, for α < 0 is maximum which is the rate of change of x, and x is the metrological parameter.

Linear equation is given as:

$$refractivity, y = ax + b$$

Where, b is the linear constant which represents minimum or maximum refractivity depends on a. For a > 0 is minimum, for a < 0 is maximum which is the rate of change of x, and x is the metrological parameter.

Power series equation is given as:

$$refractivity, y = Ax^n$$

Where, A is the power seriesor product coefficient, n is the power series and x is the metrological parameter.

Polynomial equation is given as:

$$refractivity, y = \beta_n x^n + \beta_{n-1} x^{n-1} + \beta_{n-2} x^{n-2} + \beta_{n-3} x^{n-3} + ... + \beta_1 x + \beta_0$$

Where, β_n, β_{n-1}, β_{n-2}, ---, β_0 are polynomial coefficients, n is the order and x is the metrological parameter. For this analysis, maximum value of n is 6.

Logarithmic equation is given as:

$$refractivity, y = B \ln x + C$$

Where, B is logarithm factor, C is the refractivity constant which can represent the maximum or minimum point and x is the metrological parameter.

III. RESULTS

The following graphs is the results of January, February, April, May, August, September, November and December which represents late dry season, early rainy season, late rainy season and early dry season respectively.

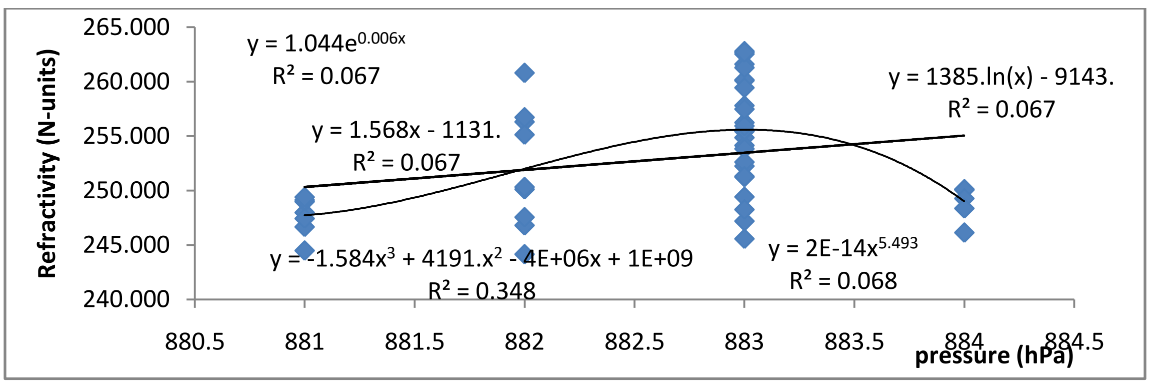

Fig. 1: characterised curve of refractivity with pressure in January, 2014

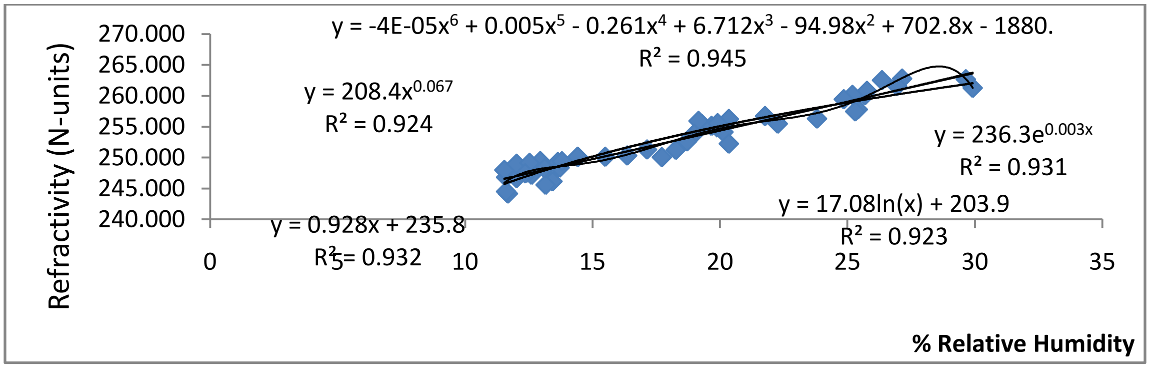

Fig. 2: characterised curve of refractivity with % relative humidity in January, 2014

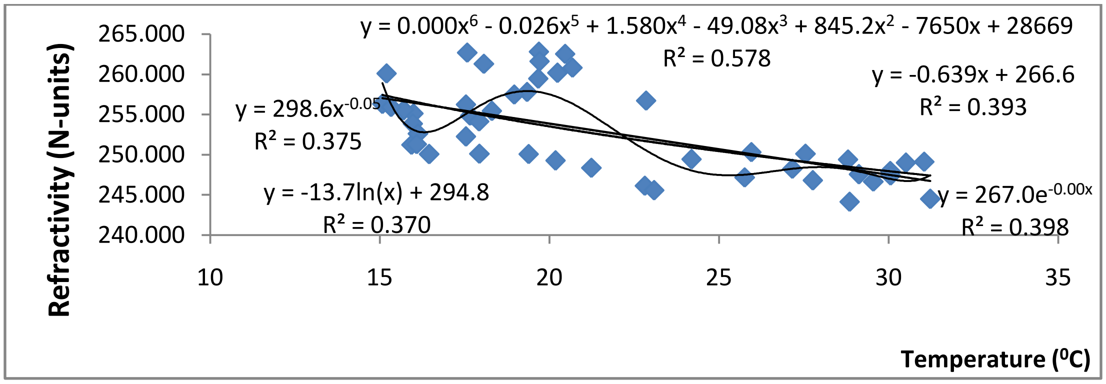

Fig. 3: characterised curve of refractivity with Temperature (^{0}C) in January, 2014

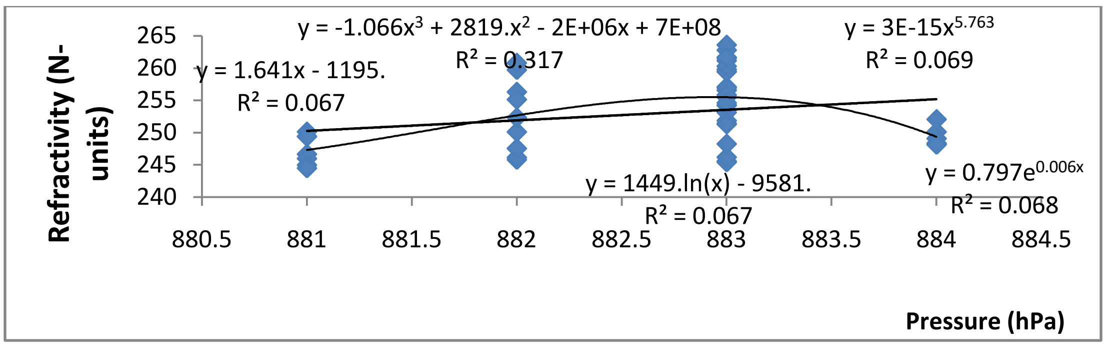

Fig. 4: characterised curve of refractivity with Pressure (hPa) in February, 2014

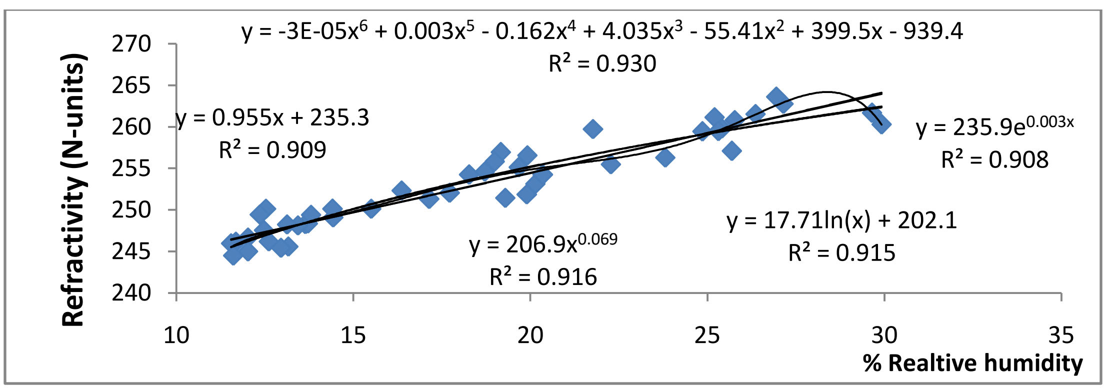

Fig. 5: characterised curve of refractivity with % Relative humidity in February, 2014

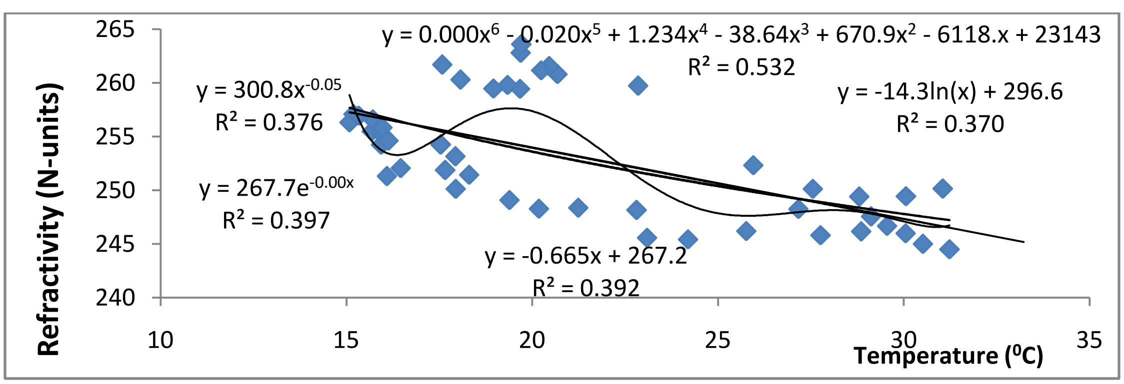

Fig. 6: characterised curve of refractivity with Temperature (^{0}C) in February, 2014

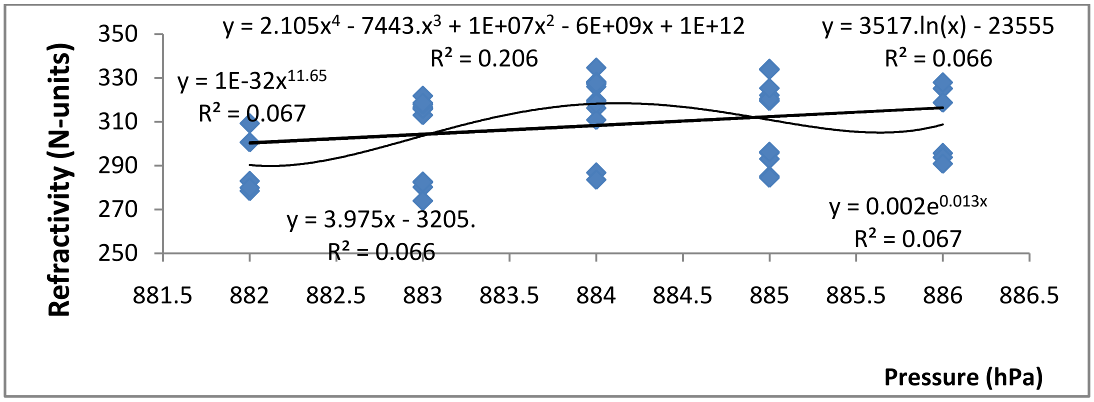

Fig. 7:characterised curve of refractivity with Pressure in April, 2014

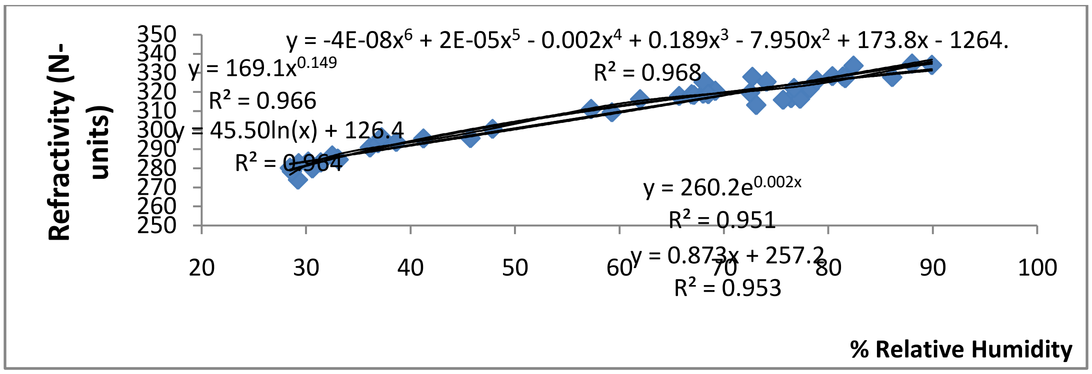

Fig. 8: characterised curve of refractivity with % Relative humidity in April, 2014

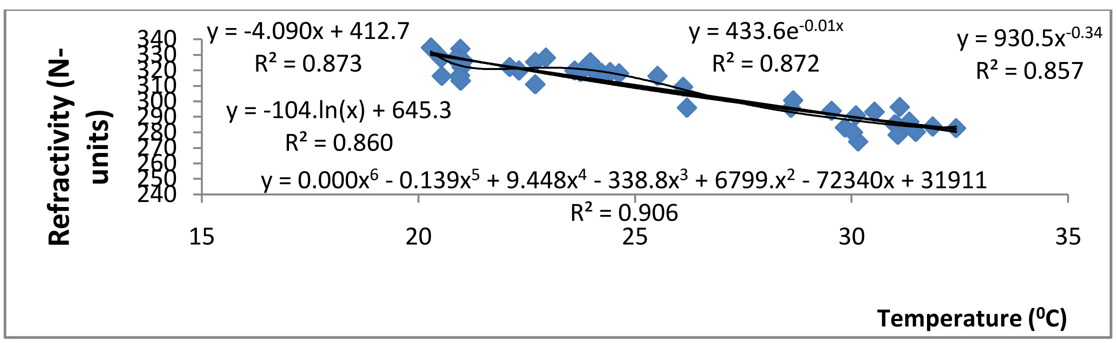

Fig. 9: characterised curve of refractivity with Temperature (^{0}C) in April, 2014

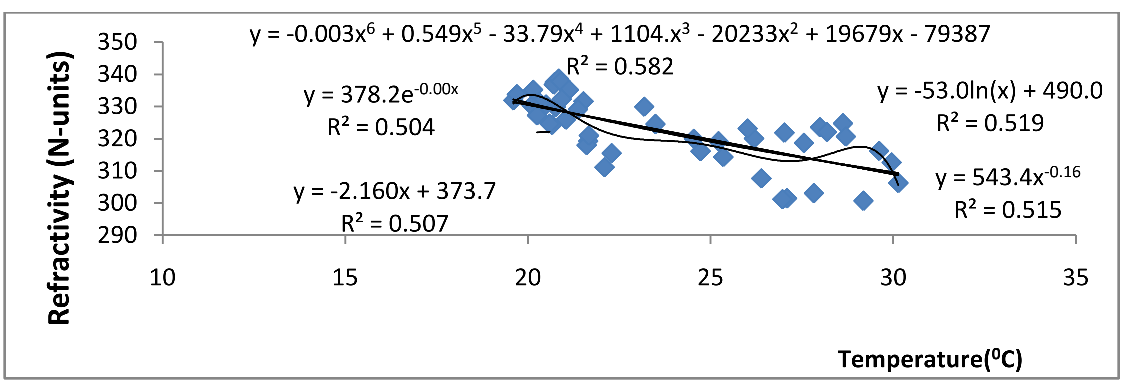

Fig. 10: characterised curve of refractivity with Temperature (^{0}C) in May, 2014

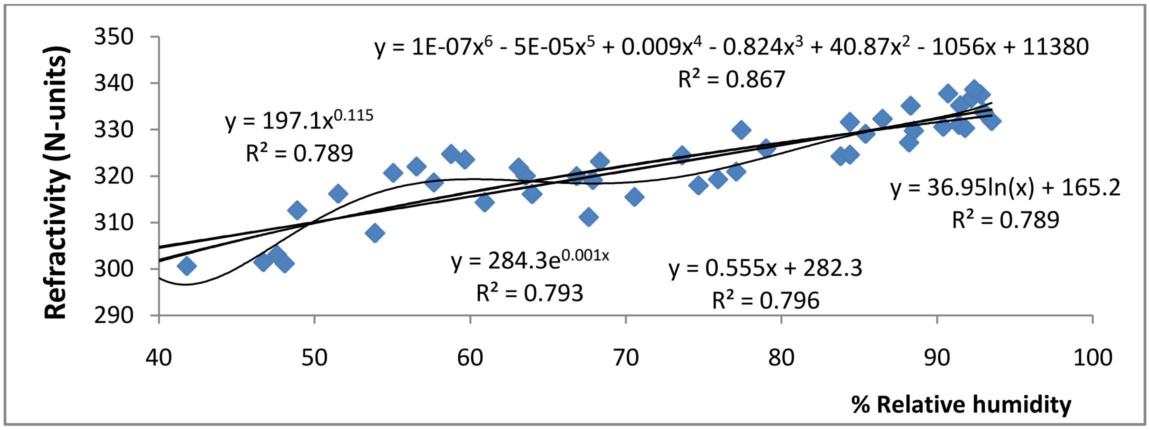

Fig. 11: characterised curve of refractivity with % Relative humidity in May, 2014

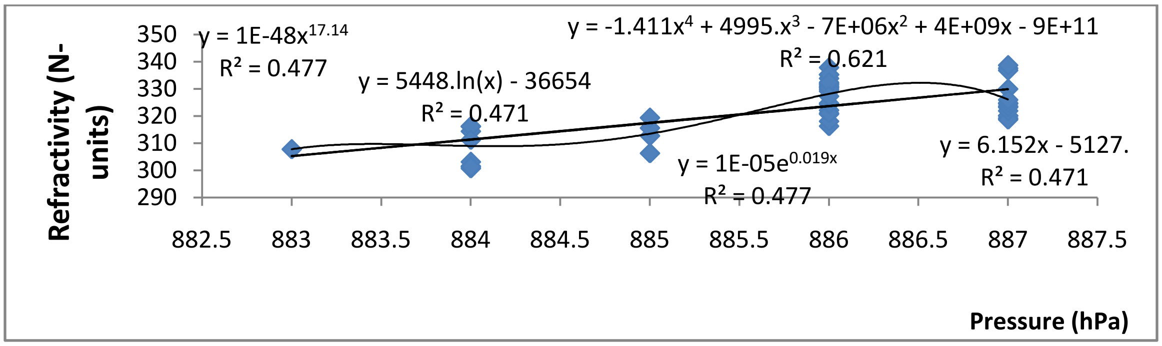

Fig. 12:characterised curve of refractivity with Pressure (hPa) in May, 2014

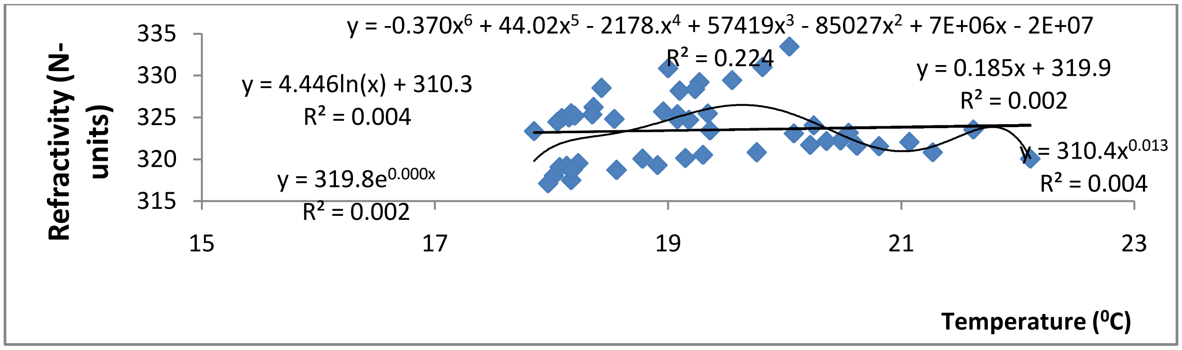

Fig. 13: characterised curve of refractivity with Temperature (^{0}C) in August, 2014

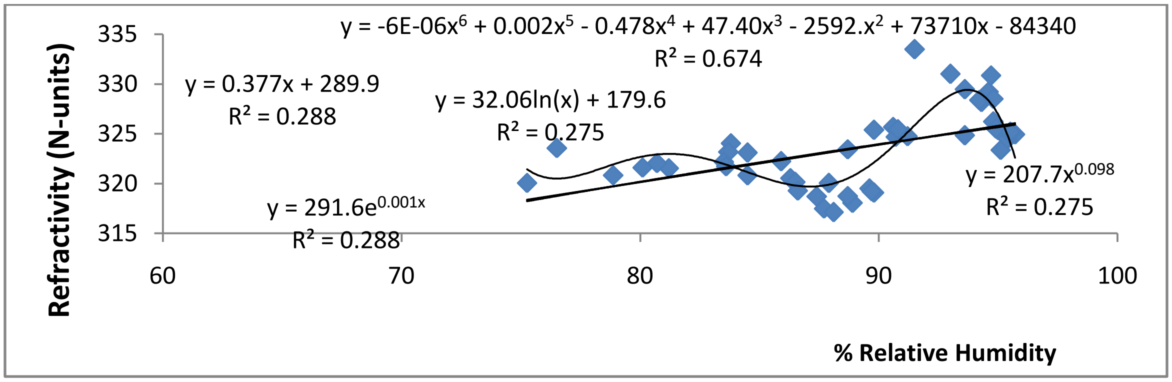

Fig. 14: characterised curve of refractivity with % Relative humidity in August, 2014

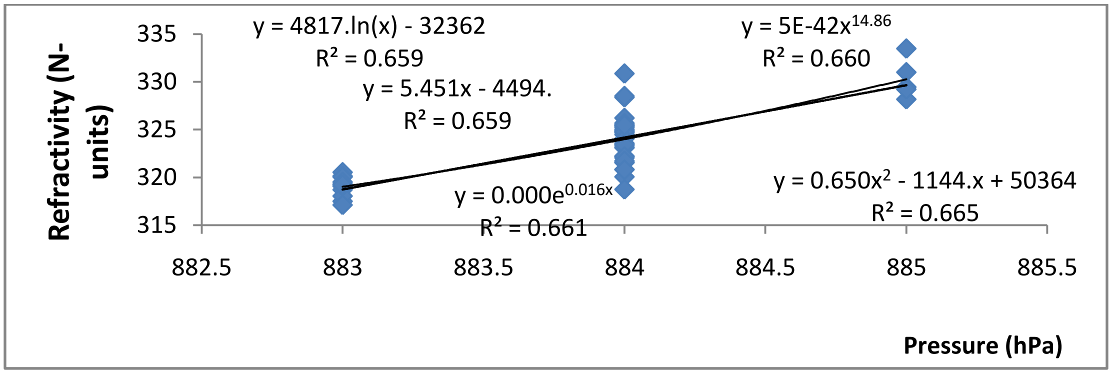

Fig. 15: characterised curve of refractivity with Pressure (hPa) in August, 2014

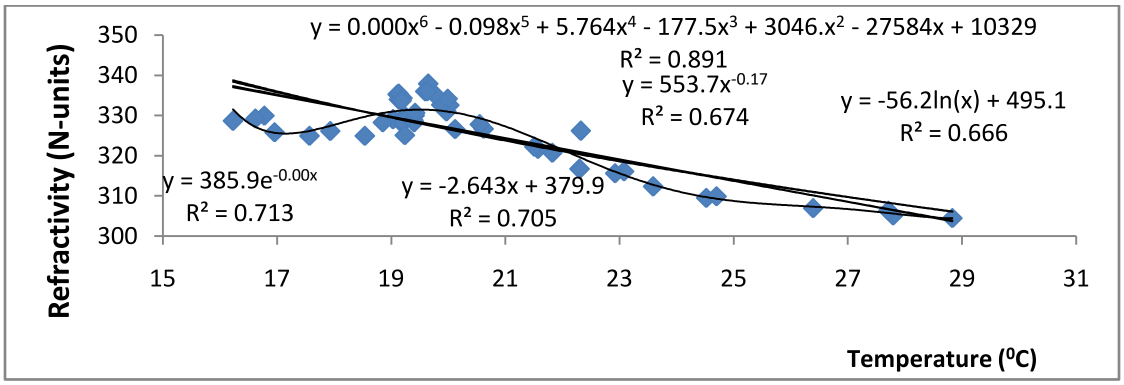

Fig. 16: characterised curve of refractivity with Temperature (^{0}C) in September, 2014

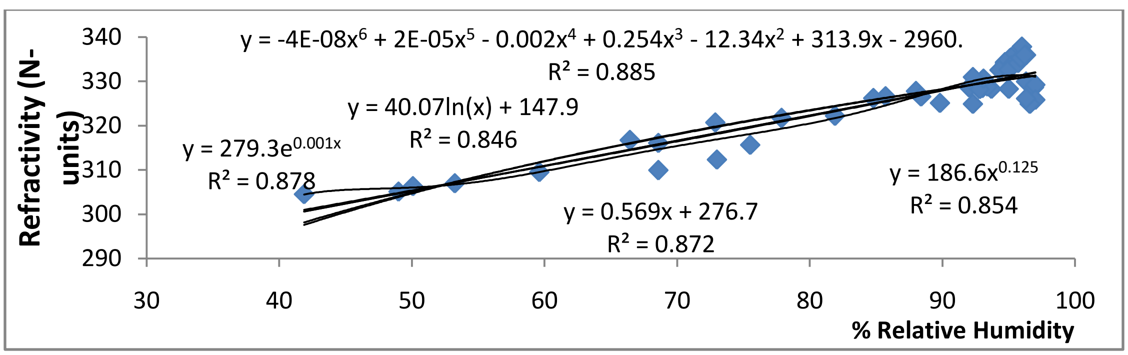

Fig. 17: characterised curve of refractivity with % Relative humidity in September, 2014

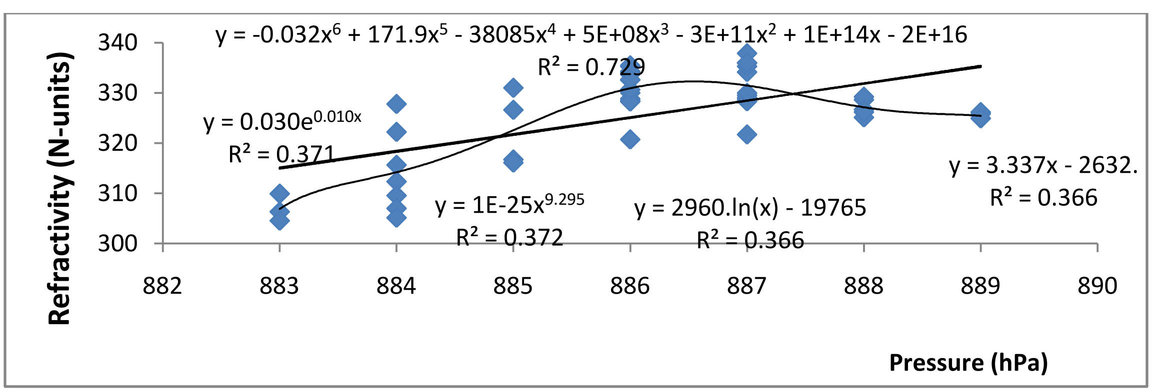

Fig. 18: characterised curve of refractivity with Pressure (hPa) in September, 2014

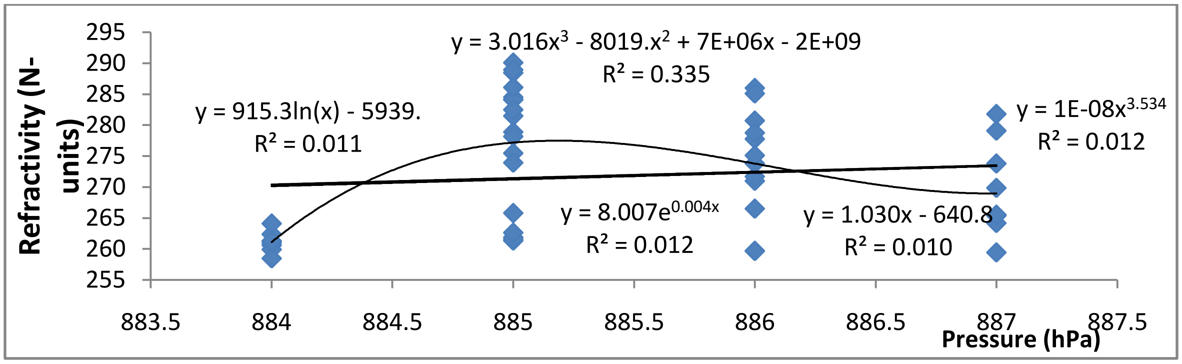

Fig. 19: characterised curve of refractivity with Pressure (hPa) in November, 2014

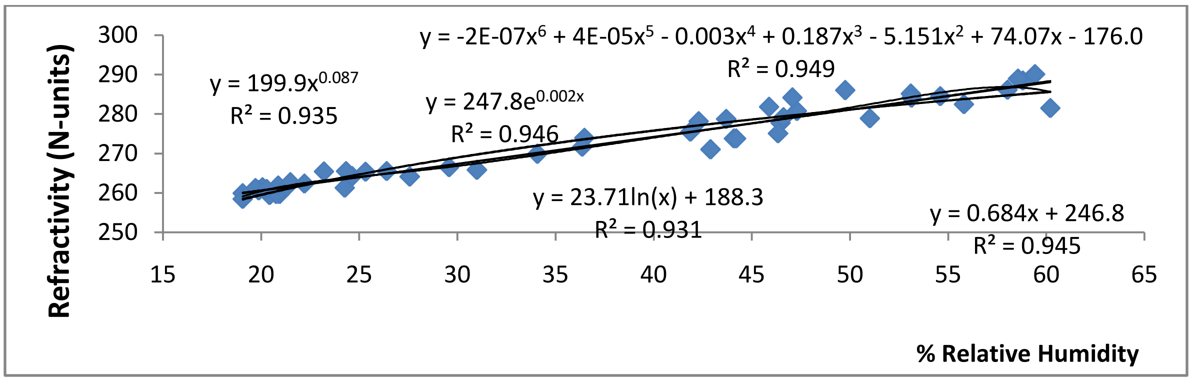

Fig. 20: characterised curve of refractivity with % Relative humidity in November, 2014

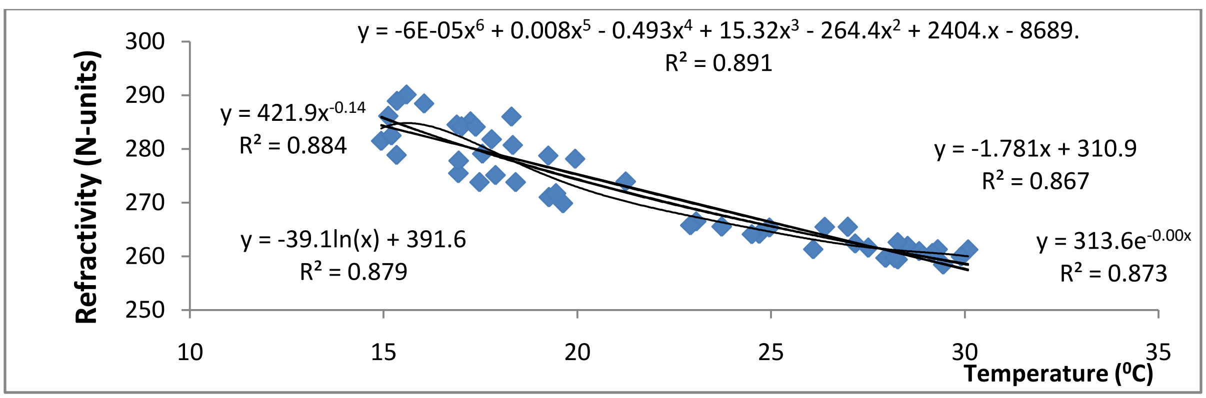

Fig. 21: characterised curve of refractivity with Temperature (^{0}C) in November, 2014

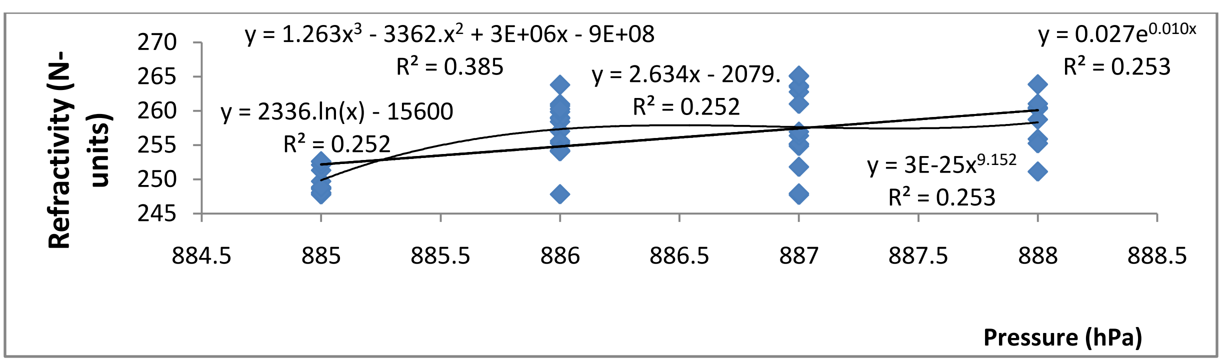

Fig. 22: characterised curve of refractivity with Pressure in December, 2014

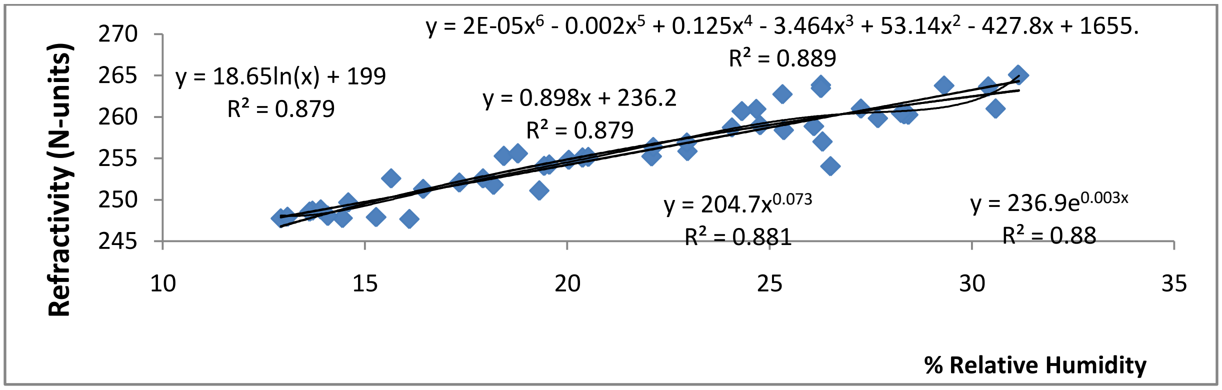

Fig. 23: characterised curve of refractivity with % Relative humidity in December, 2014

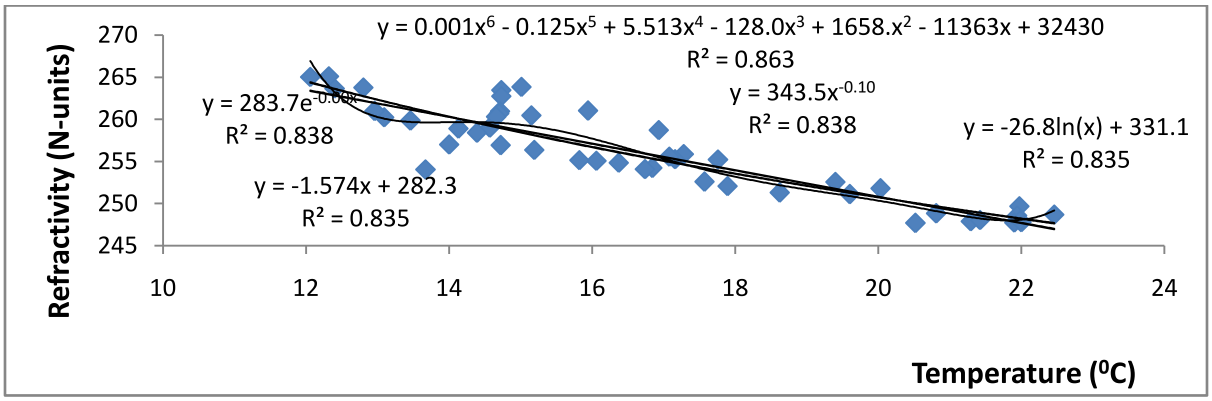

Fig. 24: characterised curve of refractivity with Temperature (^{0}C) in December, 2014

IV. DISCUSSION

From Fig. 1-24, polynomial series represents the best predicting equation for refractivity with pressure, temperature and relative humidity follow by exponential equation, linear equation, power series and logarithms. Although, the accuracy for pressure is very small but can be used to study variation with pressure. Also, there is increase in refractivity with increasing pressure and relative humidity and decreasing with increasing temperature.

Throughout the eight months, for linear equation, the best predicting equation for pressure, humidity and temperature are a = 5.4511N-units/hPa, 0.8736N-units/%, -4.0907N-units/^{0}C and b = -4494.6N-units, 257.23N-units, 412.7N-unitswith correlation of 0.6597, 0.9537, 0.87373 in the months of August, April respectively. For logarithmic equation, B = 4817.9N-units/hPa, 45.505N-units/%, -10.45N-units/^{0}C and C = -32362N-units, 126.47N-units, 645.32N-units with correlation of 0.6597, 0.964, 0.87373 in the months of August and April respectively.For exponential equation, K_1= 1 x 10^{-4}N-units, 260.23N-units, 433.67N-units and α = 0.0168/hPa, 0.0029, -0.013/^{0}C with correlation of 0.661, 0.9515, 0.872 in the month of August and April respectively. For power series equation, A = 5 x 10-42N-units, 169.15N-units, 930.37N-units and n = 14.868/hPa, 0.966, 0.8579/^{0}C and for polynomial equation, β_6 = -0.0323N-units/(hPa)^6, 4 x 10^{-8}N-units9 x 10^{-4}N-units/(^{0}C)^6 ; β_5 = 171.9N-units/(hPa)^5, 2 x 10^{-5}N-units,0.1398N-units/(^{0}C)^5; β_4 = -380851N-units/(hPa)^4, -0.0025N-units, 9.4489N-units/(^{0}C)^4; β_3 = 5 x 10^{8}N-units/(hPa)^3, 0.1891N-units, -338.88N-units/(^{0}C)^3; β_2 = 3 x 10^{11}N-units/(hPa)^2, -7.9509N-units, 6799N-units/(^{0}C)^2; β_1 = 1 x 10^{14}N-units/(hPa), 173.86N-units, -72340N-units/(^{0}C); and β_0 = 2 x 10^{16}N-units, -1264.9N-units, 319114N-units with correlation of 0.7291, 0.9686, 0.9061 in the month of August and April respectively.

For late dry season (January to March), the best predicting polynomial equation for pressure, relative humidity and temperature are β_6 = 0N-units/(hPa)^6, 4 x 10^{-5}N-units 2 x 10^{-4}N-units/(^{0}C)^6 ; β_5 = 0N-units/(hPa)^5, 5.3 x 10^{-3}N-units,-0.0268N-units/(^{0}C)^5; β_4 = 0N-units/(hPa)^4, -0.0025N-units, 1.5805N-units/(^{0}C)^4; β_3 = -1.584N-units/(hPa)^3, 0.1891N-units, -49.081N-units/(^{0}C)^3; β_2 = 4191N-units/(hPa)^2, -55.417N-units, -7650N-units/(^{0}C)^2; β_1 = -4 x 10^{6}N-units/(hPa), 173.99N-units, -1N-units/(^{0}C); and β_0 = 1 x

10^9N-units, -939.46N-units, 2806N-units with correlation of 0.3489, 0.9686, 0.5786 respectively.

For early rainy season (April to June), the best predicting polynomial equation for pressure, relative humidity and temperature are β_6 = 0N-units/(hPa)^6, 4 x 10^{-8}N-units, 9 x 10^{-4}N-units/(^{0}C)^6 ; β_5 = 0N-units/(hPa)^5, 2 x 10^{-5}N-units,0.1398N-units/(^{0}C)^5; β_4 = -1.4116N-units/(hPa)^4, -0.0025N-units, 9.4489N-units/(^{0}C)^4; β_3 = 4995.4N-units/(hPa)^3, 0.1891N-units, -338.88N-units/(^{0}C)^3; β_2 = -7 x 10^6N-units/(hPa)^2, -7.9509N-units, 6799N-units/(^{0}C)^2; β_1 = 4 x 10^9N-units/(hPa), 173.86N-units, -72340N-units/(^{0}C); and β_0 = -9 x 10^{11}N-units, -1264.9N-units, 319114N-units with correlation of 0.6656, 0.9686, 0.9061.

For late rainy season (July to September), the best predicting polynomial equation for pressure, relative humidity and temperature are β_6 = -0.0323N-units/(hPa)^6, 4 x 10^{-8}N-units 7 x 10^{-4}N-units/(^{0}C)^6 ; β_5 = 171.9N-units/(hPa)^5, 2 x 10^{-5}N-units, -0.0989N-units/(^{0}C)^5; β_4 = -380851N-units/(hPa)^4, -0.0029N-units, 5.7643N-units/(^{0}C)^4; β_3 = 5 x 10^8N-units/(hPa)^3, 0.2543N-units, 177.56N-units/(^{0}C)^3; β_2 = 3 x 10^{11}N-units/(hPa)^2, -12.348N-units, 3046.2N-units/(^{0}C)^2; β_1 = 1 x 10^{14}N-units/(hPa), 313.9N-units, --29584N-units/(^{0}C); and β_0 = 2 x 10^{16}N-units, 2960.4N-units, 103296N-units with correlation of 0.7291, 0.8858, 0.8917.

For early dry season (October to December), the best predicting polynomial equation are β_6 = 0N-units/(hPa)^6, 2 x 10^{-5}N-units 1.2 x 10^3N-units/(^{0}C)^6 ; β_5 = 0N-units/(hPa)^5, -0.0024N-units, -0.1257N-units/(^{0}C)^5; β_4 = 0N-units/(hPa)^4, 0.253N-units, 5.5138N-units/(^{0}C)^4; β_3 = 1.2638N-units/(hPa)^3, -34.042N-units, -128.01N-units/(^{0}C)^3; β_2 = 3362.8N-units/(hPa)^2, -53.147N-units, 1658.3N-units/(^{0}C)^2; β_1 = 3 x 10^6N-units/(hPa), -427.82N-units, -11363N-units/(^{0}C); and β_0 = -9 x 10^8N-units, -1655.8N-units, 32430N-units with correlation of 0.3853, 0.8895, 0.8915

V. CONCLUSION

The study shows that refractivity increases with pressure and relative humidity while decreasing with temperature. Polynomial series represents the best predicting equation for refractivity with % relative humidity, pressure and temperature; follow by exponential equation, linear equation, power series and logarithms. The best regression equation of refractivity with pressure, temperature and relative humidity is β_6 = -0.0323N-units/(hPa)^6, 4 x 10^{-8}N-units 9 x 10^{-4}N-units/(^{0}C)^6 ; β_5 = 171.9N-units/(hPa)^5, 2 x 10^{-5}N-units,0.1398N-units/(^{0}C)^5; β_4 = -380851N-units/(hPa)^4, -0.0025N-units, 9.4489N-units/(^{0}C)^4; β_3 = 5 x 10^8N-units/(hPa)^3, 0.1891N-units, -338.88N-units/(^{0}C)^3; β_2 = 3 x 10^{11}N-units/(hPa)^2, -7.9509N-units, 6799N-units/(^{0}C)^2; β_1 = 1 x 10^{14}N-units/(hPa), 173.86N-units, -72340N-units/(^{0}C); and β_0 = 2 x 10^{16}N-units, -1264.9N-units, 319114N-units with correlation of 0.7291, 0.9686, 0.9061 in the month of August and April respectively. The correlation of pressure, temperature and relative humidity ranges from 0.2067-0.7291, 0.2242-0.9061 and 0.6741-0.9686 respectively. The correlations in early rainy and dry seasons for humidity and temperature and late rainy for pressure have highest value. Other regression equations for humidity have better performance in humidity and worst in pressure.

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