Effect Of Latitudinal, Daily And Solar Activity Variations On Vertical Ionization Velocity For Maximum Peak Height For F2 Layer

Dr. Ali Hussein Ni'ma

Al-Mustansiriyah University, College of Science, Department of Atmospheric Sciences.

E-mail: draluqaily2014@gmail.com

Abstract:

This paper aims to calculate the vertical ionization velocity of maximum peak height of F2 layer of the ionosphere. Also, this paper deals with the effects of the latitudinal, daily and the solar activity variations on $\frac{\overline{dN_{m\,F2}}}{dt}$. Another goal is to construct a simplified correlations for $\frac{\overline{dN_{m\,F2}}}{dt}$ as a function of the latitude and month as a function of monthly mean sunspot number (MMSN). $\frac{\overline{dN_{m\,F2}}}{dt}$ has a greater value for winter season than for summer season. Also, the relation of the $\frac{\overline{dN_{m\,F2}}}{dt}$ with the monthly mean sunspot number MMSN shows an abnormal relation, also the hourly variation of $\frac{\overline{dN_{m\,F2}}}{dt}$ obeys the fact that the electron density have the minimum values at sunrise and sunset, and has a maximum value for January month.

Key words: Electron density, plasma frequency, continuity equation, plasma production, loss, ion drift, Plasma diffusion, F2 region, Maximum peak height.

تأثير تغيرات خطوط العرض، التغيرات اليوميه و النشاط الشمسي على سرعة التأين العموديه لارتفاع قمة طبقة F2

د. علي حسين نعمه

الجامعه المستنصريه/كلية العلوم/قسم علوم الجو

الخلاصه:

يهدف هذا البحث الى حساب سرعة التاين العمودية لطبقة F2 من الايونوسفير. كذلك يتناول هذا البحث تاثير الموقع الجغرافي، النشاط الشمسي و التغير اليومي على $\frac{dN}{dt}$. هدف اخر للبحث و هو انشاء علاقات رياضيه بسيطه بين $\frac{dN}{dt}$ كداله لخطوط العرض الجغرافي و الشهر من ناحيه ومن ناحيه اخرى كداله للنشاط الشمسي متمثلا بالمعدل الشهري لعدد البقع الشمسيه (MMSN). تكون قيمة $\frac{\overline{dN_{m\,F2}}}{dt}$ لفصل الشتاء اكبر منه لفصل الصيف. كذلك فان العلاقة بين $\frac{\overline{dN_{m\,F2}}}{dt}$ و المعدل الشهري لعدد البقع الشمسية MMSN يوضح علاقة غير طبيعية. كما ان التغير اليومي ل $\frac{\overline{dN_{m\,F2}}}{dt}$ يخضع للحقيقة القائلة ان الكثافة الالكترونية له قيم صغرى عند فترتي الشروق و الغروب وله قيمه عظمى في شهر يناير.

Introduction:

The ionosphere, having characteristics of plasma, is very sensitive to electromagnetic disturbances whose intensity and number vary with solar activity. These disturbances cause numerous complicated physical, chemical and dynamical phenomena in the lower ionosphere and may direct affect human activities, especially in the telecommunications industry. Due to a varying complex structure of the atmosphere and because of numerous influence coming from the earth and outer space, experimental simulations of processes in the ionosphere are very difficult [1].

The plasma continuity equation, which relates the change in electron (ion) density per unit time to production, loss and divergence of plasma flux, may be written as:

$$\frac{\partial N}{\partial t} = P - L - D.(Nv) \qquad (1)$$

Where N is the electron (ion) density, P and L are the production and loss rates respectively and v is the transport velocity [2].

A radio wave propagates through the ionosphere is affected by the chemical and physical prevailing within the medium. Consequently, information regarding the temporal and spatial distribution of electron and ion density and composition becomes important from the point of view of the communication engineers and for understanding the characteristics of the medium.

There have been many developments in the theoretical formulation and calculation of the ion and electron density distribution in the F-region and topside ionosphere. The validity of a model is checked using the most frequently measured ionospheric variables, namely, ionospheric total electron content (TEC), ionospheric critical frequency (foF2, foE) and bottom-side electron (ion) density profiles [3].

Many models have been proposed to predict the electron density distribution of ionosphere at low geo-magnetic latitudes (equatorial regions). Some of these models are theoretical, some of them are, partially theoretical, partially observational, the rest are purely empirical. A part from these, international reference ionosphere (IRI) models are also available for low and mid-geomagnetic latitudes.

All these models essentially use three parameters, namely hmF2 (height above ground at which maximum electron density occurs), NmF2 (maximum electron density in the F2 region) and Y_m (semi thickness of bottom side ionosphere) to generate the electron density profiles. The parameter vary as a functions of, geomagnetic latitude of the place, hour of the day, season (equinox, winter and summer) and solar activity [4].

In this study, we have to investigate the behavior of the rate change of electron density at the maximum peak height of F2 region, this parameter can be called as the velocity of the ionization over the ionosphere at hmF2 $\left|\frac{dN_{mF2}}{dt}\right|$.

Model used in the calculation

In this work, the rate change of ionization of F2 region has been calculated. Thus the term $\left|\frac{dN_{mF2}}{dt}\right|$ refers to the ionization velocity of the maximum peak height of F2 region. The diurnal variation of the maximum electron density NmF2 can been acquired using two models, firstly, real data of the global ionospheric radio observatory (GIRO). GIRO provides accurate specification of electron density profiles in the earth's ionosphere at more than 60 locations in the world. GIRO sites are equipped by Digisonde instruments that use high frequency remote sounding technique to probe bottom side ionosphere from 80 km up to the peak of ionospheric plasma density http://giro.uml.edu/ionogrammovies/. Secondly, the ionospheric parameter, NmF2 is estimated using the international prediction model, the International Reference Ionosphere (IRI) 2007 http://iri.gsfc.nasa.gov/.

The International Reference Ionosphere (IRI), a joint project of URSI (International Union of radio Science) and COSPAR (Committee on Space Research), is the de facto international standard for the climatological specification of ionospheric parameters and as such it is currently undergoing registration as Technical Specification (TS) of the International Standardization Organization (ISO). IRI by charter and design is an empirical model based on a wide range of ground and space data. It describes monthly averages of ionospheric densities and temperatures in the altitude range 50–1500 km in the non-auroral ionosphere. Since its inception in 1969 the IRI model has been steadily improved with newer data and with better mathematical descriptions of global and temporal variation patterns. A large number of independent studies have validated the IRI model in comparisons with direct and indirect ionospheric measurements not used in the model development [5].

Data assimilation and method of calculation

The area of study concerns on the locations doesn't taken in to account from the GIRO due to lack of some stations in the area of our study. The data used are the concentration of the maximum peak height of F2 layer which obtained using IRI2007 model. These data are taken for two seasons (winter and summer for the same year) with locations have different geographical latitude and the same longitude. The operation will be applied over the hourly electron density profiles (N_mF2 vs LT) for seven locations through the world for two seasons, the first for 15/6/2014 (summer season) and other for 15/1/2014 (winter season). The calculation will be achieved using the MATLAB Language.

The rate change of ionization velocity of electron density for maximum peak height of F2 region can be estimated using the following three steps:

1. Getting the electron density for the maximum peak height N_{mF2} using the application online IRI 2007 model.
2. The $\frac{dN_{mF2}}{dt}$ was calculated using the definition of differentiation which given by the following equation [6]:

$$\frac{df}{dt} = \frac{f(t,t+h)-f(t)}{\Delta t} \quad (2)$$

So,

$$\frac{dN_m}{dt} = \frac{N_m(t+h)-N_m(t)}{\Delta(t)} \quad (3)$$

where h is the time interval of local time and the output of the rate change equation is (n-1) where n is the number of observed data.

3. Calculate the average of the absolute value of the output of equation mentioned in point 2.

The second objective of this study is to describe and correlate the rate change of electron density with the solar activity for the same location. This study will adopt solar cycle 24 (year 2013) over geographical coordinate (Baghdad City with latitude $\lambda = 33^o.3$, longitude $\ell = 44^o.4$). Table (1) shows the Mean Monthly Sunspot Number (MMSN) for 2013 from January to December http://www.ips.gov.au.

Table (1): The mean monthly sunspot number for 2013 from January to December [9]

Month	1	2	3	4	5	6	7	8	9	10	11	12
MMSN	62.3	38	57.9	72.4	78.7	52.4	57	66	36.9	85.6	77.6	90.3

Results and discussions

In this study, the maximum electron density of F2 region acquired over twenty-four hours for seven locations through Worldwide and for two seasons. The main purpose of this study is to estimate and Correlate the rate change of electron density or velocity of ionization for F2 region as a function of different latitudes and solar activities.

Using the procedure for estimating the rate change of electron density mentioned above for (15/6/2014) and (15/1/2014) results in the following table, and configured in figure (1).

Table (2): The values of $\left|\frac{dN_{mF2}}{dt}\right|$ for two seasons and different latitudes

Location	$\left|\frac{dN_{mF2}}{dt}\right| \frac{m^{-3}}{h}$	
Longitude=44.4º Latitude (deg.)	15/1/2014	15/6/2014
0	1.02E+11	1.22E+11
13.3	1.58E+11	1.14E+11
23.3	1.69E+11	1.16E+11
33.3	1.05E+11	5.39E+10
43.3	1.04E+11	3.87E+10
53.3	9.72E+10	2.76E+10
63.3	7.31E+10	1.29E+10

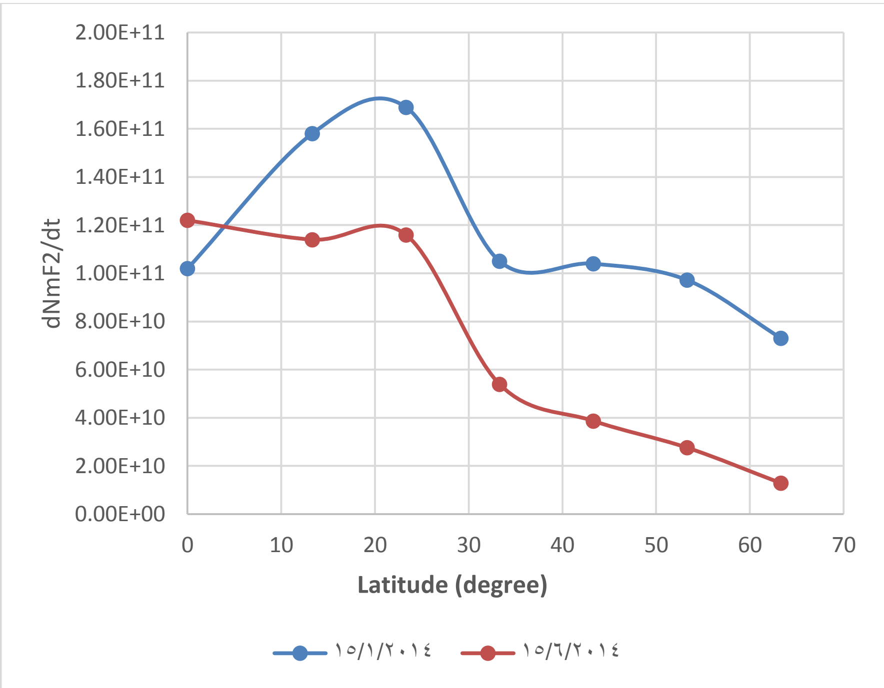

Figure (1): the variation of $\left|\frac{dN_{mF2}}{dt}\right|$ as a function of latitude for two seasons

From figure (1) it is seen that the rate change of ionization (velocity of ionization) for the maximum peak height of F2 region is decreasing through moving from the equator to pole, where at the low latitudes, this rate shows the abnormal behavior for two seasons. It can be noticed apparently that in winter there are known anomaly is called the equatorial or Appleton anomaly, instead of the electron density coming to a maximum over the equator, as we might expect, there is actually a minimum over the magnetic equator, and two maxima 10° to 20° north and south of it [7,8].

1. The correlation of $\left|\frac{dN_{mF2}}{dt}\right|$ as a function of Month and location

The correlation of $\left|\frac{dN_{mF2}}{dt}\right|$ as a function location and the month. Two steps must be achieved to get a simplified equations for specifying the correlation above. Firstly,

$$\left|\frac{dN_{mF2}}{dt}\right| = f(M, \lambda) \quad (4)$$

Where the relation with month results from graphing $\left|\frac{dN_{mF2}}{dt}\right|$ with the month results in fine straight line equation defined by:

$$\left|\frac{dN_{mF2}}{dt}\right| = a_o + a_1 * M \quad (5)$$

The coefficients a_o and a_1 are listed in table (3).

Table (3): The values of a_i resulted from regression of $\left|\frac{dN_{mF2}}{dt}\right|$ as function of seasons.

λ (degree)	a_o	a_1
0	9.8E+10	4E+09
13.3	1.668E+11	-8.8E+09
23.3	1.796E+11	-1.06E+10
33.3	1.1522E+11	-1.022E+10
43.3	1.1706E+11	-1.306E+10
53.3	1.1112E+11	-1.392E+10
63.3	8.514E+10	-1.204E+10

Secondly, concern with the correlation of the coefficients obtained above (a_i) with the locations of the study of area. The graph of the coefficients a_i with the locations are shown below in figure (2).

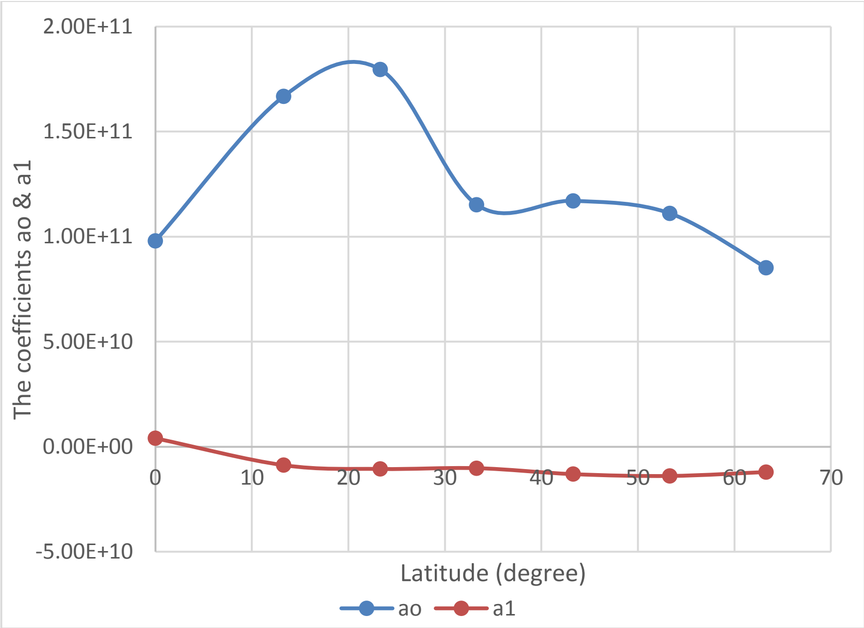

Figure (2): The coefficients a_o & a_1 as a function of latitude

For modelling the relationship between the coefficient a_o and the latitude of the area of study, the suggested power series (polynomial) equation has been adopted depending on the behavior of a_i on the latitude, which can be represented in the following form:

$$a_o = \sum_{i=0}^{n} b_i * \lambda^i \qquad (6)$$

Where a_o is the predicted coefficient (equation 5), λ is the latitude of the study's location, b_i is the polynomial coefficient and n is the order of the polynomial. Equation (6) can be expanded as follow:

$$a_o = b_o + b_1 \lambda + b_2 \lambda^2 + b_3 \lambda^3 + \ldots\ldots\ldots\ldots\ldots\ldots + b_n \lambda^n \qquad (7)$$

In the present work, the best order (n) of the above polynomial (equation 7) is 5 which gives an (6) unknown coefficients (b_o, b_1, b_2, b_3 , b_4 and b_5) which is obtained using the nonlinear curve fitting and the Gaussian elimination methods, gives the following resulted coefficients: b_o= 9.76E10, b_1=5.118E09, b_2= 3.6458E09, b_3=-3.469E07, b_4=7.838E05, and b_5=-5.4937E03. So, equation (7) results in the following form:

$$a_o = 9.76E10 + 5.118E09\lambda + 3.6458E09\lambda^2 - 3.469E07\lambda^3 + 7.838E05\lambda^4 - 5.493E03\lambda^5 \qquad (8)$$

The second coefficient (a_1) can be correlated with the latitude by a power series of polynomial of order (3), so,

$$a_1 = c_o + c_1\lambda + c_2\lambda^2 + c_3\lambda^3 \quad (9)$$

Where c_o=-3.4077E09, c_1=-1.0629E09, c_2=2.3111E07, c_3=-1.6325E05. Equation (9) can be written as:

$$a_1 = -3.4077E09 - 1.0629E09\lambda + 2.3111E07\lambda^2 - 1.6325E05\lambda^3 \quad (10)$$

To illustrate the adequacy of the regression model for the rate change of ionization as a function of month (M) and the location of the area of study (λ). The quantity [9]:

$$R^2 = \frac{\sum(y_{est} - \bar{y})^2}{\sum(y - \bar{y})^2} \quad (11)$$

is called the coefficient of correlation, must be carried out for results of the non- linear regression which resulted in two coefficients (equation 5). The coefficients of correlation for both a_o and a_1 are **93.09%** and **94%** respectively, which gives a high positive correlation.

2. The correlation of $\left|\frac{dN_{mF2}}{dt}\right|$ as a function of monthly mean Sunspot number MMSN

The second objective of this study concerns in studying the relation between the rate changes of ionization for the maximum peak height with the monthly mean sunspot number and correlate this relation. Figure 4 shows the values of $\left|\frac{dN_{mF2}}{dt}\right|$ as a function of MMSN and for 2013.

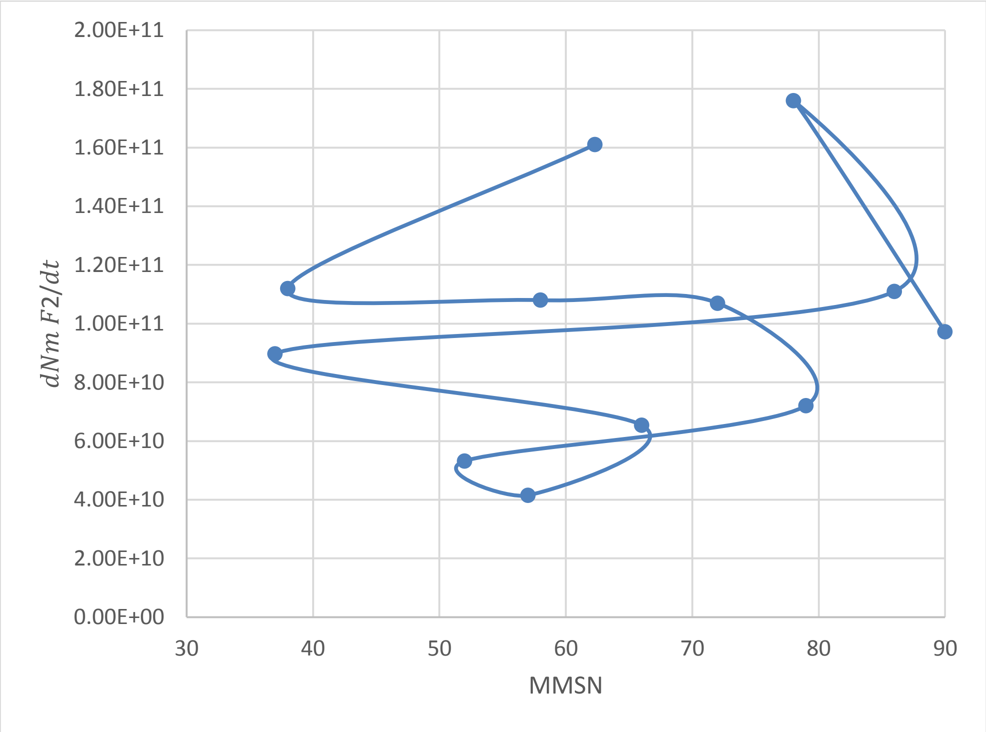

Figure 4: the values of $\left|\frac{dN_{mF2}}{dt}\right|$ as a function of MMSN and for 2013.

From figure (4), it is seen that the variations of $\left|\frac{dN_{mF2}}{dt}\right|$ with the monthly mean sunspot number has an irregular behavior which means that there are no positive nor negative correlation between them, in other word, the increases of solar activity doesn't affect the variation of rate change of ionization of F2 peak.

3. The hourly variation of $\left|\frac{dN_{mF2}}{dt}\right|$

Using the results of the variation of the rate change of ionization density with different solar activities for 2013, an enticing fact about the hourly variation of ionization, the high variation of ionization (large value of $\left|\frac{dN_{mF2}}{dt}\right|$) during the time of sunrise and sunset which explain the reversion of the case from the losses of ionization during the recombination and drift to high altitude (for F2 region) to the ionization after sunrise and a reverse process occurs in the sunset. Figure (5) shows the value of the $\left|\frac{dN_{mF2}}{dt}\right|$ with the local time for 2013 from 15 January to December.

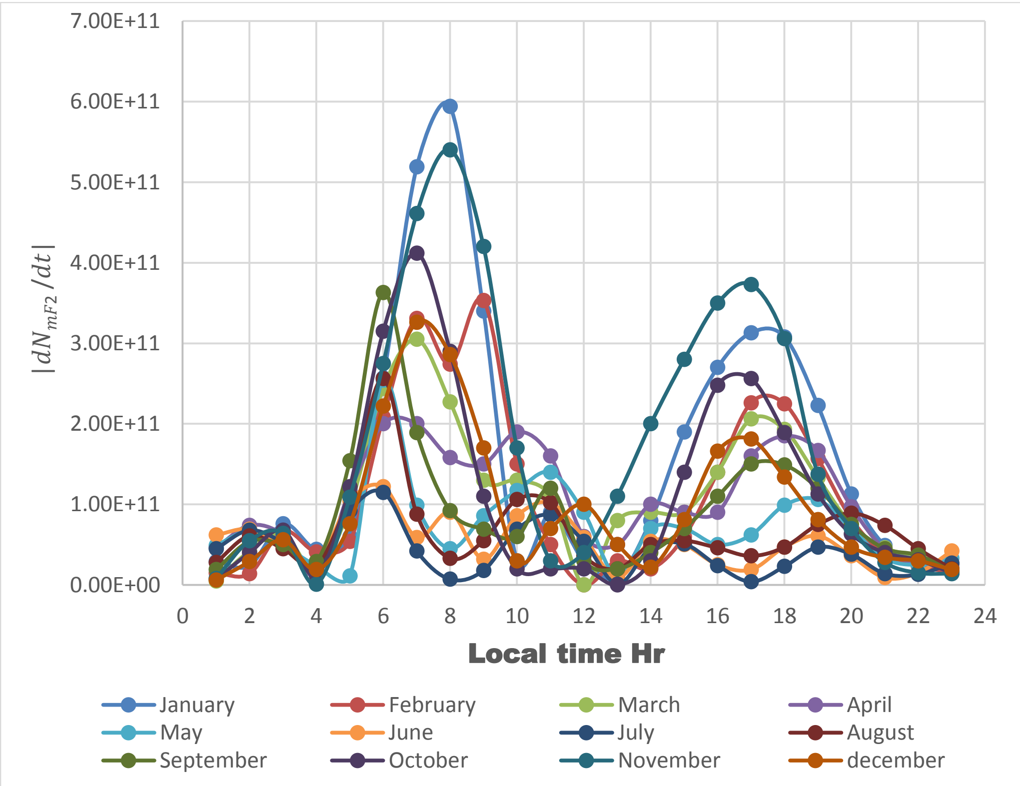

Figure (5) the hourly variation of $\left|\frac{dN_{mF2}}{dt}\right|$ for 2013 from January to December

From figure (5) it is seen that the hourly variation of rate of ionization for F2 peak has a maximum value at the local time interval (6-8 hr) located at sunrise and (16-18) at sunset. The maximum of this variation occurs for January.

Conclusions

More important conclusions have been investigated about the rate change of ionization for F2 peak over different locations and solar activities. $\overline{\frac{dN_{m\,F2}}{dt}}$ for winter season has a greater value than for summer season. Also, the relation of the $\overline{\frac{dN_{m\,F2}}{dt}}$ with the monthly mean sunspot number MMSN shows an abnormal relation which doesn't give any clear correlation between them. Finally, the hourly variation of $\overline{\frac{dN_{m\,F2}}{dt}}$ obeys the fact the electron density have the minimum values at sunrise and sunset, and has a maximum value for January month.

References

1. H. Rishbeth, "The equatorial F-layer: progress and puzzles". Ann. Geophysicae, Volume 18, pp 730-739, (2000).
2. P K Bhuyan & P K Kakoty, "A modeling study of Indian low latitude ionosphere-part I: description of the model". Indian Journal of Radio and Space Physics, Volume 30, pp 59-65, April 2001
3. P. K. Bhuyan & P. K. Kakoty, "A modeling study of Indian low latitude ionosphere-part II: Results and comparison with SROSS-C2 satellite data". Indian Journal of Radio and Space Physics, Volume 30, pp 66-71, April 2001.
4. S. Sukumar, "Ionospheric Refraction Effects on Radio Interferometer Phase". Journal of Astrophysics and Astronomy, volume 8, pp 281-294. 1987.
5. D. Bilitza & B.W. Reinisch, "International Reference Ionosphere 2007: Improvements and new parameters". Advances in Space Research, volume 42, pp 599–609. 2008
6. Burden R. L. and Faires J. D." Numerical Analyses", 9th Edition, Brooks/Cole, Cengage Learning, 2011.
7. J. K. Hargreaves, "The solar-terrestrial environment, an introduction to geospace - the science of the terrestrial upper atmosphere, ionosphere and magnetosphere". Cambridge University Press 1992.
8. Michael C. Kelley, "The Earth's Ionosphere. Plasma Physics and Electrodynamics", 2nd Edition, Elsevier Inc.2009.
9. C. M. Douglas & C. R. George, "Applied Statistics and Probability for Engineers". Third Edition, John Wiley & Sons, Inc.2003.