Studying the Relationship between TEC, I95 Index and Wp Index and Affect Them on Ionosphere in Iraq, Romania and South Africa

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***Abstract*—This article study the state of Ionosphere in some continents across the world, spots had been chosen in South Africa, Europe, and Asia. The Ionosphere in these spots are so different and they have different TEC because they are located different coordinates in Longitude and Latitude in the Earth. The Ionosphere has activity points based on the solar wind and another parameter, this can affect the signal that transmitted from the ground station to the Satellites. This article has been used some programs that simulated the perturbations because of the activity in the Ionosphere, Three different models have been used, Nequick model, IRI Plaz-2017 and Trignet from 0 to 1000Km. The goal of this paper to study the Ionosphere with different indices to confirm the disturbance of the Ionosphere. Nequick model at 2016, 2018 for IRI-Plaz 2017 and 2018 for Trignet the date for study. These results produce that the Ionosphere activity and conductivity for reflection signals are hard in the Equatorial region compared to the Poles.**

***Index Terms*—SWIPOSS, TRIGNET, Nequick model, TEC**

I. Introduction

The Ionosphere is a wastage medium for radio alerts, so by meeting measurements at the equal time on frequencies dispatched by using a satellite, most of them have an impact on of the Ionosphere may be destructed [1], [2]. But, a unique frequency system which includes most car navigation and reachable receivers don't take the luxury the correction of twin-frequency. These systems ought to depend upon an unmarried-frequency correction model [3]. The measurements which are dependent for one of these versions comprise within the navigation messages transferred by all GPS satellites. Known as the Ionosphere Correction algorithm or Klobuchar set of rules, it eliminates at the least 50 percent of the Ionosphere's effect [4], [5].

II. State of Art

In [6], TEC for high latitudes has been investigated by two IRI-Plas and NeQuick models in Lovozero. TEC is updated by two stages, firstly by changing the azimuth angle and keep the elevation angle 45°. Secondly the total area of 360° was divided into 20 subsectors. In [7], Wp index has been investigated for at latitudes 60°N to 60°S with a phase of 5° and longitudes 0° to 345°E with a stage of 15° given that the data for 00:00 to 23:00h of local time. The level disturbance, DTEC, was computed as a log of TEC belong to soft changes in the median for 27 days. In [8], TEC was measured at same time and analyzing by dual frequency signals of GPS in two regions north Nigeria Ahmadu Bello University Zaria (ABUZ) at latitude (11.16°N) and Longitude (7.65°E) and Birnin Kebbi Polytechnic (BKFP) at latitude (12.46°N) and Longitude (4.20°E) at 2013. The results show that TEC is not stable and there are maximum and minimum values for TEC. These parameters are important to evaluate the state of the Ionosphere. Trignet model was used with all previous parameters to check the perturbations of the Ionosphere. Trignet uses several sensors are distributed in South Africa, these sensors work as receivers.

They receive all signals are reflected from the Ionosphere on multi-altitudes. Trignet is a network is connected with GNSS base stations covering South Africa. All of them managed by single control station in (NGI). It comprises now 55 operational stations and further station under planning for execution. Trignet will add to this work further confirmation on the results.

III. Related Works

In [9], the modification in the pathway is due to the structure of electron density in the ionosphere and the existence of Ionosphere horizontal slope, which effects lower carrier frequency (L2) to refract larger than the upper carrier frequency (L1). In [10], the expectation of the Ionosphere delay is significant as it affects a delay in ranging quantities which in produce an error in navigation explanation. It is detected that the worst range delay of 8.57m for L1 frequency is acquired at 14:00thhr of the day. In [11], the convenience of Ionosphere perturbation indices presently under expansion will improve the approval of GNSS-based Ionosphere data services at the operator level. This work has been used these different articles to evaluate the disturbance by three different models. In [3] The article introduced of D region absorption, critical angles, and critical frequencies. By using the Solar Eclipse QSO Party (SEQP) Rules. The

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signals with frequency 14MHz will refract at altitude <125km with a low angle. If the angle of elevation will increase then the refracted frequency signal will be reduced.

IV. TEC Models Explanation

Considerable more simple than the use of actual TEC maps, requiring a permanent Ionosphere monitoring, is the use of prototypical data. Empirical simulations of the Ionosphere provide a climatological approximation of the Ionosphere ionization [12]. Storm examples equations capable to define robust disturbances of the electron density and its distribution. For assessing the trans-Ionosphere time delay or range error, several Ionosphere models are currently available e.g.:

- GPS correction model or Klobuchar model used for GPS
- NeQuick 3D model planned to be used for Galileo

A. Klobuchar Ionosphere Model

GPS satellites transmission the factors of the Klobuchar Ionosphere model for one frequency users. The Klobuchar model was intended to reduce user calculation difficulty and user computer storage as far as to keep the lowest number of coefficients to transmit on a satellite-user link. This broadcast model is created on an empirical approach [Klobuchar, 1987] and is estimated to decrease about the 50% RMS Ionosphere range error worldwide [10]. (Fig. 1 and Table I)

$$\sigma_{ion}^{i} = \frac{e^2}{8\pi^2 m\varepsilon_0 c f^2}\, I_{slant}^{i} \equiv \frac{I_{slant}^{i}}{A} \qquad (1)$$

TABLE I. The Constant in Equation (1)

1	e	Electron charge.
2	f	Frequency of signal transmitted.
3	m	mass of electron
4	c	Speed of light

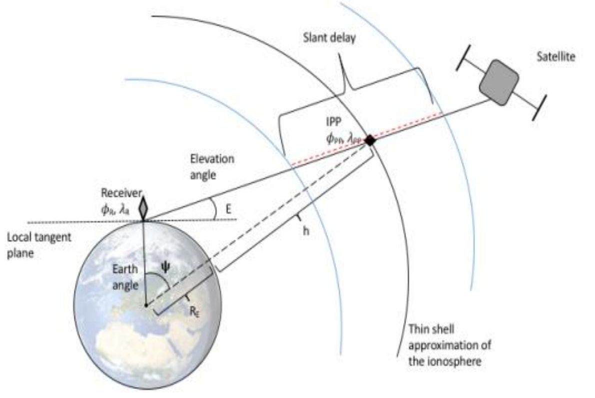

Figure 1. IPP points determination by Klochubar method [13].

When I substitute the physical constants, m_e, q, ϵ_o, with 5 significant digits the first, second and third order coefficients, s_1, s_2 and s_3, read (note that the International System of Physical Units (SI) is used, e.g. a magnetic field is expressed in Tesla):

$$s1 = 40.3 \int_T^R N_e * dl \qquad (2)$$

B. Nequick Model

NeQuick 2 is the up-to-date form of the NeQuick Ionosphere electron density typical used and evolved at the Aeronomy and Radio Propagation Laboratory (now T/ICT4D Laboratory) of the Abdus Salam International Centre for Theoretical Physics (ICTP) - Trieste, Italy with the cooperation of the Institute for Geophysics, Astrophysics and Meteorology of the University of Graz, Austria. The NeQuick is a modern and highly dependent Ionosphere electron density exemplary, representative particularly intended for trans-Ionosphere broadcast requests. To outline the electron density of the Ionosphere up to the peak of the F2 layer, the NeQuick procedures a profile system which comprises 5 semi-Epstein layers with showed thickness parameters. 3 profile anchor factors are processed: the E layer peak, the F1 height and the F2 top, which might be displayed in terms of the Ionosonde parameters foE, foF1, foF2 and M (3000) F2. These values may be modelled (e.g. ITU- R coefficients for foF2, M3000) or practically analyzed. A semi-Epstein layer signifies the model topside with a rather based thickness parameter empirically determined. The NeQuick system the electron density for positions inside the Ionosphere with peak, geocentric latitude and geocentric longitude as a coordinate on a spherical earth. Sun interest is extraordinarily impact thing in TEC (given through month-to-month-suggest sunspot variety R12 or 10.7 cm solar radio flux F10.7) season (month) and time (popular Time UT). The NeQuick package consists of workouts to compute the electron density factor to stop point any ground-to-satellite straight line ray-path and the corresponding Total Electron Content (TEC) by numerical integration [7].

C. Hartly Appleton Equation

Hartly Appleton equations depend on refraction index.

The error distance between the transmitter and receiver. The error distance highly depends on electron density. The error distance a1 is used in this work [14].

$$n^2 = f(variables) general\ formula \qquad (3)$$

$$\delta_{error} = \int_T^R c\,\frac{dl}{v} - \rho = \int_T^R (n-1)\, dl \qquad (4)$$

$$a_1 = (40.3).\int_{T_X}^{R_X} N_e\, dl \qquad (5)$$

$$\delta_{error} = -\frac{a_1}{f^2} - \frac{a_2}{f^3} - \frac{a_3}{f^4} \qquad (6)$$

D. Planetary Ionosphere-Plasmasphere Storms from JPL GIM-TEC IONEX Maps

The mark of DTEC states the positive or negative phase of the Ionosphere disturbance. A sliding reference, TECmed consider the time equivalent median of 27 days earlier a day of observation. It is presumable that the period of 27 days, matching to the solar cycle, produce the median value that might also be valid for the 28th day.

$$DTEC = log(TEC/TECmed) \qquad (7)$$

E. By Using I95 Index

With the instalment of dense GPS reference station networks, unique correction fashions of distance-established biases that are especially caused by atmospheric refraction could be produced for the primary time. These correction models are based totally on the ambiguity-resolved service segment. Observations and are thus able to record differential. Atmospheric effects with millimetre to centimetre accuracy. The I95 Ionosphere index is based on these Ionosphere model coefficients (Wanninger 1999). In order to condense their information content every two corresponding coefficients are combined by

$$\nabla I = \sqrt{\nabla I_{LAT}^2 + \nabla I_{LON}^2} \quad (8)$$

I95 index is a statistical figure supplying statistics on the number of differential Ionosphere biases as they are tested by workers of differential GPS positioning. The index is calculated from dual-frequency ambiguity-fixed carrier phase observations, which permit the approximation of the differential Ionosphere biases with subcentimeter accuracy (L1). A single I95 value combines the differential Ionosphere biases of all accessible satellite signals of at least 2 baselines (at least 3 reference stations) into a single number. I95 index values do not only depend on the ionosphere circumstances but also on some other factors, as e.g.:

- GPS reference station distances and elevation mask angle
- I95≤2: a small quantity of electron content and is not disturbed by Ionosphere conditions.
- 2≤I95≤5: large electron content but no anomalies.
- I95 values of 10 or even more: average scale instabilities, whereas small-scale instabilities can reason even larger values [15].

V. Simulations and Analyses

A. By Using Nequick Model

Nequick model depends on (IPP), this point determines the highest point of electron density in the Ionosphere. The results of the Nequick model is very relative to the Klobuchar Ionosphere Model. The Nequick model is used to check the Ionosphere state in 2016 in Iraq and Romania regions (Fig. 2 and Fig. 3). This model showed that Iraq suffers from higher TEC than Romania. This belongs to that Iraq is closer to the Equatorial region. The electron density is much more ionized in the Equatorial region than high latitudes. (Table II and Table III)

TABLE II. Minimum and Maximum Points of TEC at Iraq Space

No.1	TECU	Elevation angle
Min	1.18	89
Max	3.74	5

TABLE III. The Minimum and Maximum Points of TEC at Romania Space

No.1	TECU	Elevation angle
Min	1.57	89
Max	2.65	5

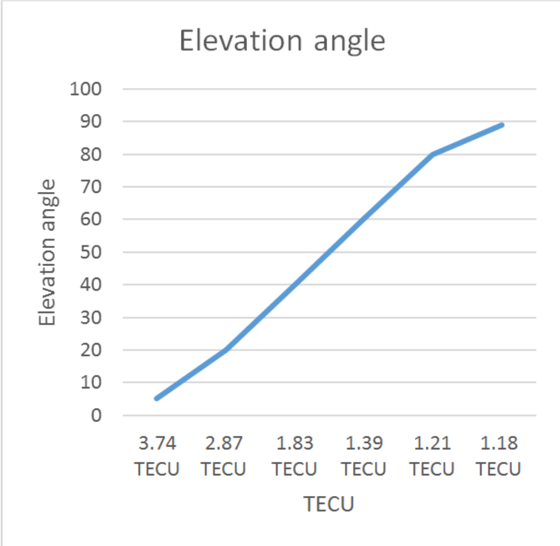

Figure 2. This plot shows how TEC change with different elevation angles at Iraq.

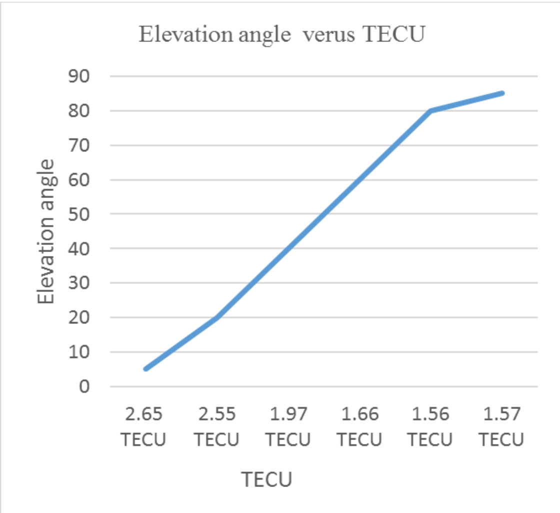

Figure 3. This plot shows how TEC change with different elevation angles in Romania.

B. By Using IRI-Plaz 2017

By using IRI-Plaz 2017 model that depends on electron density. The input parameters of this model are the coordinates if Iraq and Romania regions (Fig. 4 and Fig. 5). By the equations were used to produce the error distance. The error distance is an important parameter to evaluate the perturbations of the Ionosphere by using GPS signals. The mean value error distance in Iraq is about 15 meters, but in Romania region is about 11 meters. These results confirm the IRI-Plaz is efficient parameters and produce logical results for the Ionosphere state. (Table IV and Table V)

TABLE IV. Mean Value for Iraq Region in Summer

Index	Distance in Ionosphere in [km]	Error distance in a meter for GPS signal [m]	Estimation
1	350	15	Maximum
2	200	6	Minimum
3	1000	3.5	Medium

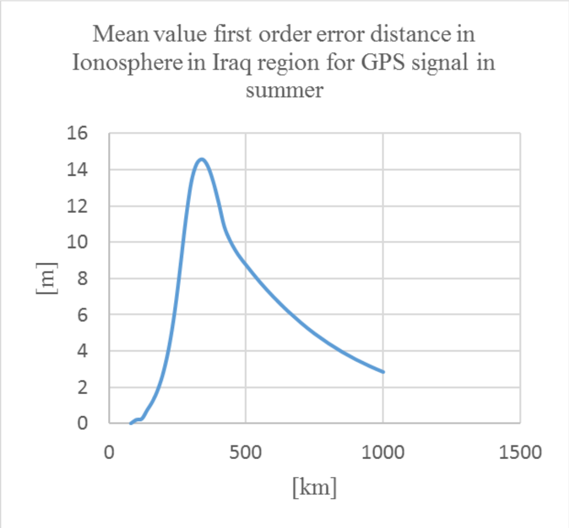

Figure 4. Mean value first order error distance in Ionosphere in Iraq region for GPS signal in summer.

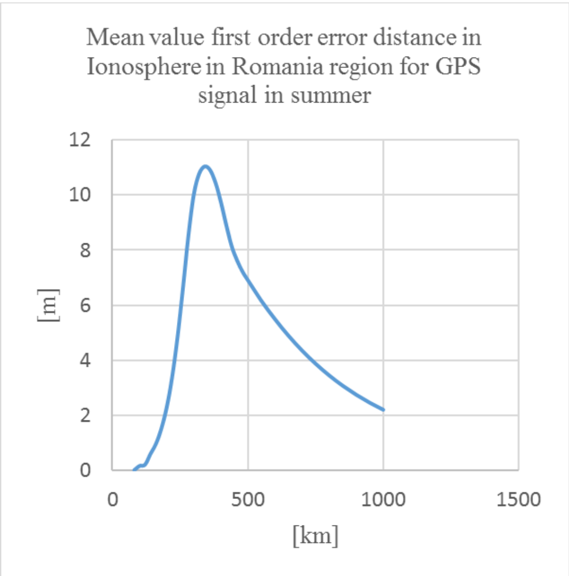

Figure 5. First order the delay in Ionosphere Region at Summer Romania coordinates for GPS signal.

TABLE V. MEAN VALUE FOR ROMANIA REGION IN SUMMER

Index	Distance in Ionosphere in [km]	Error distance in meter for GPS signal [m]	Estimation
1	350	11.5	Maximum
2	200	2	Minimum
3	1000	2.2	Medium

C. By Using Planetary Ionosphere-Plasmasphere Storms from JPL GIM-TEC IONEX Maps

The image represents the disturbance Wp index the state of Ionosphere along 1994 to 2017 and graph shows this disturbance is not systematic but it is chaos according to the solar wind and other effect and this parameter is very important to describe the TEC because when Wp index increase TEC will also increase and then the modification on signal transmitted will be higher. The decimal logarithm of the hourly assessment evaluation of the TEC, relative to the unobtrusive reference TECmed, is taken as computation of TEC disturbance at all lattice dots of the map (Gulyaeva *et al.*, 2008):

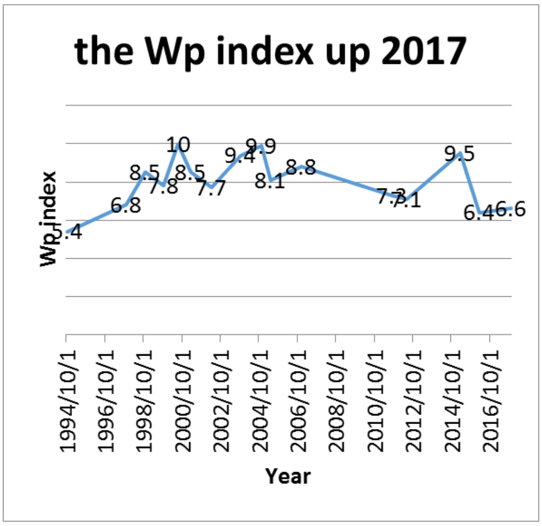

Figure 6. The global W index maps are produced for a period 1999–2014 from Global Ionosphere Maps of Total Electron Content, GIM-TEC, designed by Jet Propulsion Laboratory, converted from the geographic frame (-87.5:2.5:87.5 °) in latitude and (-180:5:180 °) in longitude.

The results from Fig. 6 show that the Wp index between South and North Poles are stable, but not indicate high values of anomalies. This confirms the state is not stable media and instead of that is dispersive medium and suffer from disturbance. The highest values are 2000 year.

D. By Using I95 Index

The TRIGNET model was used to investigate the Ionosphere region in South Africa. The TRIGNET model uses 55 sensors to receive the VLF signals are reflected from the Ionosphere. These signal will indicate the perturbations in the Ionosphere. At high latitudes are small anomalies because the Ionization is very poor. This work shows that Ionosphere state is activated at 12:00 P.M and go back it to quite a state at night. This result is expected but this version shows us strict results (Fig. 7).

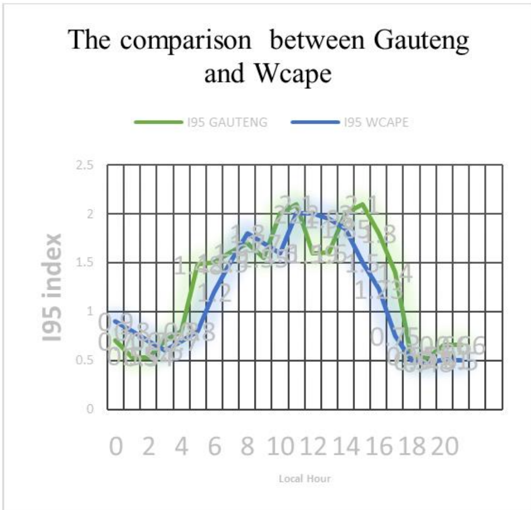

Figure 7. Ionosphere index I95 RTK_VRS_GAUTENG South of Africa.

VI. Conclusion

In section A Nequick model is used because the results are relative to Klobuchar. That leads to TECU is so relative with Nequick model that mean the errors in both ways are similar and the signal will suffer approximately the same value. Nequick model proved that TECU in Iraq is higher than in Romania. The TECU is decreased with increasing the elevation angle. The most important is the elevation angle not the azimuth angle. The azimuth angle is not important and does not affect the transmission signal. In section B it has been used IRI-Plaz 2017. The results of the error distance by using a GPS signal in summer has confirmed the results of the Nequick model. The results of error distance in the Iraq region is 15 meter compared to Romania 12 meters. The average error distance is proportional to the electron density. In section C the Wp index is a log of the DTEC. The results show is not extreme values of the Wp index between the north and south. In section D the I95 index has been used. I95 index is the average value of the TEC as in equation (8). I95 index is stable at South Africa by using TRIGNET. TRIGNET has used 55 stations and these stations are connected in one single base station. As a consequence if the number of stations is increased that means the computations are stricter. This technology is developed by the future plan in increasing the number of stations. In the GAUTENG city has been installed all stations for monitoring the Ionosphere. These four models confirm that the disturbance in the Equatorial region is higher latitudes. For future work it is recommended to study the auroral propagation. The Poles in the North and the South suffered from the high magnetic field and poor Ionization. The high magnetic field will move heavy particles like ions and this lead increase the ion temperature and produce new phenomena.

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The Data is used in this work of Wp index are provided from ftp://sideshow.jpl.nasa.gov/pub/. The program for achieving the TEC are executed by Nequick model https://t-ict4d.ictp.it/ that has Nequick model and is updated up to 2016 January. The Ionosphere activity I95 are provided by https://www.swipos.ch/Network/Ionosphere.aspx, and http://www.trignet.co.za/MemberPages/Ionosphere.aspx.

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