Empirical Relation Between foE Over Tanjungsari and Sunspot Number

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ABSTRACT

Hunsucker and Hargreaves (2002) expresse the correlation between critical frequence of ionospheric E layer foE and solar activity as $f_oE = \alpha\ [(1 + \beta R) \cos \chi]^{0.25}$, where $\alpha = 3.3$ dan $\beta = 0.008$. Calculation by using foE data taken from Tanjungsari station on January and December 2001, March and July 2000 when solar activity maximum and foE data on January and December 2007-2009, March 2007-2008 and July 2008 when solar activity minimum is obtained $\alpha = 3.35$ dan $\beta = 0.011$.

It is compared between deviation of foE reference to foE data (ΔfoE ref) and foE calculation to foE data (ΔfoE cal), where foE reference is foE obtained based on $\alpha = 3.3$; $\beta = 0.008$ and foE calculation is foE obtained based on $\alpha = 3.35$; $\beta = 0.011$ and foE data is foE observed from Tanjungsari ionosonde on 2010. It seems that ΔfoE ref higher than ΔfoE cal and it is found that 76.1% foE results by using $\alpha = 3.35$ dan $\beta = 0.011$ more close to foE real data than foE calculation by using formula of Hunsucker dan Hargreaves.

Keywords: Critical frequence, foE, and Solar activity

1. INTRODUCTION

Ionosphere is a layer that contains a collection of electrons or electrically charged atoms and molecules that surround the Earth and extends from a height of about 60 km to 600 km. These layers are formed due to the ionization of atoms and neutral molecules in the atmosphere by solar radiation. Layer of the ionosphere can be divided into multiple regions or layers. Starting from the lowest layer is a layer of D (60-90 km), E layer (90-110 km) and the F layer (200-600 km), but sometimes in the E layer appears a very thin layer and its emergence was not permanent at an altitude of about 100 km then the layers are named sporadic E layer or Es.

Since the signal - transmission experiments carried telegraphy without wires from England to France by Nikola Tesla (1899) and receives the radio signal frequency of 500 KHz in Canada that are emitted in the UK by G. Marconi then study the propagation of radio waves associated with the more advanced. In 1902 then believed that the reception of radio waves with very long distances that there must be something caused. Finally it was found that the ionosphere is a layer that serves as a reflector of radio waves. With its believed that the ionosphere layer is useful as a reflector of radio waves, then continue to do research on the ionosphere.

Some research shows that the number of electrons or the number of ions in the ionosphere layer is not homogeneous but a function of height to a certain extent. Up to an altitude of about 350 km, the electron density reaches a peak and then decline. In addition to the electron density as a function of altitude, the electron density also has a variation of: time, season, location and solar activity. Therefore, in the utilization of the ionosphere as a reflector of HF radio waves need to consider the types of ionospheric variations mentioned above. From the results obtained that the electron density in the ionospheric plasma frequency is proportional to the square, in other words the critical frequency ionosphere layer is also influenced by the four factors above.

The purpose of this paper is to calculate α and β constans related to the influence of solar activity on the electron density of ionospheric E layer which according to Hunsucker and Hargreaves in the literature of the high latitude ionosphere and its effects on radio propagation expressed by the equation :

$$foE = 3.3\ [(1 + 0008\ R) \cos \chi]^{0.25} \text{......... (1)}$$

where R is the sunspot number; χ is the solar zenith angle; α = 3.3 and β = 0.008 Since Indonesia is located in areas of low latitude regions, then these constants should be calculated by making a time limitation, whether applicable in the morning, afternoon or evening. In this case the calculation of constants will be done based on Tanjungsari ionospheric data.

2. DATA

Solar activity that indicated by the sunspot number (R) has a cycle of 11 years, it means that maximum solar activity peak to peak for next maximum is 11 years. Solar activity was very influential on the formation of electrons in the ionosphere so that the relationship between the electron density is expressed by the critical frequency of foE against solar activity is shown by the equation :

$$foE = \alpha\ [(1 + \beta\ R) \cos \chi]^{0.25}\ \text{MHz},$$

We would like to calculate the α and β constants for the ionosphere over the Tanjungsari observatory. To obtain the constants α and β used the median monthly data of foE Tanjungsari observatory at maximum activity expressed by Rmax for January and December of 2001, March and July of 2000, as well as at the time of minimum solar activity expressed by Rmin for January and December Year 2007-2009, the years 2007-2008 in March and July of 2008. While data of solar activity showed by sunspot number (R) is used monthly data for the same month with the median monthly data of foE. foE data obtained from ionosonda that taken every 15 minutes, but in the calculation we take each hour's data. In this calculation we define the term of the day is from 11:00 until 13:00 hours. Rmin and Rmax are respectively indicate the number of sunspot during the solar activity is minimum and maximum. foE Rmin and foE Rmax is foE value when the solar activity is minimum and maximum

Table 2.1. foE and Sunspot dat

Month/Year	R_{min}	foE_{Rmin}	R_{max}	foERmax	Time
Jan' (01&09)	1.5	3.04	95.6	3.21	Morning
Jan' (01&08)	3.4	3.15	95.6	3.21	Morning
Jan' (01&07)	16.9	2.96	95.6	3.21	Morning
Mrc'(00&08)	4.8	2.9	138.5	3.35	Morning
Mrc'(00&07)	9.3	2.98	138.5	3.35	Morning
Jul'(00&08)	0.5	2.85	170.1	3.15	Morning
Dec'(01&09)	0.8	2.95	132.2	3.34	Morning
Dec'(01&08)	10.6	3.27	132.2	3.34	Morning
Dec'(01&07)	10.1	3.12	132.2	3.67	Morning
Jan' (01&09)	1.5	2.14	95.6	3.89	Noon
Jan' (01&08)	3.4	3.3	95.6	3.9	Noon
Jan' (01&07)	16.9	3.38	95.6	3.89	Noon
Mrc'(00&08)	4.8	3.44	138.5	3.61	Noon
Mrc'(00&07)	9.3	3.63	138.5	3.1	Noon
Jul'(00&08)	0.5	3.2	170.1	4.92	Noon
Dec'(01&09)	0.8	3.5	132.2	4.22	Noon
Dec'(01&08)	10.6	3.69	132.2	4.22	Noon
Dec'(01&07)	10.1	3.39	132.2	4.18	Noon
Jan' (01&09)	1.5	2.45	95.6	2.97	Afternoon
Jan' (01&08)	3.4	2.76	95.6	2.97	Afternoon
Jan' (01&07)	16.9	2.92	95.6	3.28	Afternoon
Mrc'(00&08)	4.8	3.14	138.5	3.63	Afternoon
Mrc'(00&07)	9.3	2.79	138.5	3.63	Afternoon
Jul'(00&08)	0.5	2.49	170.1	3.71	Afternoon
Dec'(01&09)	0.8	2.76	132.2	3.05	Afternoon
Dec'(01&08)	10.6	3.1	132.2	3.49	Afternoon
Dec'(01&07)	10.1	2.72	132.2	3.05	Afternoon

3. METHOD

To obtain constants α and β in the equation (1) is used the monthly median foE data from Tanjungsari when solar activity is maximum expressed by R_{max} for January and December of 2001, March and July of 2000, as well as when solar activity is minimum which is showed by Rmin for January and December of 2007-2009, the years 2007-2008 in March and July of 2008. Whereas, solar activity data in the form of sunspot numbers (R) is used monthly data for the same month with the monthly median data of foE.

foE data are obtained from ionosonde every hours. We define noon foE data is average of foE data from 11:00 am to 01:00 pm. R_{min} and R_{max} are respectively indicate the number of sunspots on the condition of solar activity is minimum and maximum.

foE Rmin and foE Rmax are the value of foE when the solar activity is minimum and maximum respectively.

4. CALCULATIONS

By using equation (1), for R_{max} and R_{min}, we find :

1. foE when R maximum

$$f_oE_{Rmax} = \alpha\ [(1 + \beta.R_{max}) \cos \chi]^{0.25} \quad \text{.... (3.1)}$$

or

$$\alpha = \frac{(f_oE_{Rmax})}{[(1+ \beta.Rmax) \cos \chi]^{0.25}} \quad \text{............... (3.2)}$$

2. foE when R minimum

$$f_oE_{Rmin} = \alpha\ [(1 + \beta\ R_{min}) \cos \chi]^{0.25} \quad \text{......... (3.3)}$$

substitute equation (3.2) to equation (3.3), then equation (3.3) become:

$$f_oE_{Rmin} = \frac{(f_oE_{Rmax}).\ [(1 + \beta.R_{min}) \cos \chi]^{0.25}}{[(1+ \beta.Rmax) \cos \chi]^{0.25}} \quad \text{....(3.4)}$$

to get β, equation (3.4) is powered by 4 so that equation (3.4) become:

$$(foE_{Rmin})^4 = \frac{(f_oE_{Rmax})^4.\ [(1 + \beta.R_{min}) \cos \chi]}{[(1+ \beta.R_{max}) \cos \chi]} \quad \text{..(3.5)}$$

$$(foE_{Rmin})^4 = \frac{(f_oE_{Rmax})^4.\ [(1 + \beta.R_{min})]}{[(1+ \beta.R_{max})]}$$

$$(foE_{Rmin})^4 .\ [(1+ \beta.R_{max})] = (f_oE_{Rmax})^4.\ [(1 + \beta.R_{min})]$$

$$(foE_{Rmin})^4 + \beta.R_{max}\ (foE_{Rmin})^4 = (f_oE_{Rmax})^4 + \beta.R_{min}\ (f_oE_{Rmax})^4$$

$$\beta.[R_{max}.\ (foE_{Rmin})^4 - R_{min}\ (f_oE_{Rmax})^4] = (f_oE_{Rmax})^4 - (foE_{Rmin})^4$$

then will be obtained :

$$\beta = \frac{(f_oE_{Rmax})^4 - (foE_{Rmin})^4}{[R_{max}\ (foE_{Rmin})^4 - R_{min}\ (f_oE_{Rmax})^4]} \quad \text{...... (3.6)}$$

By using 2 equations (3.2), (3.6) and data on the table 2.1, α and β will be obtained, they are : $\alpha = 3.35$ and $\beta = 0.011$

5. RESULTS AND DISCUSSION

Based on the calculation, we find that the constant at noon time are $\alpha = 3.35$; $\beta = 0.011$, it seems to approach the results of the reference $\alpha = 3.30$; β = 0008, but results of constant calculations between foE and R is needed to be tested to know their accuracy. Tests carried out at once to α and β constants obtained including α and β reference. In these tests will be compared between the foE calculation (foE cal) based on α and β constants calculation ($\alpha = 3.35$; $\beta = 0.011$) against the real foE data observed from Tanjungsari ionosonda (foE data) for January – November 2010 monthly median hourly. Also the same method we carried out for foE from reference ($\alpha = 3.30$; $\beta = 0.008$) that we called foE reference (see table 4.1) then deviations obtained to foE data are expressed by ΔfoE cal and ΔfoE ref.

Table 4.1. foE literatur, FoE calculation and foE data of Tanjungsari observatory – 2010

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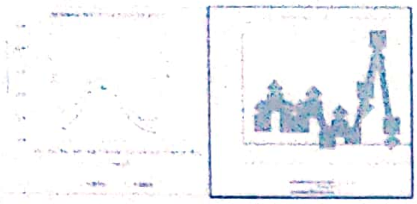
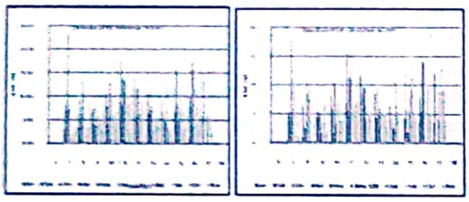
In this paper we calculate deviation of foE from January – November 2010, and it could be explained that the maximum deviation of reference (ΔfoE ref.) occurs in April 2010 at 07.00 a.m (see figure 1.a) by amount of 23.09%, and for maximum deviation of calculation ΔfoE cal (19.89%) occurs in November at 16.00 p.m (see Figure 1.b).



(a) (b)

Figure 1. Deviation of foE Reference (ΔfoE ref) *and* calculation (ΔfoE cal) : (a) on April 2010, (b). on November 2010

All the Deviation of foE reference (ΔfoE ref) and the deviation of foE calculation (ΔfoE cal) in 2010 are expressed in Figure 2.a & b.



(a) (b)

Figure 2.(a) Deviation of foE reference (ΔfoE ref) and (b) Deviation of foE calculation (ΔfoE cal) in 2010

Figure 3 and 4 show foE and deviation of foE on March and June 2010, we identify that mostly ΔfoE ref highly than ΔfoE cal, it means foE calculation by using $\alpha = 3.35$; $\beta = 0.011$ approach foE data observed by Tanjungsari ionosonde than foE reference from the calculation by using $\alpha = 3.30$; $\beta = 0.008$. From total number 117 of data there are 76.1% of ΔfoE cal less than ΔfoE ref.

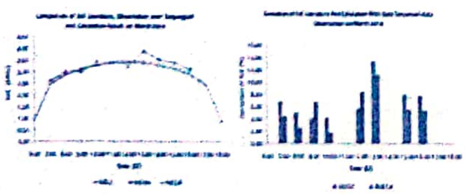


Figure 3. foE and deviation of foE for March

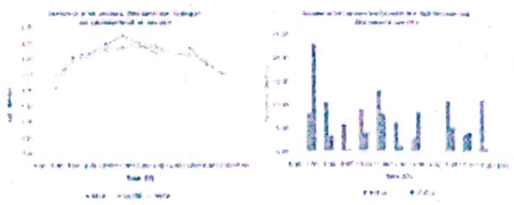


Figure 4. foE and deviation of foE for June

6. CONCLUSION

The constants α and β that show correlation between critical frequency of electron density in the E layer and sunspot number R can be calculated based on ionospheric data from each location. In this case is used foE data from ionosonde of Tanjungsari and it is obtained constants $\alpha = 3.35$ and $\beta = 0.011$. Therefore correlation between foE and sunspot number R is expressed as

$$foE = 3.35\,[(1 + 0.011\,R)\cos\chi]\,0.25$$

7. ACKNOWLEDGEMENT

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