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A 3-year observation of the ionospheric critical frequency over Malaysia

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Abstract – The ionosphere is the topside of the atmosphere that contains high concentration of ions and can reflect radio waves due to refraction. The ionospheric region of interest is located above the equatorial region at longitude 1° 52' and latitude 103° 48' (Parit Raja, Johor). The observations of the ionospheric critical frequency were made from 2005 to 2007. The critical frequency is determined by using the monthly median value for each day. Regression analysis was used on the theoretical and observed value. The observed value is obtained from ionogram measurements with five-minute intervals using logarithmic frequency steps from 1 Mhz to 20 Mhz. The sunspot number is used as a parameter to compare the values of critical frequency at high sunspot and low sunspot numbers for the day. The critical frequency for the years 2005, 2006 and 2007 show that the higher value is for 2005 while the critical frequency is much lower for 2006 and 2007. The correlation analysis is used to determine the relationship for the yearly value. The correlation is made using the median value of the foF2 critical frequency from 2005 until 2007. The regression and correlation analysis of the critical frequency was able to show the trend of the critical frequency for the year 2005, 2006 and 2007.

Keywords**:** Ionosphere, Critical Frequency, Equatorial Region, Solar Minimum

I. INTRODUCTION

The variations of the ionospheric layer is depending on the solar terrestrial relationship such as sunspot number, solar flare and magnetic index. The HF communication frequency value determine by the variability observed from the ionospheric layer reflection from the radio wave. Due to the variability of the ionospheric layer from the effect of the solar system, further investigation and study for the ionosphere region is important. The early researcher on the ionosphere is focus on the total electron content analysis. This research is using the GPS receiver for the value of the research and the facility for the system is growing at large [1]-[3]. The researcher in European country study the critical frequency foF2 using diurnal variation. The hysteresis of the foF2 is base on the sunspot number relation for long-term prediction [4]-[5]. The trend profile in Malaysia for ionosphere region is still undetermined. This research is one step to identify the critical frequency of the ionosphere in the Malaysian region, specially Batu Pahat, Johor. The parameter include in this research is the critical frequency and virtual height of the F-layer.

II. IONOSPHERIC OBSERVATION STATION

The ionospheric station was located at Universiti Tun Hussein Onn Malaysia (UTHM) main campus in Batu Pahat, Johor. The ionospheric station is monitor by Wireless and Radio Science Centre and known as WARAS Centre. The system can use two type of sounding the signal through the ionosphere, the vertical incidence and oblique incidence. The ciritcal frequency of the reflection of the ionospheric layer can be determined using the ionogram. The ionogram can show the parameter of the ionosphere such as the critical frequency and the virtual height of the ionospheric layer [6].

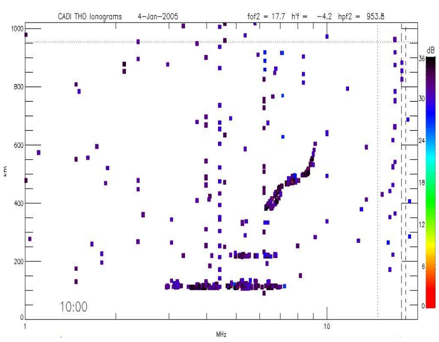

Figure 1: Ionogram capture from Ionospheric Station in Parit Raja.

In the system design, the computer is use as a control and storage of the reflection from the ionospheric layer. The 4 (four) receiver is use for the system to give the ionogram and drift value of the ionosphere. The transmitter card is connected from the amplifier and the amplifier will boost the signal to the transmitting antenna. The receiving card is connected from the pre-amplifier from the receiving antenna to the card. The frequency for transmitting the signal can be choose using the program located in the PC. The single frequency sounding is to determine the drift of the ionosphere [7]-[8].

III. CRITICAL FREQUENCY ANALYSIS

The theoretical value of *fo*F1 was determined using the formula of the foF1 critical frequency. The measurement value of the *fo*F1 critical frequency and *fo*F2 critical frequency was determined through the ionogram observation from the ionosphere layer reflection. The critical frequency is collected daily and specified using the median value. The critical frequency value was determined using the ionogram interpretation. The sunspot number is use to compare between the critical frequency for year 2005 until 2007 is in the solar minimum cycle state. In year 2005, the sunspot number is much higher, and the sunspot number for 2006 and 2007 is much lower. The statistical analysis is in form of linear regression analysis of the theoretical and measurement value of the critical frequency. The median observation value for critical frequency was selected for each day. There will be 30 or 31 median value for each month (28 median values for month of February) and from this value the regression analysis of each month can be determined.

The critical frequency is when electromagnetic wave is lunched vertically into the ionosphere, reflection will occurs and from this obtain the highest frequency at which reflection will occur. This equation can be write as;

$$n_x = \sqrt{1 - (81N_x / f^2)} \qquad 1$$

The electromagnetic wave can be reflected from the ionosphere layer if $n_x = 0$. The equation can be write as;

$$n_x = \sqrt{1 - (81N_x / f^2)} = 0 \qquad 2$$

The highest frequency can be obtain at which reflection will occurs when Nx is a maximum;

$$f_c = 9 \sqrt{N_{max}} = \omega_c / 2\pi \qquad 3$$

where,

f_c = critical frequency

N_{max} = total electron density

The critical frequency sometimes called *plasma frequency*. Each of the ionosphere layers has a specific N_{max} at a given location and time, and the maximum frequencies at which reflection is made by the various layers are often labeled *fo*E, *fo*F1, *and fo*F2. These are not constant but vary diurnally, seasonally and with other solar pattern.

The variation of the critical frequency is related to the tilt angle of the sun and the sunspot number (SSN). The estimates for the critical frequency can be alter as;

$$foF1 = (4.3 + 0.01R)\cos^{0.2}(\chi) \qquad 4$$

where, R is the sunspot number and χ is the zenith angle of the sun [9].

The comparison of the measurement and theoretical value from the calculation of the *fo*F1, and determine the value with the sunspot number.

IV. RESULTS

The measurement result is consists of the critical frequency from the year 2005, 2006 and 2007. The sunspot number can give high effect for the *fo*F1 critical frequency [10]. The changes of the sunspot number for the year 2005 until 2007 shows in figure 5, 6, and 7. The comparison between the theoretical and measurement value of the critical frequency is using the median value in noon. The theoretical value calculation is using the zenith angle of the sun for afternoon only. The measurement for critical frequency is determine using the median value. The regression equation for the year 2005 is 4.67 + 0.0003x, Figure 2. The correlation for the *fo*F1 critical frequency is 0.178 from the sunspot number. The observation value is with the dot and the linear line is the regression analysis value.

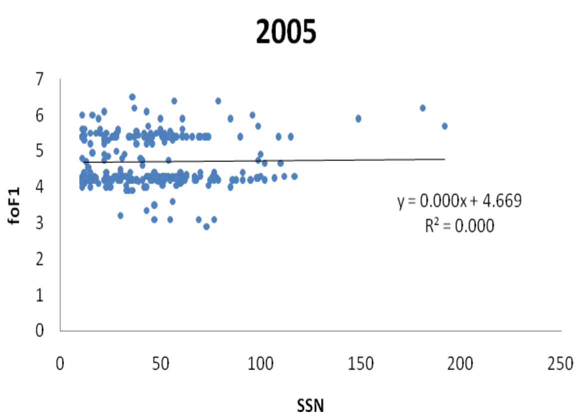

Figure 2: Regression analysis of the *fo*F1 critical frequency in 2005.

In Figure 3, The regression analysis for 2006 is y = 0.013x + 4.362.

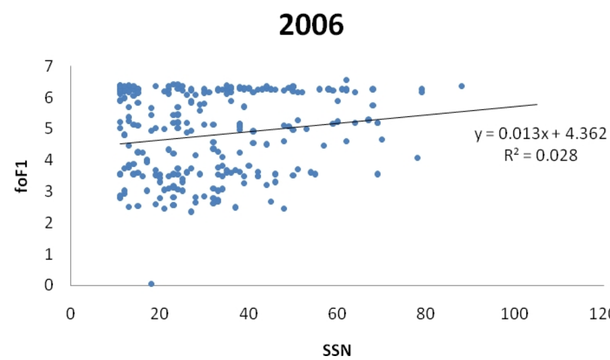

Figure 3: Regression analysis of the *fo*F1 critical frequency in 2006.

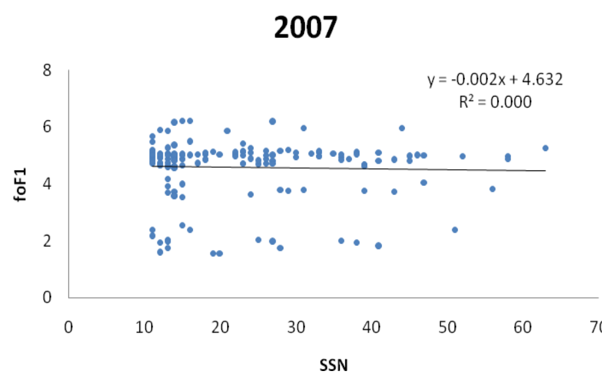

Figure 4: Regression analysis of the *fo*F1 critical frequency in 2007

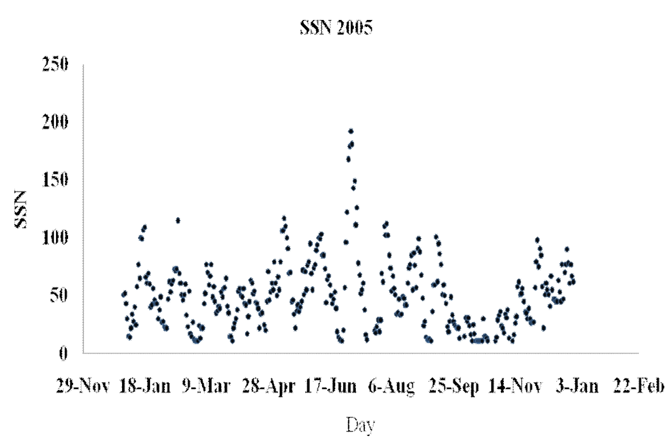

Figure 5: The sunspot number for year 2005

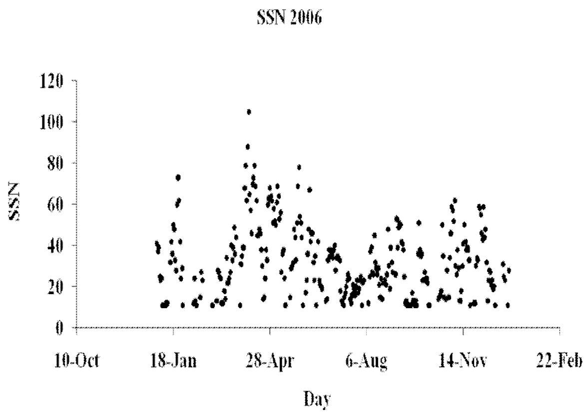

Figure 6: The sunspot number for year 2006

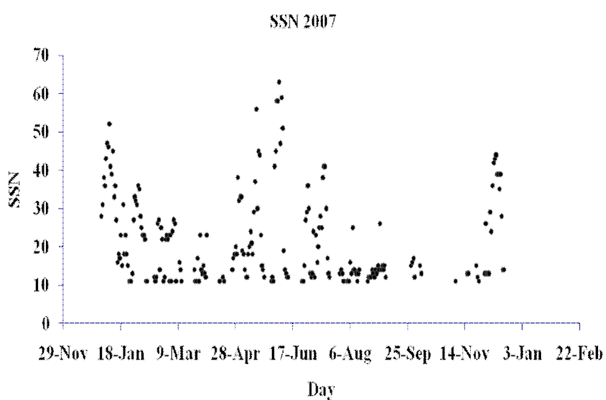

Figure 7: The sunspot number for year 2007

The analysis of the critical frequency is using the trend line analysis from the daily value. The daily value is taken from the median value daily and each value is can be determine from the sounding routine from the digisonde. The critical frequency of *fo*F1 value is taken from noon value but the critical frequency is taken every 30 minute interval daily.

The observation of the critical frequency of *fo*F2 is clearly have the high image of the reflection of the ionosphere during high noon from 8:00 AM until late evening at 5:00 PM local time (LT) and the UTC time for this particular time is from 0:00 until 13:00 UTC. The comparison between critical frequency and sunspot number in the year 2005 is show in the Figure 8. The critical frequency is much higher in early month of May. In the month of July the critical frequency is much lower and increases in the month of September.

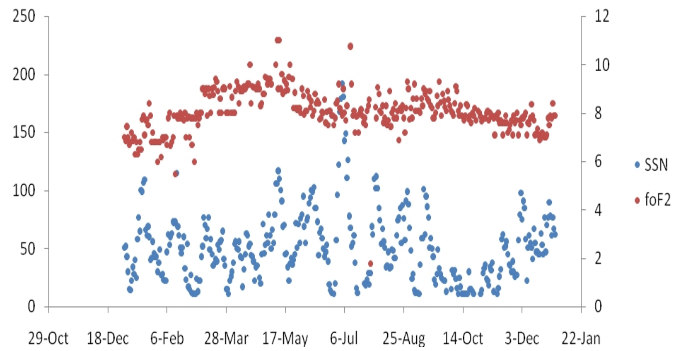

Figure 8: The Sunspot number and the *fo*F2 critical frequency in 2005.

The regression equation for the 2005 is y = 0.005x + 7.795.

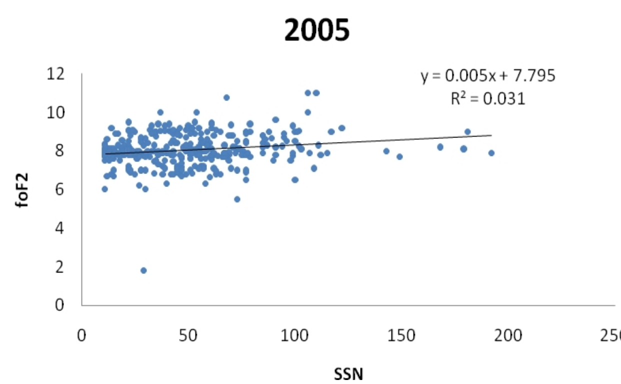

Figure 9: Regression analysis of the *fo*F2 critical frequency in 2005.

The comparison between critical frequency and sunspot number for 2006 is show in Figure 10. The critical frequency is much higher in month of April and month of September. The critical frequency is same in the year 2005.

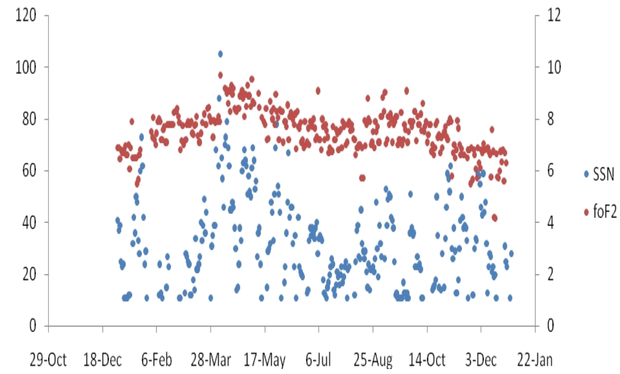

Figure 10: The sunspot number and *fo*F2 critical frequency in 2006.

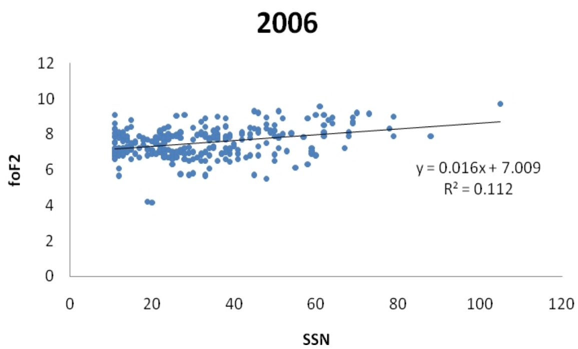

Figure 11: Regression analysis of the *fo*F2 critical frequency in 2006.

The Figure 12 shows the comparison between critical frequency and sunspot number for year 2007.

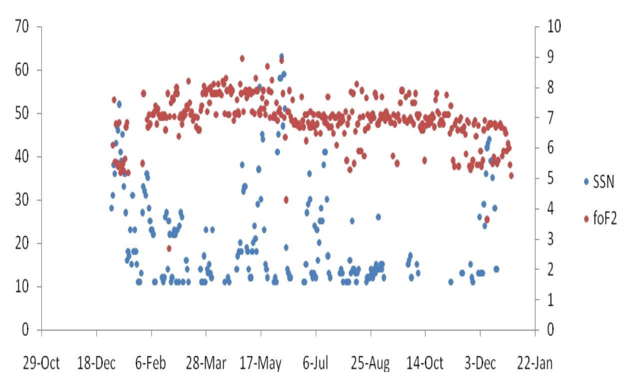

Figure 12: The sunspot number and *fo*F2 critical frequency in 2007.

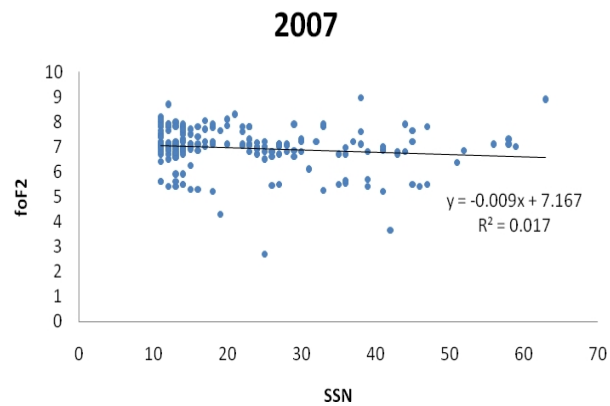

Figure 13: Regression analysis of the *fo*F2 critical frequency in 2007.

V. CONCLUSIONS

The critical frequency at low solar activity show the decreasing in the year 2007. The sunspot number for the year 2007 is much lower than the year 2005. The UTC is use for the observation value. The high critical frequency is in the day time from 11:00 LT until 16:00 LT (03:00 UTC until 08:00 UTC). The reflection of the critical frequency also can be seen in the night at 20:00 LT until 22:00 LT (12:00 UTC until 14:00 UTC). The critical frequency is much lower at 01:00 LT until 06:00 LT (17:00 UTC until 22:00 UTC).

The highest sunspot number recorded in 2005 is 109 and the lowest is 14. The sunspot number for the year 2006 is different because the some of the day in the month, the sunspot number did not appear. The highest of the sunspot number is 73. The year 2007, recorded 52 as the highest sunspot number. Solar activity is expected to be very low to low in this month but on day 22 the solar activity is expected moderate for 2005. In 2007 is much lower than the year 2005 and 2006. There is 3 day having a high sunspot number but only in 2005, that is 15, 17 and 18 January about 100 to 109. The two year 2006 and 2007 show a low sunspot number.

The solar activity from the sun can give the effect for the critical frequency in every day at any time. The analysis of the critical frequency can give the variation of the critical frequency for the reference of the critical frequency prediction.

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