Occurrence of Es over Taipei

by

Huang. Yinn-Nien （黄胤年）
Radio Wave Research Laboratories
Ministry of Communications

ABSTRACT

Using the foEs data in the period March 1960-August 1964, the diurnal, seasonal, and solar cycle variations of the percent occurrence of foEs greater than 5 Mc/s over Taipei were studied. The results were about the same as those of the other Asian stations ever reported.

The correlations between $\overline{P}$ and $\overline{R}$ as well as between $\overline{P}$ and $\overline{A}p$ were also studied. The results show slight negative correlations. No significant correlation was found between the daily geomagnetic activity and daily occurrence of Es. Comparing the present results with those obtained for another epoch of the solar cycle, it seems to conclude that the correlation of $\overline{P}$ on $\overline{R}$ and that of daily geomagnetic activity on daily occurrence of Es are different for different epoch of the solar cycle.

INTRODUCTION

Extensive studies were made in the past on the occurrence of sporadic E in Asia zone. Es occurrences related to time of day and season over Ahmedadad were studied by Kotadia (1956); and those over Waltair by M.M. Rao and B.R. Rao(1964). Singh (1963) studied the Es occurrence related to solar and geomagnetic activity and meteoric showers and sporadic metoors over New Delhi. Kasuya (1957) studied the long term variation of fEs over four Japanese stations; and found that no appreciable correlation exists between 12 months running average of monthly median fEs and that of sunspot numbers. Mitra and Dasgupta (1963) examined the percent occurrence data of midday Es for thirty-three stations in different regions of the globe in relation to solar activity for the period 1953-1959. They concluded that slight positive correlation for Akita, Kokubunji, Wakkanai; positive correlation for Okinawa, Yamagawa; and negative correlation for Singapore at equatorial region exist.

Ionospheric data on sporadic E have the well known limitation that the scaled fEs or foEs values are sensitive to transmitter power, receiver gain, and type of aerial, etc., and so those of the different stations are not always comparable. However, for a particular station, it is possible to study the relative diurnal and seasonal variation of the Es layer. Since March 1960, the automatic ionosphere sounder of NBS type C2 has been used for routine ionospheric soundings at Taipei. Changes of equipment characteristics as well as changes in interpletation of ionogram have been held to minimum since then which made possible a close study of the Es variation over Taipei.

The coordinate of Taipei are:

Geographic latitude 25°02N, longitude 121°31′E
Geomagnetic latitude 13.8°N, magnetic dip 34°

THE DATA USED FOR STATISTICAL ANALYSIS

The foEs data in the period March 1960 to August, 1964 were used. For sporadic nature of the appearence of Es, the parameter chosen for study was the percent occurrence of foEs greater than 5 Mc/s instead of actual foEs values. To minimize any possible effect of D-region absorption as well as the obscuring effect of the E layer, a limiting frequency of 5 Mc/s was selected.

DIURNAL AND SEASONAL VARIATION OF Es

The percent occurence of foEs greater than 5 Mc/s for each hour calculated for the period from Jan., 1961 to Dec., 1963 were shown in Fig. 1. The diurnal variations of the percent occurrence of foEs>5Mc/s for all days, summer, winter and equinoctial months are shown respectively on the figure. For all days, the maximum and minimum values appear respectively around 11th and 5th hour of the day. The variation is skewed with respect to the hour of maximum value: increasing rapidly from minimum to maximum, and decreasing slowly from maximum to minimum. Comparing the percent occurrence of foEs>5Mc/s for summer, equinox, and winter, it can be seen that the occurrence in summer is the largest and that in winter the least. The diurnal maximum for summer appear also respectively at 11th and 5th hour; whereas a very flat maximum appear at afternoon hours for equinox as well as for winter. The occurrence is very rare after midnight to presunrise for equinox, and to 9th hour for winter.

The seasonal variation of occurrence of fo Es greater than 5 Mc/s for all hours calculated for the period Jan., 1961 to Dec., 1963 is shown in Fig. 2. The maximum value appears between May and June and minimum one at winter season. The occurrence of Es is largest in the summer seasons. It increases rapidly from vernal equinox to June solstice and decreases sluggishly from June solstice to autumnal equinox. The seasonal and diurnal variation for Taipei is similar to those for Ahmdadad located about on the same latitude (Kotadia. 1956).

In figure 3 is shown the contour chart of the percent occurrence of foEs greater than 5Mc/s determined for the period 1961-1963. The cluster of the large occurrence of Es in the summer months and in the day hours as well as the sluggishness in variation from June to December solstices is remarkable. The diurnal maximum, which appeares at 10th hour in June, shifts its position gradually to noon time in winter.

SOLAR CYCLIC VARIATION OF OCCURRENCE OF foEs GREATER THAN 5Mc/s

In Figure 4 is shown the variation of the monthly percent occurrence of foEs greater than 5Mc/s for all hours, P, for the period Mar., 1960 to August, 1964. The seasonal maximum and minimum appear respectively on the June and December solstices. On the same figure, the 12 months running mean of P, $\overline{P}$, is also shown. Comparing the trend of $\overline{R}$, 12 months running average of monthly mean sunspot number, and $\overline{P}$, the slight negative correleation of $\overline{P}$ on $\overline{R}$ is to be seen. Figure 5 shows the scatter diagram, in which a negative correlation is more clearly seen. The correlation coefficient and regression line are determined as follow:

$$r = -0.711$$

$$\overline{P} = -0.0600\overline{R} + 17.6 \qquad (\%)$$

CORRELATION OF OCCURRENCE OF Es WITH GEOMAGNETIC ACTIVITY

To study the possible effect of the long term varation of the geomagnetic activity on the occurrence of Es, the 12 months running average of monthly mean Ap, $\overline{Ap}$, was determined and shown in Fig. 4. A slight negative correlation can be seen in the Figure. The correlation coefficient is calculated as-0.681. The multi-regression function of $\overline{P}$ with $\overline{R}$ and $\overline{Ap}$ are also determined as:

$$\overline{P} = 18.9 - 0.0390\ \overline{R} - 0.158\overline{Ap}$$

The standard deviation of $\overline{R}$, σ_R, and $\overline{Ap}$, σ_{AP}, are respectively

$$\sigma_R = 22.8, \qquad \sigma_{AP} = 3.36$$

To increase the same amount of $\overline{P}$ as $\overline{R}$ would make if it decreases an amount of σ_R with $\overline{Ap}$ fixed constant, $\overline{Ap}$ should decrease 1.67 σ_{AP} with $\overline{R}$ kept constant. Therefore, it appears that $\overline{R}$ is 1.7 times more effective compared with $\overline{Ap}$.

The above results of negative correlation are obtained for the long term variation of occurrence of foEs greater than 5Mc/s and that of

$\overline{A}$p. To study the possible correlation between daily geomagnetic activity and occurrence of Es, the percent occurrence of foEs greater than a limiting frequency in half a megacycle unit was determined with the data of summer months in 1960-1964 for international magnetically calm and disturbed days separately. Table 1 shows the results. It can be seen that: though, the occurrence of Es in disturbed days is slightly less frequent than that in calm days for the limiting frequency $\leqq$ 5Mc/s, there is, as a whole, no significant difference in occurrence of Es between magnetically calm and disturbed days.

DISCUSSION

Though, a slight negative correlation of $\overline{P}$ on $\overline{R}$ was found for the period during Mar., 1960 to Aug., 1964, a reversed correlation was, however, found for another epoch of the sunspot cycle using the manual midday fEs data. In Table II is shown the ranges of $\overline{R}$ within which the correlation is positive or negative for the rising half cycle of cycle 19. $\overline{P}$ rises gradually from $\overline{R}=0$ to 80 and begins to fall up to 170 then rises again up to 200. Similar phenomena were also found by mitra and Dasgupta for another stations (1963). and by Huang for those in Western Pacific Region (1965a). The Magnetic effect on the daily occurrence of Es was also investigated, using the same method as cited above, for the summer months of IGY and IGC 1959; however, contrary to the results of 1960-1964, a slight positive correlation was found (Table 3). A slight positive correlation was also found for Delhi during the period May 1958-May 1960 (Singh, 1963); and for Kokubunji, Yamagawa, Taipei, and Baguio durimg IGY and IGC 1959 (Huang, 1965b). Smith (1957) found however, no significant correlation forthe stations located within 30-0°N geomagnetic latitude using 1949-1952 data. The different findings of the respective author, using different data in different epoch of the solar cycle, lead to support the conclusion that the correlation of $\overline{P}$ on $\overline{R}$ and the geomagnetic effect on the occurrence of daily Es is different for different epoch of the sunspot cycle.

CONCLUSION

From these brief investigation, it can be concluded that the diurnal as well as the seasonal variation of percent occurrence of foEs greater than 5Mc/s is similar to other Asian station ever reported. The sunspot cycle variation of $\overline{P}$ is negatively correlated with $\overline{R}$ as well as with $\overline{A}p$; and the geomagnetic effect on the daily occurrence of Es is not remarkable for the period 1960-1964. However, the sense of correlation between $\overline{P}$ and $\overline{R}$ as well as the geomagnetic effect on the daily occurrence of Es seems different for different epoch of the sunspot cycle.

ACKNOWLEDGEMENT

The author wishes to express his cordial gratitude to Prof. T. V. Miao and Prof. C. C. Wang, Director and Deputy Director respectively of the Radio Wave Research Labs. for their guidance and encouragement.

REFERENCES

Huang Y. N.	1965a J. Elec. Eng., Vol.8, No.1, PP. 13
Huang Y. N.	1965b J. Geophys. Research, 69, 3633
Kasuya I	1957 J. Radio Res. Labs., 5, 117
Kotadia K. M.	1956 J. Atmosph. Terr. Phys. 8, 331
Mitra R.K. and Dasgupta M.K.	1963 J. Atmosphe. Terr. Phys. 25, 415
Rao M. M. and Rao B. R.	1964 J. Atmosph. Terr. Phys. 26, 831
Singh R. N.	1963 J. Atmosph. Terr. Phys. 25, 589
Smith E. K.	1957 Worldwide occurrence of sporadic E, NBS Circ. 582

TABLE I

Limiting Frequency (Mc/s)		4.0	4,5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0
P (%)	Calm Days	38.0	31.3	24.3	20.1	17.2	12.8	10.2	7.29	5.73	3.82	2.69	2.43	1.95	1.82	61.5	1.56	1.29
	Disturbed Days	37.2	29.8	23.8	20.8	17.3	12.6	9.93	7.38	5.85	4.00	3.12	2.15	1.89	1.67	1.63	1.27	1,01

TABLE II

Correlation	Positive	Negative
$\overline{R}$	0-80 170-200	80-170

TABLE III

Limiting Frepuency (Mc/s)		4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0
P (%)	Calm Days	46.8	41.5	34.6	28.7	23.2	18.6	13.6	10.2	8.30	7.21	5.77	4.87	3.70	2.80	2.53	2.08	1.90
	Disturbed Days	50.5	44.2	35.8	29.0	22.1	17.5	13.6	10.4	9.07	8.45	7.13	5.99	4.58	3.70	3.35	2.82	2.47

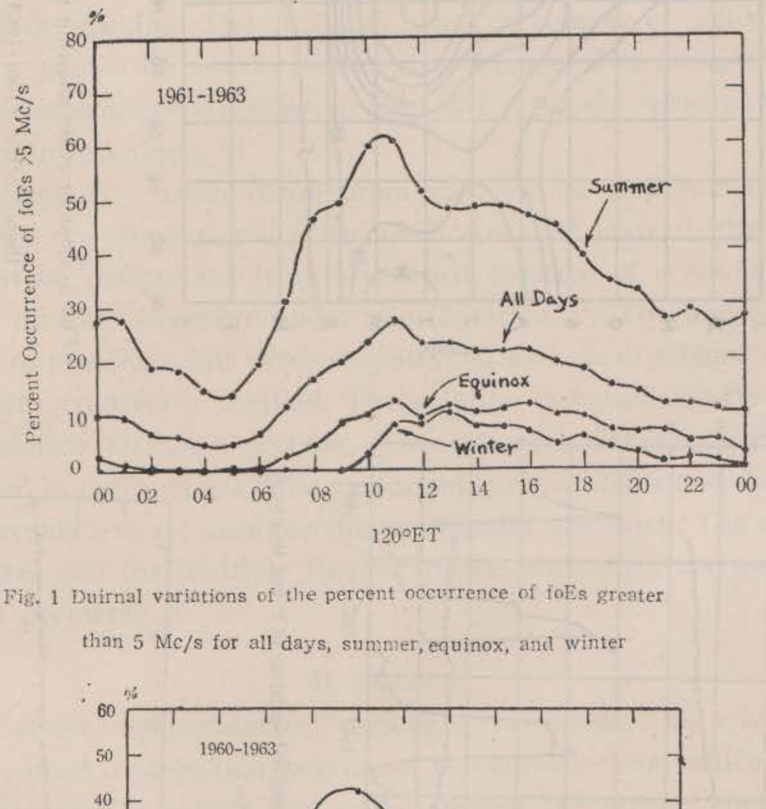

Fig. 1 Duirnal variations of the percent occurrence of foEs greater than 5 Mc/s for all days, summer, equinox, and winter

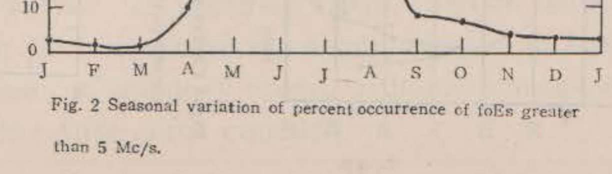

Fig. 2 Seasonal variation of percent occurrence of foEs greater than 5 Mc/s.

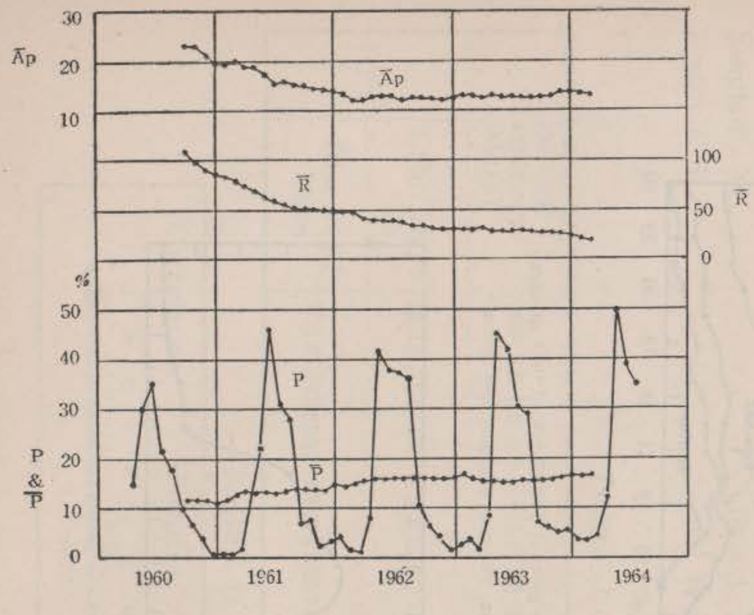

Fig. 4 Curves showing the seasonal variation of P and long term variations of $\overline{P}$, $\overline{R}$, and $\overline{A}$p.

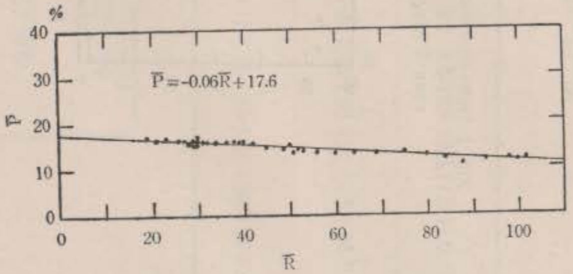

Fig. 5 Scatter diagram and regressionline of $\overline{P}$ on $\overline{R}$. (Mar. 1960-Aug. 1964)

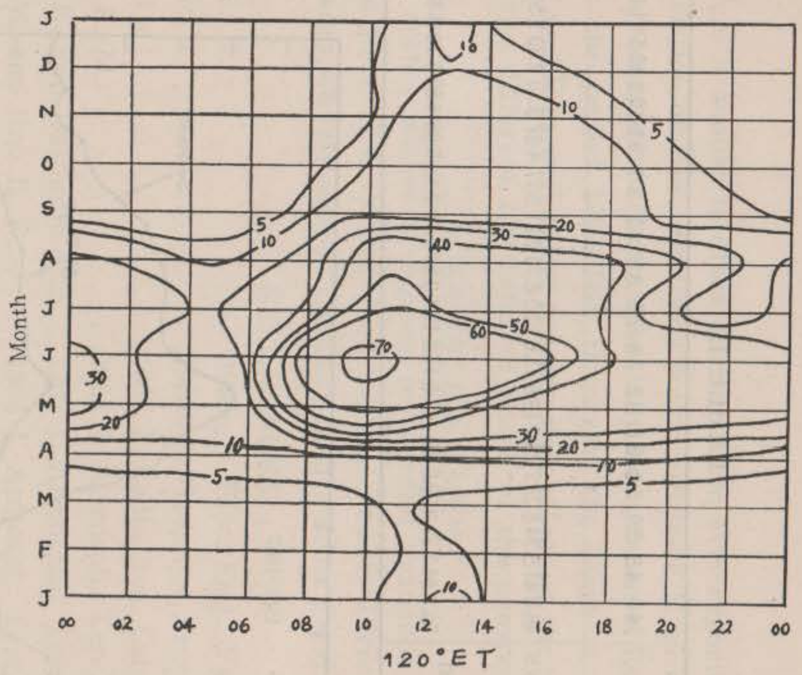

Fig. 3 Contour chart showing the percent occurrence of foEs greater than 5 Mc/s. (1961-1963)