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TÍTULO: NIGHTTIME FLUCTUATIONS (SCINTILLATION) IN FARADAY ROTATION ANGLE OF VHF SIGNALS FROM GEOSTATIONARY SATELLITES

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by

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1 - INTRODUCTION

The amplitude, phase and angle of arrival of radio waves that have traversed through the non-homogeneous ionosphere are found to fluctuate at the receiver. These fluctutations are often called scintillations. The scintillations in amplitude, phase and angle of arrival of radio star and satellite signals have been extensively used for studying ionospheric irregularities. The scintillation studies are usually made by using suitable scintillation indices. These studies made from scintillation indices do not give the precise measure of electron density distribution in the irregularities and hence are of very little help towards understanding the relationship between properties of ionospheric irregularities and the effects on wave propagation and communication.

Owing to the birefringent property of the ionosphere the polarization angle of a plane polarized radio wave rotates as it traverses the ionosphere. The polarization rotation (more commonly known as Faraday rotation) depends on the total number of free electrons along the ray path. The ground based recordings of Faraday rotation of VHF (137.35MHz) signals from geostationary satellite ATS-3 have been made since July 1972 at São José dos Campos (Geog. Lat. 23.2°S, Geog. Long. 46°W, Geomag. Lat. -12.6°) using an automatic polarimeter. The polarimeter contains four-element Yagi antenna rotating at 90 r.p.m. and capable of plotting Faraday rotation angle every two seconds.

The records obtained exhibit nighttime fluctuations during summer and Equinoctial months. In the present article we have examined the relationship between these fluctuations and the ionospheric irregularities.

2 - ANALYSES AND RESULTS

The temporal width of these fluctuations was found to vary from several seconds to about an hour. However, only the fluctuations of duration more than two minutes possessed the amplitudes more than 20^{o} and could be deemed significant. The 20^{o} variation in Faraday rotation angle well includes the variations resulting from the vertical rearrangement of ionization. All the recordings were made at a convenient chart speed of 6" per hour.

In Fig. 1 two sample records of these fluctuations are reproduced. It is seen that these fluctuations are not random but are of sustained type. As the amplitude of these fluctuations decreases their temporal width increases. This is suggestive of the gradually decaying irregularities moving across the ray path. Further to study the correlation of bottomside spread-F and these fluctuations a comparison of the two phenomena was made. Day-to-day correlation between the occurrence of these fluctuations and spread-F on the ionograms taken at São José dos Campos is shown in Fig. 2. The nights of little or no fluctuations were also those of negligible spread-F activity and nights of sustained fluctuations were those when spread-F also persisted. The observed small difference in the occurrence of the two phenomena during pre-sunrise hours was noted to be owing to the fact that on these occasions the height of the F-layer was relatively more and hence the Faraday rotation angle fluctuations were of smaller magnitudes and were considered negligible according to our criterion of significance. The ionospheric points corresponding to vertical soundings and the Faraday rotation measurements are also slightly different.

A close examination of the ionograms and the Faraday rotation angle records further revealed that in general after sunset the ionospheric F-layer height first increases and then starts decreasing around 20 hours (L.M.T.). Sometimes this decrease in height results in the onset of spread-F on the ionograms and simultaneously the onset of fluctuations in Faraday rotation angle also takes place. In no case the onset of the fluctuations took place with out the lowering of ionospheric F-layer. This association of the lowering of the ionospheric F-layer with the onset of fluctuations as well as that of spread-F activity is shown in Fig. 3. The referred vertical movement of F-layer ionization could be due to either of the two known causes, the dynamo electrostatic field and the motions of the neutral air (e.g. Rishbeth, H., 1971 and the references there in). The vertical movement will be accompanied by the horizontal component of motion and the fluctuations in Faraday rotation angle might be the result of the horizontal movement of the plasma embodying the irregularities.

The consideration that these fluctuations are the result of plasma irregularities moving across the ray path provides us a means of investigating the electron distribution in the irregularity structure. The amplitudes of these fluctuations are the direct measure of the electron content fluctuations in the irregularities and the temporal widths of these fluctuations would depend upon the horizontal drift of ionization and the size of the irregularities. The average amplitude of these fluctuations is estimated to be $(3.2 \pm 0.8) \times 10^{16}$ electron/m^2.

The spectrum of the periodicities constituting these fluctuations was obtained using Fast Fourrier transform technique (FFT) (Cooley and Tukey,1965) of measuring the power spectrum. Essentially the procedure adopted for the estimation of power spectrum was the same as described in Bendat and Piersol (1971). Only twenty sample records of relatively longer lengths were considered in the present analysis. The records were digitized at an interval of one minute and the length of each record varied from 300 minutes to 540 minutes. The periodicities higher than 100 minutes were filtered out in the analysis. The spectral estimates were then made and averaged in the periodicity ranges of 2 to 7, 7 to 12..... etc. minutes. The lowest periodicity of 2 minutes corresponds to the Nyquist frequency. Of these average estimates significant components were determinated. An estimate was deemed significant if its magnitude was three times the mean noise level. This corresponds to 95 per cent significance point for one tailed test of spectral peak. The distribution of significant periodicities is shown in Fig. 4. Two distinct categories of dominant periodicities are noted. The dominant periodicities are about 5 minutes and 45 minutes respectively. Assuming a plasma drift velocity of 100 m/s in the equatorial region (Rishbeth, H., 1971; Yeboah and Koster, 1972) we obtain the scale sizes of dominant irregularities to be 30km and 270km respectively. At this stage it may also be mentioned that Yeboah and Koster (1972) from their Faraday rotation angle measurements at an equatorial station Legon (Ghana) also reported the occurrence of frequent night-time peak structures of periodicities 75 ± 10 minutes during equinoctial months and considered them to be due to moving neutral plasma irregularities. However since their observations were made by a polarimeter having a sampling rate of 10 minutes, the existence of periodicities lower than 20 minutes must have considerably polluted (aliased) their results. Hence a word of caution looks to be overdue with regard to their results.

3 - SUMMARY AND CONCLUSION

Faraday rotation angle of VHF (137.35MHz) signals from a geostationary satellite is found to fluctuate violently when the signal traverses the nighttime Spread-F non-homogeneities of magnetic equatorial ionosphere. These fluctuations have periodicities from several seconds to about an hour and in analogy with phase and amplitude scintillations they may be called as "scintillations in Faraday rotation angle". The studies of these scintillations offer additional advantages over phase and amplitude scintillation studies, by making it possible to measure the electron distribution in the irregularity structure.

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CAPTIONS FOR THE DIAGRAMS

Fig. 1 - Tracings of typical records of nighttime fluctuations in Faraday rotation angle.

Fig. 2 - Day-to-day occurrences of nighttime fluctuations (scintillations) in Faraday rotation angle and spread-F at São José dos Campos.

Fig. 3 - Variation of the minimum height of F-layer at the time of the onset of the fluctuations in Faraday rotation angle and the spread-F activity.

Fig. 4 - Histogram of the occurrences of significant periodicities in the nighttime fluctuations of the Faraday rotation angle.

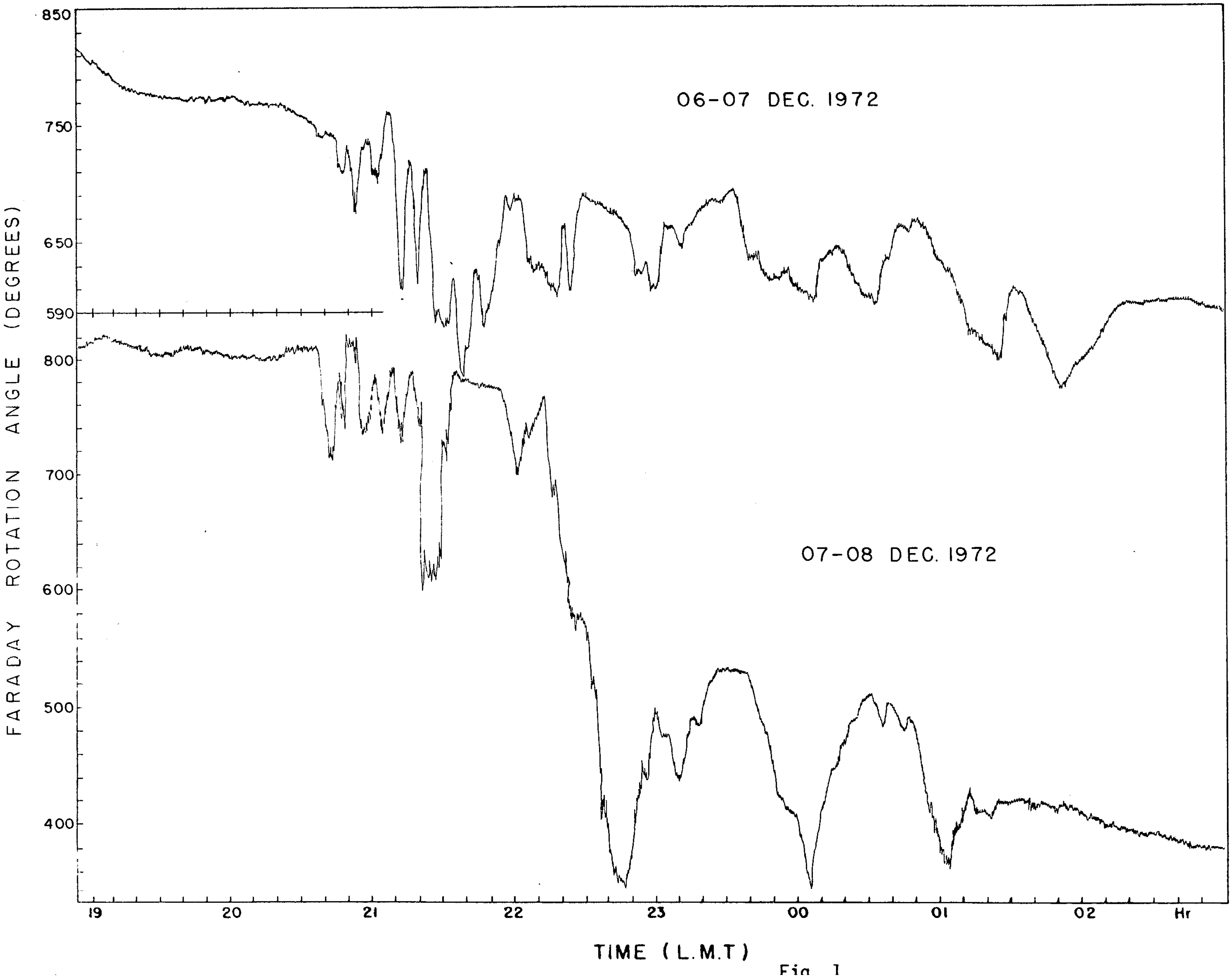
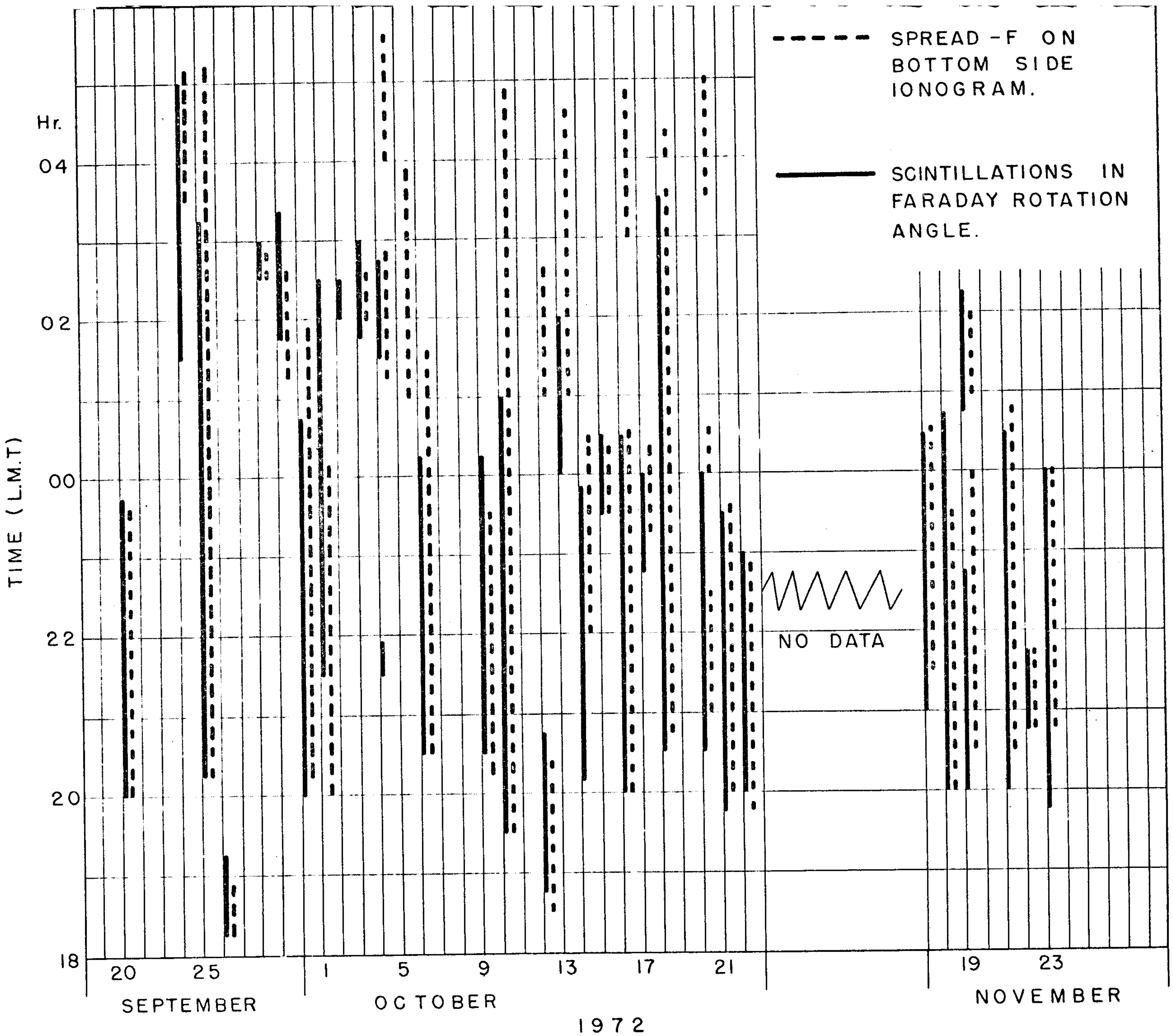
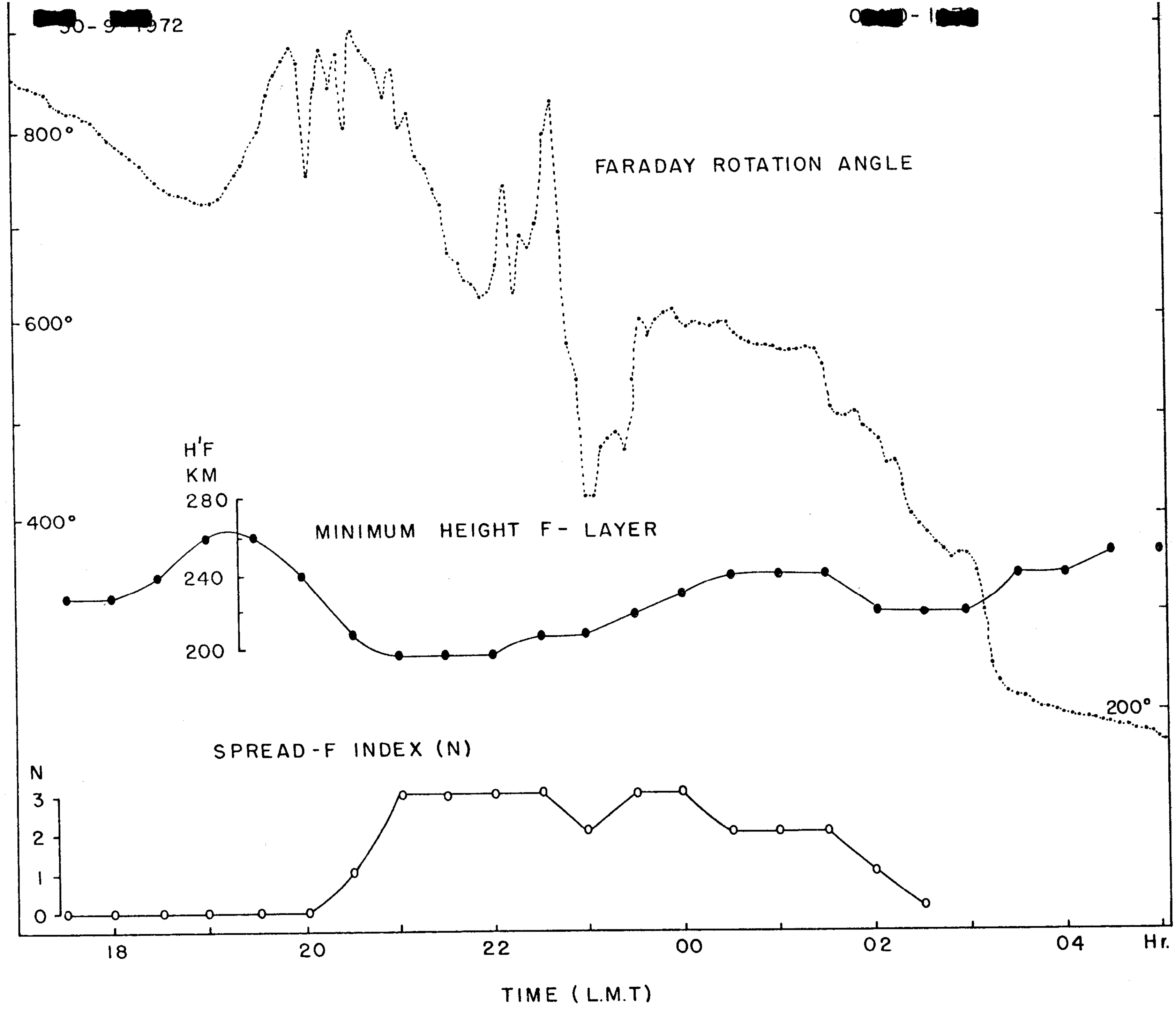

06-07 DEC. 1972
07-08 DEC. 1972
FARADAY ROTATION ANGLE (DEGREES)
850
750
650
590
800
700
600
500
400
19
20
21
22
23
00
01
02
Hr
TIME (L.M.T)

Fig. 1



SPREAD - F ON BOTTOM SIDE IONOGRAM.
SCINTILLATIONS IN FARADAY ROTATION ANGLE.
NO DATA
Hr.
04
02
00
22
20
18
TIME (L.M.T)
20
25
SEPTEMBER
1
5
9
13
17
21
OCTOBER
19
23
NOVEMBER
1972


[redacted] 30-9-[redacted]972
O[redacted]-1[redacted]
FARADAY ROTATION ANGLE
800°
600°
400°
200°
H'F
KM
280
240
200
MINIMUM HEIGHT F- LAYER
SPREAD-F INDEX (N)
N
3
2
1
0
18
20
22
00
02
04
Hr.
TIME (L.M.T)
Fig. 3

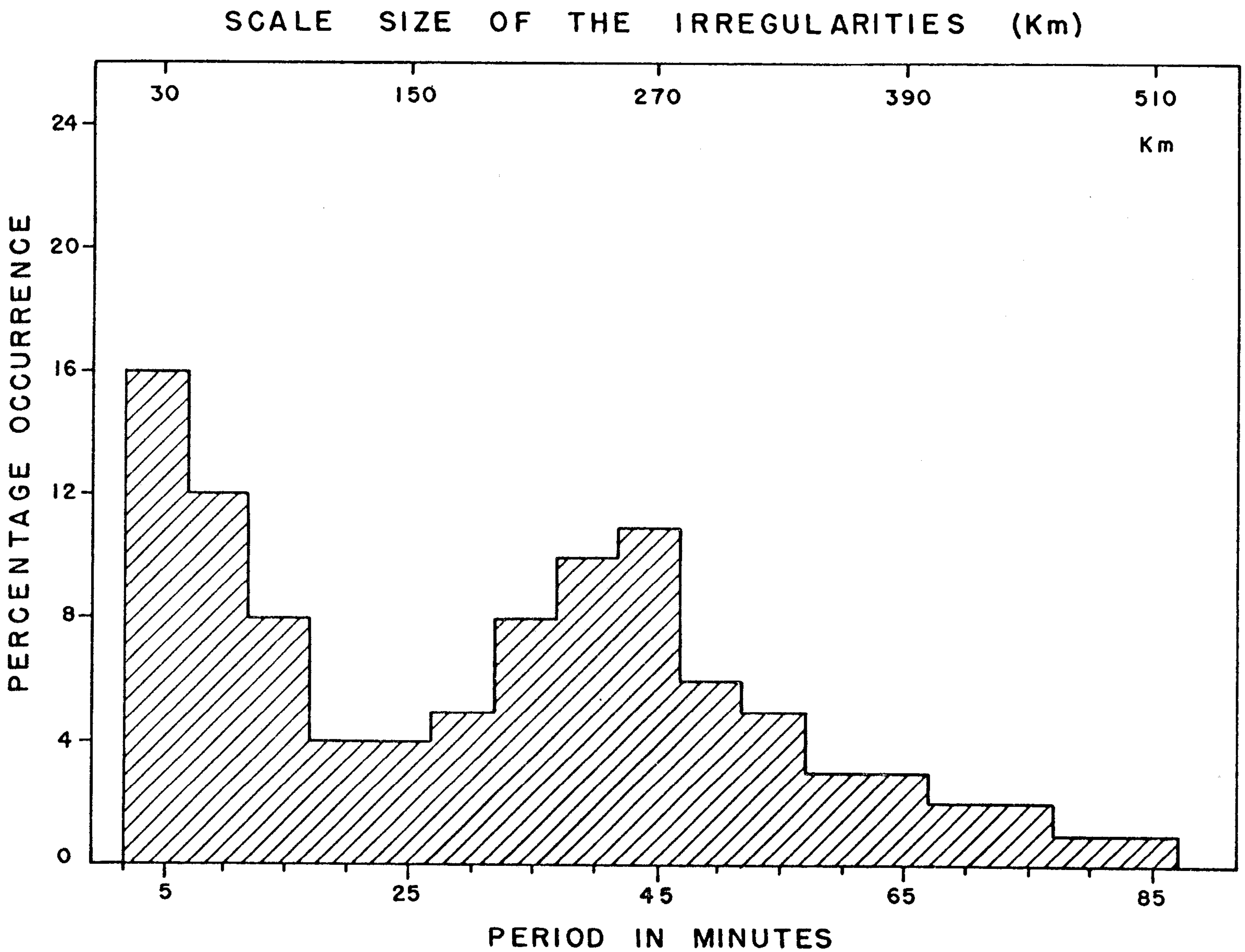

SCALE SIZE OF THE IRREGULARITIES (Km)
30
150
270
390
510
Km
PERCENTAGE OCCURRENCE
24
20
16
12
8
4
0
5
25
45
65
85
PERIOD IN MINUTES

Fig. 4