The Ionospheric F_2 Layer over India in Minimum Sunspot Year 1953

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1. Introduction

The present paper is a summary of facts relating to the F_2 layer in the ionosphere over India which have been put together by the authors as a preliminary to more extended studies of its many interesting features which are found in low latitudes. The stimulus for this work came from the daily contact with the vertical pulse sounding records which are obtained at Ahmedabad.

With assistance from the Government of India, an ionospheric research station was established at the Physical Research Laboratory, Ahmedabad early in 1953 and a multi-frequency automatic ionospheric recorder of the British N.P.L. type was installed. The frequency range of the equipment is 0·6 to 25 Mc/s; the peak power output for a pulse-width of 280 μ s varies from 1720 watts in the low frequency range to 240 watts in the highest frequencies. Usually, the ionospheric sounding is done with a pulse-width of 140 μ s. The pulse-repetition frequency is 50 per second and it takes nearly 5 minutes to sweep the complete range of frequencies. The aerials are vertical rhombics and the transmitter and receiver have each two separate aerials for the low and high frequency ranges.

Since the commencement of the work in February 1953, hourly values of f_0F_2, f_0F_1, f_0E_2, f_0E_1, f_0E, fE_s, h_pF_2, $h'F_2$, $h'F_1$, $h'E_2$, $h'E_1$, $h'E$ and $h'E_s$ have been regularly tabulated. The monthly median values obtained from the above daily data are published regularly in the Indian Journal of Scientific and Industrial Research. We first give a brief summary of the Ahmedabad data from the year 1953, and then compare the data of other Indian stations. The All India Radio maintains vertical sounding stations manually operated, at Delhi, Bombay, Madras and Tiruchy, the India Meteorological Department maintains a recording station at the Solar Physics Observatory, Kodaikanal and there is also a recording station at Calcutta in the Institute of Radio-Physics and Electronics. Data for all the 24 hours of the day are only available for Ahmedabad and Delhi. The data of Kodaikanal and Calcutta have been taken from the published records, while the data relating to the All India Radio stations have been obtained through the courtesy of the Chief Engineer All India Radio.

The following are the geographical and geomagnetic latitudes of the stations (Fig. 1). The values of magnetic dip at the stations are also given. The hourly values for all the stations except Calcutta correspond to 75° East meridian time.

TABLE 1

Station	Geographical Latitude North	Geographical Longitude East	Geomagnetic Latitude North	Magnetic Dip(+)
Delhi	28°·6	77°·1	18°·8	42°·4
Ahmedabad	23°·0	72°·6	13°·6	34°·0
Calcutta	22°·5	88°·3	12°·0	32°·0
Bombay	19°·0	73°·0	9°·5	24°·8
Madras	13°·0	80°·2	3°·1	10°·5
Tiruchy	10°·8	78°·8	1°·3	4°·8
Kodaikanal	10°·2	77°·5	0°·6	3°·5

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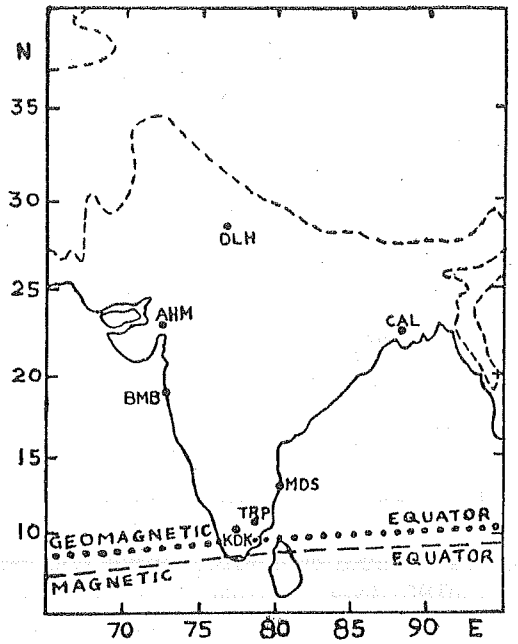

Fig. 1. Map showing locations of Ionospheric Stations in India equipped for vertical sounding

1953 was a minimum sunspot year and the relative sunspot numbers for each month are given in Table 2.

TABLE 2

Relative Sunspot numbers in 1953

Month	Sunspot number	Month	Sunspot number
Jan	28	Jul	8
Feb	4	Aug	15
Mar	7	Sep	10
Apr	30	Oct	4
May	16	Nov	2
Jun	17	Dec	1
	Mean	12	

The median values of f_0F_2 and h_pF_2 (height of reflection at $0{\cdot}834\ f_0F_2$) for February, April, July and October of 1953 for all the stations except Calcutta are plotted in Figs. 2 to 5. The data of Calcutta have not been included in the figure, because its latitude is nearly the same as that of Ahmedabad.

2. Main features of f_0F_2 curves

The following points are of interest regarding the f_0F_2 curves—

(1) The daily variation curves of critical frequencies are of the same general pattern as those shown in other longitudes, but there are differences in detail. At Kodaikanal, Tiruchy and Madras, there is a double peak in critical frequency with the evening peak at 16 to 18 hr more pronounced than the morning one in all the months. The accentuation of the evening peak is stronger in the equinoctial months.

(2) As we go northward from the geomagnetic equator, the highest frequencies are recorded at a latitude near that of Ahmedabad or Calcutta. The peaks are lower and occur earlier in the day in more northern latitudes.

(3) There is a well-marked fall in the critical frequency at low latitudes between 8 and 11 hrs. This phenomenon is noticeable at higher latitudes by a decrease in the slope of the ascending part of the curve.

(4) The rate of fall of the critical frequency following the afternoon or evening maximum is slower in low latitudes, so that the night critical frequencies are markedly higher in those regions in the first half of the night.

The daily variation curves of f_0F_2 at Calcutta and Ahmedabad were similar, the only important difference being that in April and October, the Ahmedabad curves were little higher in the afternoon hours.

3. h_pF_2 curves

There are corresponding differences in the conventional height of maximum electron density (virtual height at which a frequency equal to $0{\cdot}834\ f_0F_2$ is reflected). The virtual heights are surprisingly high at Madras and Tiruchy and it appears that the heights at Kodaikanal would be even higher. The rise in height at low geomagnetic latitudes takes place rapidly after sunrise and the height tends to reach a maximum

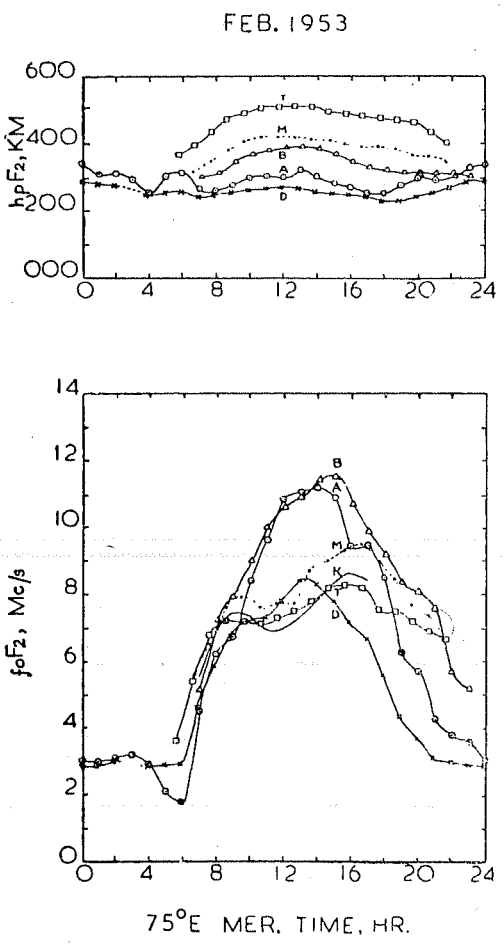

Fig. 2

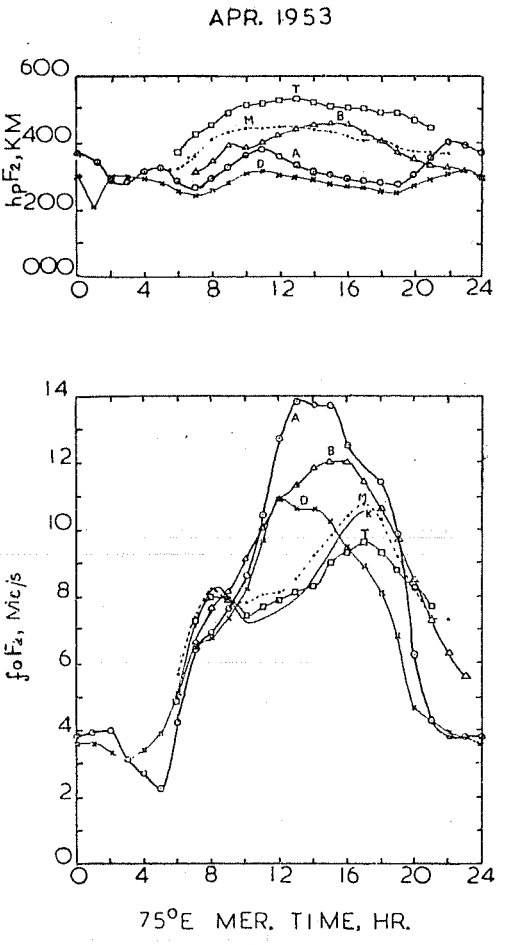

Fig. 3

Daily variation of hpF_2 and f_oF_2 at different places

(A—Ahmedabad ; B—Bombay ; D—Delhi ; K—Kodaikanal; M—Madras; T—Tiruchirapalli)

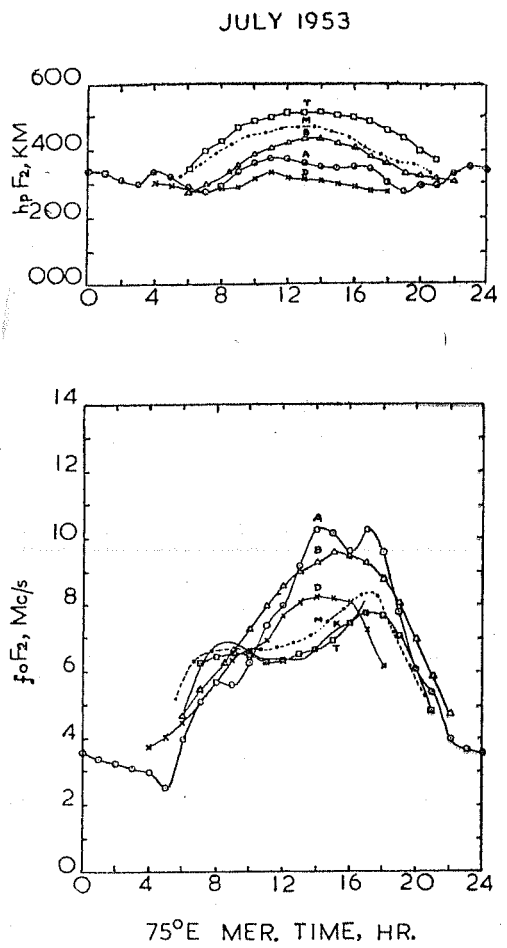

Fig. 4

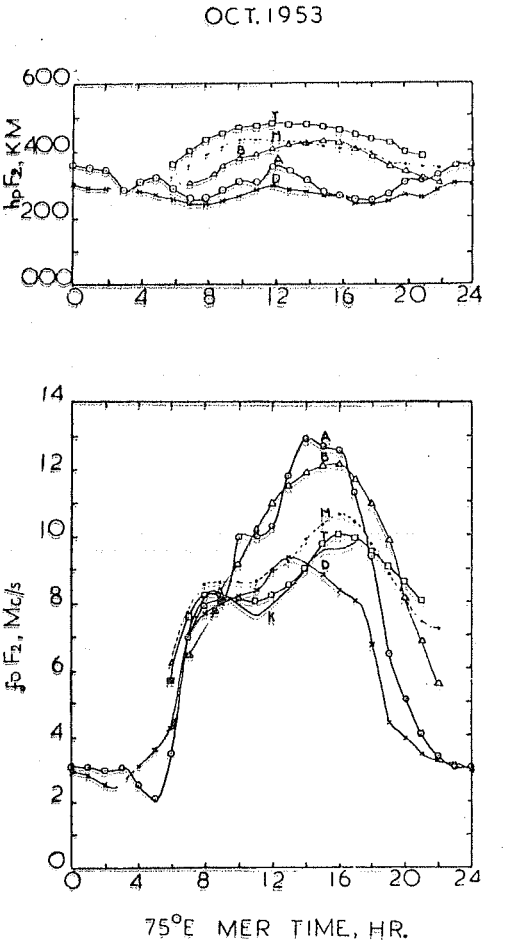

Fig. 5

Daily variation of hpF_2 and f_0F_2 at different places

(A—Ahmedabad ; B—Bombay ; D—Delhi; K—Kodaikanal; M—Madras; T—Tiruchirapalli)

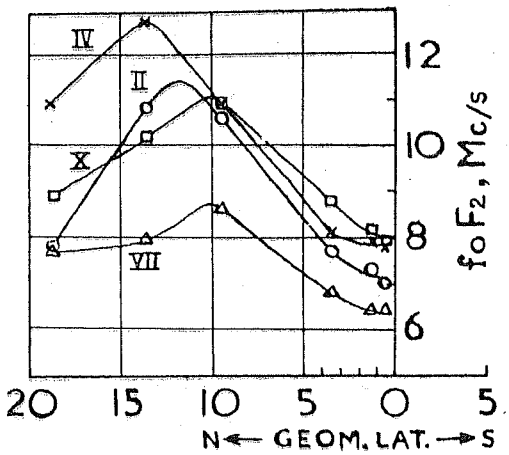

Fig. 6 (a). Monthly mean values of f_0F_2 at noon (75°E) at different geomagnetic latitudes

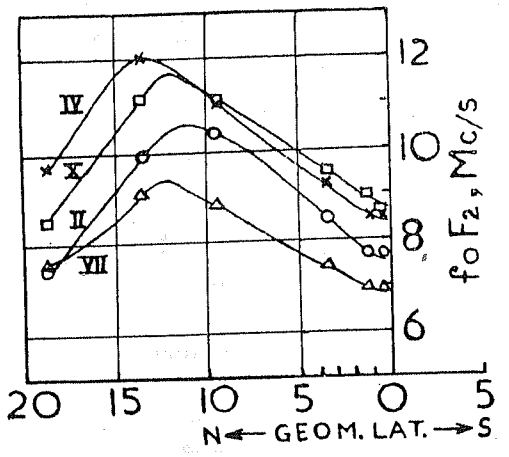

Fig. 6 (b). Monthly mean values of f_0F_2 (10-18 hrs ; 75° E.M.T.) at different geomagnetic latitudes

(II—February ; IV—April ; VII—July ; X—October 1953)

at 12 to 14 hrs. At stations north of Bombay, the morning rise of height takes place much more slowly. It is curious to note that while the Ahmedabad h_pF_2 curve lies fairly evenly between the Delhi and Bombay curves in the morning hours, in the afternoon hours, the Ahmedabad curve tends to follow the Delhi curve while the Bombay curve approaches the Madras curve. This is particularly well seen in the months April and October.

4. Variation of noon f_0F_2 with latitude

As was first pointed out by Appleton, the noon values of f_0F_2 when plotted against the geographical latitude are rather scattered, but when plotted against geomagnetic or magnetic latitude, give a much smoother curve showing a depression at the geomagnetic equator and a peak at about 15° geomagnetic latitude. The analysis of the Indian data shows that in a minimum sunspot year, the highest values of noon frequency are found at a geomagnetic latitude 10° to 15° N (Fig. 6a). If instead of noon frequencies, we consider the mean frequencies in the whole of the period 10 to 18 hrs. the curves are even smoother (Fig. 6b) and the maximum values are found to occur at 12° to 13° N geomagnetic latitude.

5. Seasonal variation of h_pF_2 (noon values), and f_0F_2 (afternoon values 12 to 17 hrs)

It has already been mentioned that the virtual heights of F_2 are extremely high at Tiruchy and Madras. In Fig. 7(a) are shown the mean monthly noon virtual heights, h_pF_2 at all the Indian stations. There is a steady increase of height with approach to the magnetic equator in all the months. The heights are nearest each other in the summer months June to August. The values of h_pF_2 for Kodaikanal are not available, but they are not likely to be significantly different from those at Tiruchirapalli. In Fig. 7(b), the values of h_pF_2 at Tiruchirapalli and of $h'F_2$ at Kodaikanal are plotted together. The difference in ordinate gives an idea of the thickness of the F_2 layer ; it varies from 100 km to 170 km.

In Fig. 8, the mean monthly afternoon values of f_0F_2 are shown at each of the stations, Delhi, Ahmedabad, Bombay and Madras. The amplitude of annual

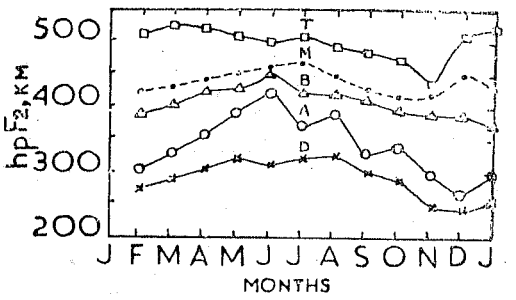

Fig. 7 (a). Seasonal variation of noon hpF_2 at different places (The geomagnetic latitude Φ varies from 1°·3N to 18°·8N) in 1953

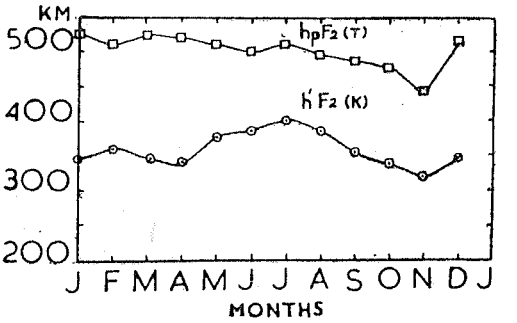

Fig. 7 (b). Seasonal variation of noon $h'F_2$ at Kodaikanal (Φ=0°·6N) and noon hpF_2 at Tiruchirapalli (Φ=1°·3N) in 1953

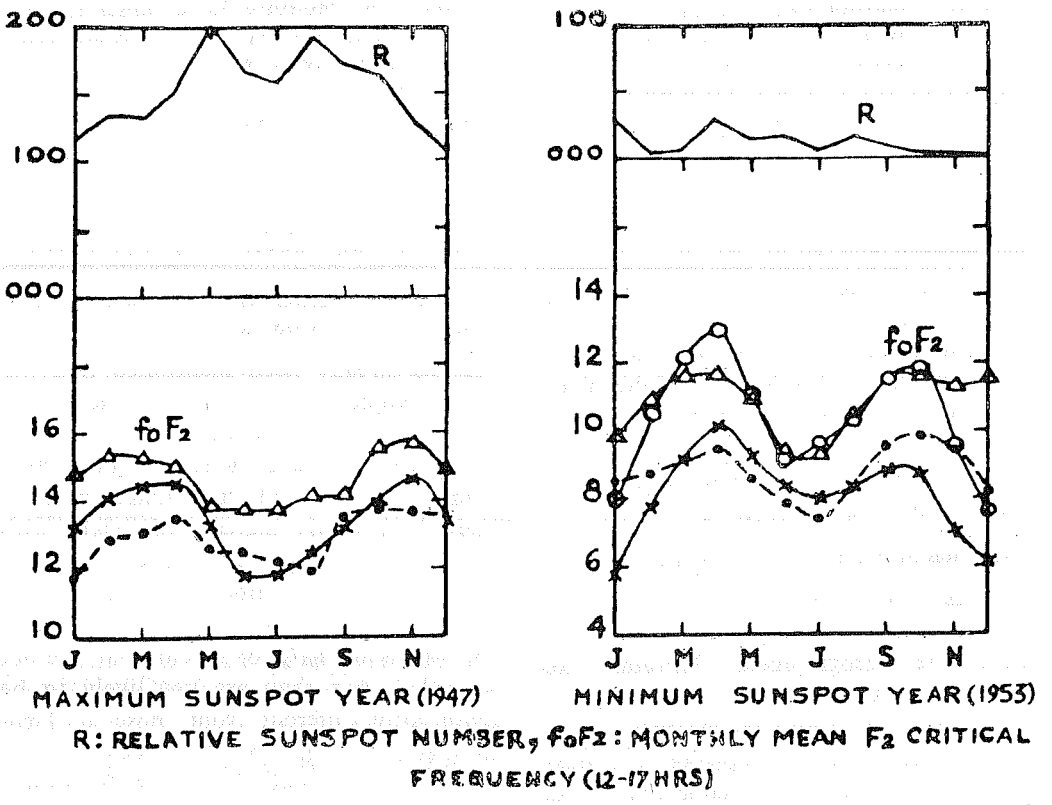

Fig. 8. Annual variation of F_2 critical frequency in afternoon hours, for maximum and minimum sunspot year

(O—Ahmedabad ; △—Bombay ; ×—Delhi ; ●—Madras)

variation is quite large and amounts to nearly 4 Mc/s at Delhi and Ahmedabad in 1953. For comparison, the corresponding values of f_oF_2 for a maximum sunspot year (1947) are also shown in the same diagram. While the critical frequencies are higher, the annual variation is smaller in the year of higher sunspot number.