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Equatorial range spread F and high multiple echoes from the F region

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Abstract

It has been shown that the post-sunset rise of the minimum virtual height ($h'F$) of the F region of the ionosphere near the magnetic equator during the high sunspot years is an effect of the overall rising of the complete F region. This feature of the F region produces very high order multiple reflections from the F regions. On some occasions strong spread F is observed simultaneously with the high multiples suggesting the F region to be smooth and devoid of irregularities inside it. The irregularities causing the spread F during the early stages of its development are suggested to be at heights below the F region.

1. Introduction

It has been well known now that the F region at equatorial stations rises up rapidly at sunset hours followed by the occurrence of strong diffused echoes, called Spread F.[1-4] The occurrence of post-sunset spread F at equatorial stations is very closely associated with the rise of $h'F$ in respect to nocturnal, seasonal as well as solar cycle behaviours of the spread F.[5]

Although a vast amount of data on spread F, mostly statistical in nature, has been collected over more than three decades, the major features of this phenomenon have remained to a large extent unexplained. The character of the spread F varies very much with latitude and the various features are not properly indicated in the routine data publications which are generally used to study the morphology of the spread F and later theories are propounded on these results.

Chandra and Rastogi[4] have shown that the spread F during the pre-midnight hours is of the range spread and that during the pre-sunrise periods is generally of the frequency spread. These different types of spread F are found to have different solar cycle and geomagnetic disturbance effects. The range spread F occurs more commonly during years of high sunspots and is inhibited during geomagnetic disturbed periods. The frequency spread F is more common during low sunspot years and its occurrence is increased during geomagnetic active periods. It is thus natural to seek different mechanisms for different types of spread F and a single theory for the generation of these features would never be complete. Here we study the association between the range type equatorial spread F and the high multiple F region echoes.

2. Results

Rastogi[6] has shown that the height of maximum ionization, h_mF_2, of the F region at station near the dip equator reaches a peak around noon but with increasing solar activity a relatively sharper peak of h_mF_2 develops shortly after sunset such that during maximum sunspot years the height of the F_2 layer is much more in the evening than around noon. In figure 1 are plotted the daily variation of the height of maximum ionization (h_mF_2), the minimum virtual height ($h'F$) and the semi-thickness (y_mF_2) of the F_2 layer at a station near the dip equator for the low sunspot year 1965 and for the high sunspot year 1967. During the low sunspot year, 1965, $h'F$ shows a flat maximum during the night hours and h_mF_2 shows a flat minimum shortly after midnight; y_mF_2 is maximum around midday and is at constant low value during the whole night hours. During the high sunspot year, 1967, $h'F$ curve is very similar to that for 1965 except during 1600 to 2100 LT when a rise of more than 150 km is seen. The h_mF_2 also shows a large and sharp peak at about 2000 LT. It is interesting to find that

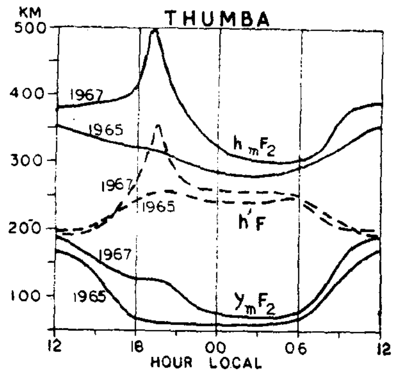

Figure 1. Daily variation of the height of the maximum ionisation (h_mF_2), minimum virtual height ($h'F$) and the semi-thickness (y_mF_2) of the F_2 layer at the equatorial station Thumba during the years 1965 and 1967.

although the values of y_mF_2 is larger in 1967 than in 1965, but the general shape is not too different during the two years. No significant peak in y_mF_2 is evident corresponding to the peaks of h_mF_2 and $h'F$. This means that during the high sunspot years, the F_2 region rises by more than 100 km after sunset keeping its thickness almost constant. Thus the different portions of the F_2 region would present a highly concave surface to the observing ionospheric station below. This curved iso-ionic surface would focus the sounding radio wave of the corresponding plasma frequency. High multiples are seen in the ionograms around periods of peak $h'F$. These high multiples cross the normal first and second order multiples. These high multiples are seen during the nighttime hours when the D region absorption is absent and when the ionospheric surface is very smooth, *i.e.*, the reflecting coefficient is high.[7]

In figure 2 are reproduced the ionograms at equatorial stations Kodaikanal (dip 3° N) and Huancayo (dip 2° N). The ionogram at Kodaikanal at 1830 LT on 21 November 1958 shows some range spread F at lower frequencies: simultaneously sharp traces of high multiple echoes (8th and 9th multiples) are clearly seen. The ionogram at Kodaikanal at 1930 LT on 24 February 1958 shows fairly clear F traces for frequencies higher than 7 MHz. At lower frequencies between 2 and 7 MHz strong range spread is seen. Simultaneously, high multiples are recorded between 5 and 8 MHz. It is interesting to note that the spread F is at heights below $h'F$. Next ionogram is at Huancayo at 1930 LT on 29 August 1958. Intense spread F and high multiple echoes are seen simultaneously for the same frequency range.

These ionograms show that high multiple echoes can be recorded at an equatorial station during periods of strong spread F. If the spread F is due to Rayleigh scattering of the incident radio waves by the irregularities embedded in the F region, as suggested by Booker and Wells,[1] then it would be impossible to record high multiple reflections. The main portion of the F layer has to be fairly smooth, free from irregularities for the high multiples to be recorded. Klemperer[8] has shown that the echo from high latitude spread F has often specular component of amplitude equal to or greater than the scattering contribution.

Cohen and Bowles[9] studied the propagation of 50 MHz signal over a transequatorial path (with mid-point near Huancayo) employing a 2580 km transmitter-receiver separation. During 10 per cent of the nighttime propagation *via* F scatter was present over this path.

Employing pulsed 50 MHz radio waves over 2580 km transequatorial path, Cohen and Bowles[9] found that propagation was possible during the

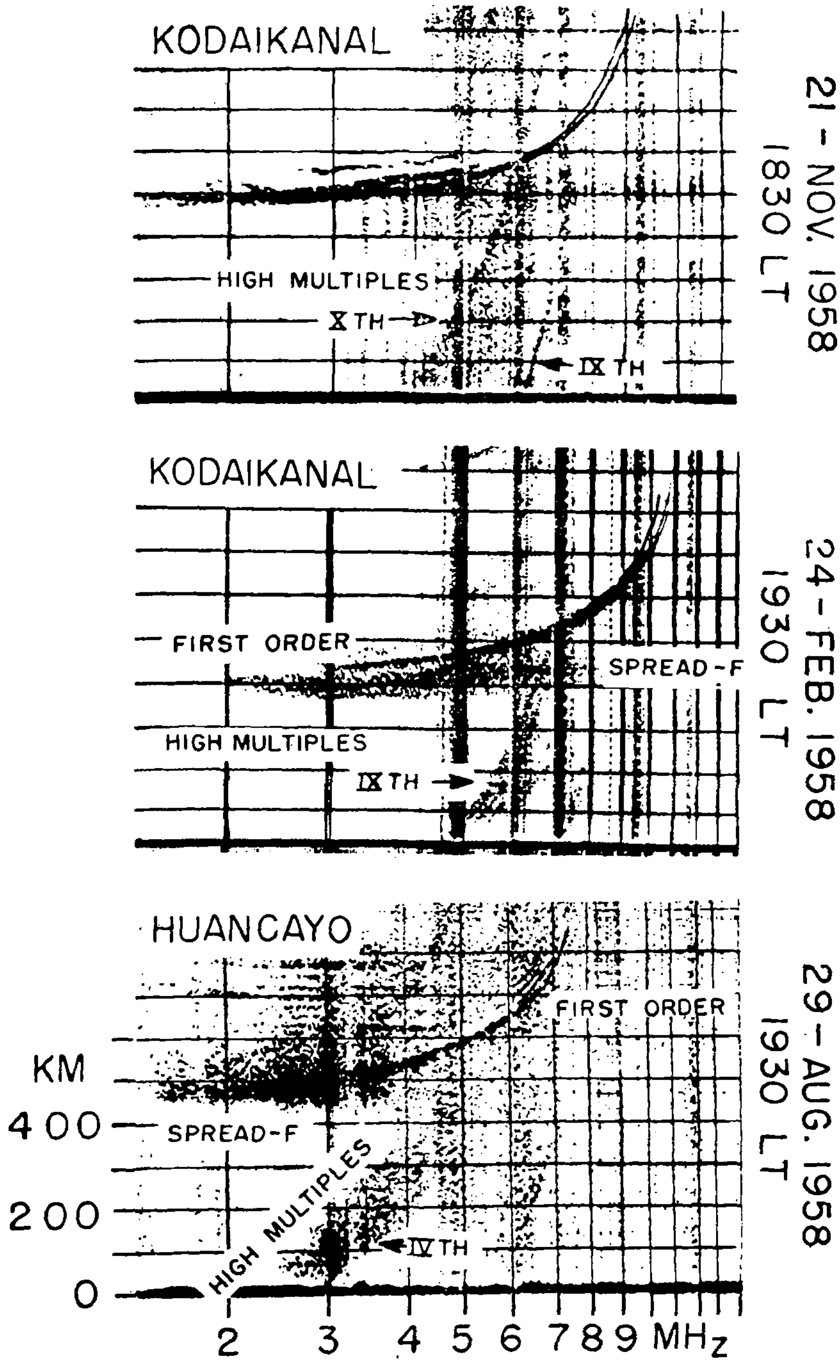

Figure 2. Ionograms at some equatorial stations showing simultaneous occurrence of the range type spread *F* and high multiple echoes.

periods when spread F was present near the mid-point. From the time delay of the pulse, they estimated the height of the scattering region to be lowest height of the associated spread F on the ionograms. They suggested the spread F to arise from scattering by relatively thin sheets of irregularities in electron density which occur at the bottom of the F layer or as much as 100 km lower.

Renau[10] has interpreted some high latitude spread F ionograms in terms of scattering by a thin screen above the E region.

Using rocket borne langmuir and plasma probes, Prakash *et al*[11] have shown the existence of electron density varying from 10^3 to 10^4 per cc in the height range of 95–120 km and a deep valley between 120–140 km during the nighttime hours over the magnetic equator. Large-scale structures in electron density profile with vertical sizes of a few km and a horizontal extent of the order of 50 km were shown to be present.

3. Conclusion

The present observations suggest that the special type of equatorial spread F when the critical frequencies are clear but the reflections at lower frequencies are spread over a range of virtual height generally during the pre-midnight hours is due to the scattering by irregularities below the main F region.

It is suggested that a more critical study of the equatorial spread F is required in collaboration with other experiments like VHF backscatter and rocket borne probes to first understand the character of these irregularities before a unified theory of spread F can be sought.

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