Sudden Frequency Deviations due to Immediate Effect of Geomagnetic Sudden Commencements

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HF Doppler data over two long low latitude radio paths (ATA-Haringhata and JJY-Haringhata) for the period June, 1966 to December 1972 has been examined for effects of sudden commencements. It is noticed that for the same type of sudden commencement, i.e., SC (+), four distinct types of frequency deviations exist, designated as SCFD (+), SCFD (–), SCFD (+–) and SCFD (–+). The occurrence and the nature of the frequency deviation effect due to sudden commencement is independent of the amplitude of the sudden commencement. A positive correlation between the amplitude of the maximum positive frequency deviation and maximum negative frequency deviation is noticed in composite events: SCFD (+–) and SCFD (–+).

1. Introduction

One of the established experimental techniques for investigating the ionospheric response to transient phenomena like solar flares and geomagnetic sudden commencements is the HF Doppler sounder technique developed by OGAWA (1958), FENWICK and VILLARD (1960) and WATTS and DAVIES (1960). DAVIES (1962), KANELAKOS and VILLARD (1962), CHAN *et al.* (1962) and AGY *et al.* (1965) have reported their results regarding the effect of storm sudden commencements on the ionosphere using the above technique. However, the effect has not been studied in detail over low latitude radio paths but for the recent effort of HUANG *et al.* (1973) who studied the Doppler data of a short low latitude path for effects of sudden commencements. The present communication deals with the results of a similar attempt using HF Doppler data over two relatively long (path length 1000 km) low latitude radio paths: ATA (10 MHz)-Haringhata (path length 1290 km) and JJY (10 MHz)-Haringhata (path length 5700 km) and geomagnetic data from the Hyderabad Geomagnetic Observatory. The frequency of transmission of both the ATA and JJY stations is 10 MHz. Geomagnetic storm sudden commencements that occurred between June 1966 to December 1972 have been used for the study of possible ionospheric effects. The Geomagnetic and Geographic co-ordinates of the locations

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Table 1.

Name of Station	Latitude:		Longitude:	
	Geographic	Geomagnetic	Geographic	Geomagnetic
ATA, Delhi	28°38'N	19°11'N	77°13'E	148°55'E
Haringhata	22 58 N	12 15 N	88 34 E	158 42 E
JJY, Tokyo	35 42 N	26 00 N	139 30 E	206 00 E
Hyderabad	17 21 N	7 39 N	78 28 E	148 57 E

of the Haringhata field station, ATA and JJY stations and the Hyderabad Geomagnetic Observatory are given in Table 1.

Between June 1966 to December 1972, 184 storm sudden commencements (SSC) have been observed at the Hyderabad Geomagnetic Observatory. (B.J. SRIVASTAVA, private communication, 1973). Out of these 184 SC's, 24 occurred during the 'off' period of transmissions and power failures at the recording site, while 67 occurred during the maintenance period of the Doppler system. For 33 SC events, poor ionospheric conditions made it difficult to identify the effects. Thus a total of 60 SC events became available to study their effects on frequency deviations over the low latitude radio paths. Distinctive effects have been noticed on 25 occasions.

2. Typical Patterns of Frequency Deviations due to SC's

A study of the frequency deviation patterns due to sudden commencements indicated that the effect may be classified into four distinct types depending on the nature of the time variation of frequency deviation, typical examples of which are shown in Fig. 1. It may be seen that in Type I (Fig. 1A) there occurs a positive frequency deviation within a few minutes from the onset of SC, whereas in Type II (Fig. 1B) there occurs a negative frequency deviation. In type III a positive frequency shift followed by a prolonged negative frequency deviation occurs (Fig. 1C), whereas in Type IV the pattern is reversed (Fig. 1D). These four types of frequency deviation patterns due to sudden commencements have been designated as SCFD (+), SCFD (—), SCFD (+ —), and SCFD (— +) respectively. MATSUSHITA (1960, 1962) reported that the major type of sudden commencement at low latitudes is SC (+) and all the 60 SC's used in the present study belong to this category. This leads to the observation that for one and the same type of SC, four distinct patterns of frequency deviations exist over low latitude radio paths.

3. Statistical Results of SCFD Events

Out of the 25 frequency deviation effects noticed in our data, 21 fit into

Fig. 1. Typical examples of SCFD events. A, SCFD (+); B, SCFD (-); C, SCFD (+-); D, SCFD (-+).

one of the types mentioned in the preceding section while the rest four show complex variation and could not be classified. Out of the 21 classified events, 14 occurred on the JJY-Haringhata path (path length 5700 km) and 7 on the ATA-Haringhata path (path length 1290 km). It is noticed that out of the four types of SCFD, SCFD (-) occurs most frequently on both the paths. It is rather interesting to note from our data that SCFD (-+) has never been observed on the ATA-Haringhata path (Period of monitoring 1100–1500 I.S.T. everyday.) during the entire period under study.

The total duration of the SCFD event is found to range from 2 to 20 min with an average value of 8.8 min for the sample of 21 events as can be seen from Fig. 2A. No clear cut dependence of the total duration of the SCFD event either on the amplitude of the sudden commencement or on the rise time is noticed. In composite events i.e., SCFD (+-) and SCFD (-+), a positive linear relationship between the maximum positive frequency deviation and maximum negative frequency deviation is noticed, (Fig. 2B). A study of the diurnal distribution of the occurrence of the different types of SCFD events showed that the most suitable period for the occurrence of Doppler frequency effects due to SC's are noon time, post-sunset and midnight periods, and that SCFD (-+) is mostly a night time event. A study of the amplitude of the sudden commencement for those SC's which produced frequency deviation effects, showed that the amplitude varies over a wide range of 3 to 99% with

Fig. 2A. Histogram of the total duration of the SCFD event. B. Correlation between the maximum positive frequency deviation and maximum negative frequency deviation in composite events: SCFD (+ -) and SCFD (- +).

most of the values lying in the range 10 to 40%. No definite dependence of the type of SCFD on the amplitude of the SC is noticed. This leads to the conclusion that the magnitude of the SC has no bearing either on the occurrence or on the nature of the frequency deviation effect due to the sudden commencement.

It is observed that during the decay period, the frequency deviation closely follows the expression:

$$\Delta f = \Delta f_0 \exp(-(t - t_0)/\tau)$$

where Δf_0 is the frequency deviation at some reference time t_0 and τ is the effective relaxation time. This feature can be clearly seen from typical examples of $\log \Delta f$ vs time plots shown in Fig. 3 for SCFD (+ -) and SCFD (-) events. The value of τ is found to vary over the range 100 to 400 seconds.

Fig. 3. Variation of negative frequency deviation with time in SCFD (+ -) and SCFD (-) events.

4. Discussion

The earlier work on the ionospheric response to geomagnetic sudden commencements using Doppler shift technique reported by DAVIES (1962) and KANELAKOS and VILLARD (1962) showed that for the SC of September 30, 1961, there occurred a sharp increase in frequency preceded by a definite decrease of frequency. A more detailed study using 12 SC's by CHAN *et al.* (1962) showed that the frequency deviation was always correlated in phase with SC (+) and in opposite phase with SC (-), SC (+-) and SC (-+). A more convincing study of the phase relationship between SC and its effect on frequency deviations has been recently made by HUANG *et al.* (1973) using Doppler data over a path of 150 km length and SC data from a place situated 95 km from the sub-radio reflection point. This study showed that there is no definite correlation between the phase of the SC and its effect on frequency deviations. A similar feature is noticed in the present study. However, it is to be emphasized that in this work as in that of CHAN *et al.* (1962) Doppler data over long paths and geomagnetic data from a location far from the radio reflection point have been used.

A comparison of the statistical features of the SCFD events, noticed in our data with those reported by HUANG *et al.* (1973) showed only partial agreement. For example, the existence of four types of frequency deviation patterns for one and same type of sudden commencement, i.e., SC (+), and the positive correlation between the maximum positive frequency deviation and the maxi-

imum negative frequency deviation in composite events SCFD (+ -) and SCFD (- +) noticed in our data agree well with the findings of HUANG *et al.* (1973). However, the correlation between the amplitudes of the positive spike and the amplitude of the SC reported by HUANG *et al.* (1973) has not been noticed in our data. It is to be emphasized that our results pertain to observations over two long radio propagation paths of different lengths (1290 km and 5700 km) while HUANG *et al.* (1973) used data for one short propagation path.

JACOBS and WATANABE (1966) theoretically investigated the relation between Doppler frequency changes and sudden commencements for vertically incident and reflected radio waves. A comparison of our results with those predicted by JACOBS and WATANABE (1966) using the equivalence theorem for frequency deviations could not be made due to lack of electron density profile data necessary to fix the angle of fire using ray tracing procedures. A study assuming reasonable value of ' θ ', the angle of incidence at the ionosphere, showed our results to differ from those predicted by Jacobs and Watanabe. However, much stress cannot be given to this in the absence of precise information about the propagation conditions for the events observed over a period of several years.

None of the frequency deviation patterns due to sudden commencements in our data showed wavelike oscillations as reported earlier by DAVIES (1962), KANLLAKOS and VILLARD (1962). To sum up, the present study showed that the effect of geomagnetic sudden commencements of the SC (+) type on low latitude ionosphere manifests as sudden frequency deviations which can be classified as on the types: SCFD (+), SCFD (-), SCFD (+ -). The magnitude of the sudden commencement has no bearing either on the occurrence or on the nature of the frequency deviation effect. The detailed statistical features of the SCFD events seem to depend on the path length.

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