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Effect of Sudden Ionospheric Disturbances on the Field Strength of an lf Radio Signal in Relation to Solar X-ray Flux in Different Wavelength Ranges

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The SID effects observed on the field strength of an lf radio signal at 280 kHz transmitted from Jessore (lat., 23° 10'N; long., 89° 10'E) in Bangladesh at a distance of about 110 km from Calcutta (lat., 22° 34'N; long., 88° 24'E) often appears as an SES or an SAS and the effect sometimes appears to be superimposed on a long duration absorption of signal. From a correlation of the SID data obtained during the period June 1972-May 1973, with the solar X-ray flux in the different wavelength ranges, it appears that the relative strength of the 0·5-3 Å flux with respect to the 1-8 Å flux would be important in determining the form of the effect. An SID effect appears to occur as an SES when the ratio of 0·5-3 Å flux to 1-8 Å flux is greater than about 0·025, while it tends to appear as an SAS when the ratio is less than about 0·025. The long duration absorption of signal appears to be associated with the longer-life soft X-ray flux in the wavelength range of 8-20 Å.

1. Introduction

IT IS NOW well established that during solar flares and microwave bursts there is an enhancement of X-ray flux emitted from the sun, which causes extra ionization in the lower ionospheric regions, thereby producing sudden ionospheric disturbances (SIDs) of different kinds[1-9]. The SIDs, for instance, appear at hf as SWF (short wave fadeout) and SFD (sudden frequency deviation), at vlf as SEA or SES (sudden enhancement of atmospherics or signals) for oblique incidence and as SAA or SAS (sudden absorption of atmospherics or signals) for steeper incidence, while at lf the effect usually appears as an SES and an SAS for oblique and steep incidences respectively[10-12]. We have been able to observe the variation of the field strength of an lf radio signal appearing in either of the forms of an SES or an SAS, even for the same angle of incidence of the signal on the ionosphere and at a fixed frequency. Moreover, the effect sometimes appears to be superimposed on a long duration absorption of signal. Some of the interesting results obtained from an analysis of the SID effects observed during the 1-yr period June 1972 to May 1973 are presented in this paper.

2. Observations

The lf signal involved is a radio navigational one at 280 kHz with a call sign JR transmitted from Jessore (lat., 23° 10'N; long., 89° 10'E) in Bangladesh at a distance of about 110 km from Calcutta (lat., 22° 34'N; long., 88° 24'E). Typical records of the effect obtained are shown in Fig. 1. It is clearly noticed from Fig. 1 that the SID effects appear as an SES or SAS on a fixed frequency radio signal. Besides this, it is also noticed from the figure that the effect observed on some of the cases such as that occurring on 4.7.72 appears as an SES preceded by an initial decrease and followed by a gradual increase. The effect, in fact, appears to be an SES superimposed on a long-duration absorption of signal (hereafter abbreviated as LAS) starting and ending at 1052 and 1154 hrs respectively. The LAS is also evident in the records of 22.7.72, 8.7.72 and 24.7.72. During the period under consideration there were altogether 29 SID effects, of which 19 effects appeared as SAS and the remaining 10 as SES. The long duration absorption of signal was evident in 7 cases. The details of the SID effects and those of the associated solar events are given in Table 1 which indicates that the effects were associated both with solar optical flares and microwave bursts. Besides this, it is also noticed from Table 1 that a great majority of the SID effects are associated with the sub-flares.

3. Discussion

Assuming an ionospheric model consisting of two regions D_α and D_β below the normal E region, the lower one, D_β, being at a small distance below the upper one, D_α, the lf signal involved would penetrate the lower region, and be reflected from a level in the upper region[13-15]. During solar flares and radio emissions the extra ionizations in these regions would be produced by the enhanced emission of X-rays in the wavelength range 1-100 Å, specially below 10 Å (Ref. 1 and 16). Due to these extra ionizations the height gradient of electron density (dN/dh) of the upper region increases, causing an increase in the reflectivity of the region, while at the same time the

Table 1—Details of the SID Effects and the Associated Solar Events

Date	SID effects				Associated solar events, flares/radio emissions				
	Start UT	Max. UT	End UT	Type	Start UT	Max. UT	Duration min.	Areawise class/type	Intensity/Peak flux density
6.6.72	0832	—	0905	LAS*	0835	0840	35	Subflare	Faint
	0841	0842	0851	SAS	0833	0834·5	3	Simple 2 (Code-3)	$5{\cdot}0\times10^{-22}$ Wm^{-2} Hz^{-1}
15.6.72	0837	0848 0905	0924	SAS	0824	—	10	Subflare	Normal
	0930	1000	1030	SAS	0925	—	—	Proton flare	—
	1032	1043	1130	SAS	0955	1003	70	Flare (1)	Bright
					1040	—	110	Fall Code 26	$8{\cdot}8\times10^{-22}$ Wm^{-2} Hz^{-1}
	1138	1139	1205	SAS	1116·8	1116·8	·1	Minor Code-6	71×10^{-22} Wm^{-2} Hz^{-1}
29.6.72	0953	0957	1013	SAS	0953	0956 D	3 D	Subflare	Normal
4.7.72	0522	—	0624	LAS	0525	0526	45 D	Flare (1)	Normal
	0542	0547	0615	SES					
	1053	1057	1106	SAS	1052	1055	4 5	Complex Code-45	—
5.7.72	0028	0034	0113	SES	0004	0032	90	Simple 3 Code-20	7×10^{-22} Wm^{-2} Hz
8.7.72	0837	—	0924	LAS	0845E	—	40 D	Subflare	Normal
	0847	0854	0913	SAS					
14.7.72	1018	1019	1034	SAS	1017	1019	12 D	Subflare	Normal
22.7.72	0250	—	0335	LAS	No flare Petrol observation				
	0303	0308	0330	SES					
24.7.72	0536	0540	0553	SFS	0532	0533	5	Subflare	Faint
	1135	—	1251	LAS	1121	1124	10	Subflare	Faint
	1151	1200	1230	SAS	1100	1140	120	Simple-3 Code-20	$2{\cdot}8\times10^{-22}$ Wm^{-2} Hz^{-1}
5.8.72	0443	0445	0449	SAS	0442	0443	9	Flare (1)	Faint
7.8.72	0825	—	1002	LAS	0845	0851	15	Subflare	Normal
	0852	0902	0925	SES					
22.8.72	0525	0532	0542	SAS	0520	0522	9	Subflare	Faint
26.8.72	0230	0235	0247	SAS	No flare Petrol observation				
	0807	0811	0820	SAS	No flare known, there were X-rays				
	1005	1007	1022	SAS	0954	0956	4	Subflare	Faint
2.9.72	1042	1044	1102	SAS	1044	1050	37	Subflare	Normal
	1111	1112	1132	SAS	1114	1121	10	Subflare	Normal
9.9.72	0830	—	0915	LAS	0838	0841	9	Subflare	Faint
	0835	0836	0858	SES					
3.11.72	1127	1140	1210	SAS	1136	1138	10	Subflare	Faint
9.4.73	0350	0420	0500	SES	0353 E	0353 U	1 D	Subflare	Faint
11.4.73	0625	0635	0655	SES	0623 E	0624	12	Subflare	Faint
	0943	0952	1028	SES	0951	0954	9	X-ray flare	
13.4.73	0815	0828	0928	SES	0820·8	0821·8	2·8	Group of bursts Code-41	100×10^{-22} Wm^{-2} Hz^{-1}
16.4.73	0917	0930	0949	SES	0913	0913·5	1	Complex Code-45	—

* LAS—Long-duration Absorption of Signal.

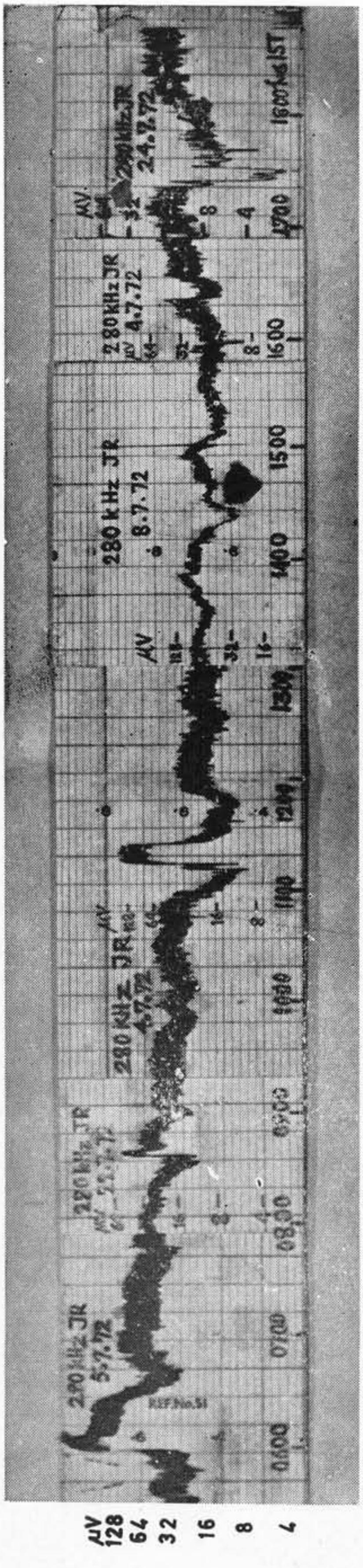

Fig. 1—Typical records obtained at the Institute of Radio Physics and Electronics, University of Calcutta, showing the SID effects appearing in either of the forms of an SAS or an SES on the field strength of an lf radio signal at 280 kHz transmitted from a distance of about 110 km (The ordinates indicate the receiver input in μV.)

electron density (N) of the lower region increases, producing an increase in the absorption of the radio signal. An SES or SAS would appear to occur as a resultant effect of these two separate changes in the upper and lower regions of the lower ionosphere producing the opposite effects on the signal strength[17]. A correlation of the SID data with the solar X-ray flux in different wavelength ranges indicates that the effect would appear as an SES when the relative strength of 0·5-3 Å X-ray flux with respect to the 1-8 Å flux is greater than about 0·025, while the effect would appear as an SAS when the same is less than about 0·025, the typical values of the ratio of 0·5-3 Å flux to 1-8 Å flux being 0·04567 and 0·0184 for an SES and an SAS respectively. This result suggests that a predominance of the hard component of X-ray flux in the 0·5-3Å wavelength range renders the lower layer, D_β a reflector of the lf signal while for a relatively smaller portion of the hard component, D_β behaves in the normal way as an absorbing region. Exceptions to this behaviour of the lower ionosphere are, however, expected if the hard component is so large as to penetrate sufficiently down below the D_β region, causing ionization in a region where collisional loss would be predominant. In such cases an SAS would be produced. Our observations also indicate such a tendency when the X-ray flux in the 0·5-3 Å wavelength range is large enough to saturate the X-ray detector. Again if an enhancement of the 0·5-3 Å flux is too low to produce sufficient ionization in the lower region D_β, and SES may be produced due to an increase in the X-ray flux practically in the 1-8 Å wavelength range producing an increase in (dN/dh) of the upper layer D_α. We have, infact, noticed in several cases of such occurrences. As regards the long duration signal absorption background, it appears from the present analysis that such cases are closely associated with an increase of X-ray flux in the wavelength range of 8-20 Å, which are believed to be enhanced before the SID and continues after the end of the SID, the total duration being sufficiently longer than that of the harder component[4,8].

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