Sudden amplitude and phase changes in subionospheric VLF transmitter signals observed at Agra

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Abstract

The monitoring of phase and amplitude of VLF transmitter signals (f=19.8 kHz(NWC), 21.4 kHz (NPM), and 24 kHz (NAA)) has been carried out at Agra (geomag. lat. 17.1^0 N, L=1.15), India during the period 1 September, 2002-30 August,, 2005. Seven cases of abrupt phase and amplitude changes similar to Trimpi/TLE phenomena have been observed. Our data show average amplitude enhancement of about 3-7 dB and phase decrease ~ 8.6 µs. It is suggested that the observed phenomena are most probably caused by Transient Luminous Events (TLE) in the lower ionosphere above active thunderstorm centers close to great circle paths.

1. Introduction

The phase and amplitude of fixed frequency VLF transmitter signals propagating between earth ionosphere waveguide are known to be influenced by several factors which include precipitation of energetic electrons, solar flares, solar zenith angle, transient luminous events, and earthquakes etc. The results pertaining to these phenomena are well documented and readily available in literature Keeping in view the importance of the subject, we have also started study of amplitude and phase monitoring of VLF transmitter signals [19.8 KHz (NWC), 21.4 KHz (NPM), 24 KHz(NAA)] at Agra station in India (Geomag. Lat., 17^0 N , L=1.1) since 01 September , 2002 This study was started initially with the main objectives of investigating whether Trimpi phenomena is possible in lower (L<1.4) latitude ionosphere or not. The background of this attempt was the fact that an enhanced occurrence of low latitude whistlers is observed during winter season (November-March) in North India which coincides with lightening activity in the conjugate region of the opposite hemisphere [1,2].The observations during this time include cases of ELF/VLF emissions also [3,4]. Such results have been reported by low latitude workers elsewhere also [5]. Further, many workers have shown that wave-particle interaction occurring in the equatorial plane near L=1.2 can diffuse the pitch angles of the resonant electrons of energy ~ 1 MeV so that particles may be precipitated in the lower ionosphere [6,7]. This has been confirmed from the satellite observations also in which multiple peaks in the energy spectrum of energetic electrons were detected at the lower edge of the inner radiation belt[8].

We have analysed the three years of phase and amplitude data obtained at our station and find that there are seven cases of sudden phase and amplitude changes recorded. In this paper, we examine the characteristics of these anomalies and show that they resemble mostly with those caused by Transient Luminous Events(TLE).

2. Experimental Setup

We have employed AbsPAL receiver obtained from LF*EM Research Ltd, Australia to monitor the phase and amplitude of fixed frequency VLF transmitter signals. We monitor the phase and amplitude of three different signals of frequencies 19.8 kHz (NWC, Australia), 21.4 kHz (NPM, Hawai), and 24 kHz (NAA, Cutler).The equipment includes electric antenna, VLF amplifier , a service unit , DSP card , and necessary software. The sampling rate of receiver is 1 sample/sec. The observations have been taken at Bichpuri, a rural area, located at about 12 km west of Agra city where local electric and electromagnetic disturbances are low.

3. Results and Discussion

The routine monitoring of the phase and amplitude of the three transmitter signals mentioned in the previous section have been started at Agra station since 01 September, 2002 and the bulk of data have been analysed recently with the main objective as stated earlier. We have found that out of the bulk of data recorded there are seven cases only which show abrupt phase and amplitude changes similar to those recorded in various events as mentioned in Introduction. The details of these events are presented in table -1 which shows the date and local time of occurrence, frequency of the transmitter signals, and whether the sudden changes occurred both in phase(P) and amplitude(A) or in any one of them only.

Table -1 Cases of sudden phase and amplitude changes recorded at Agra station.

Date	Time,LT	Frequency,kHz	∑Kp	∑Kp (±5 Days)
7.10.02	15:58	24 (PA)	39	42-12
27.09.04	14:07	24 (A)	8	20-3
03.10.04	03:48	21.4 (PA)	19	20-3
06.10.04	13:37	24 (A)	6	20-3
11.11.04	22:58	19.8 (A)	29	56-3
2.12.04	22:04	21.4 (PA)	20	5-20
15.01.05	23:13	19.8 (PA)	26	21-47

The table also shows ∑ Kp on the days of occurrence and its variation ±5days from the events . In Fig.1 we show three minutes of data for three cases in which both phase and amplitude were affected . These cases correspond to 7 October, 2002, 2 December,2004, and 15 January,2005. One of the three cases presented here corresponding to 7 October,2002 was recorded during daytime whereas rest of the two cases were recorded at nighttime. As seen from the figure the amplitude of the signal underwent sudden changes of 3 to 7 dB whereas phase underwent 40 to 86 degrees. The onset time varied from 5 to 13 seconds. In the case of amplitude variation observed on 15 January, 2005, the data shows the occurrence of three events during the 3 minutes of data.

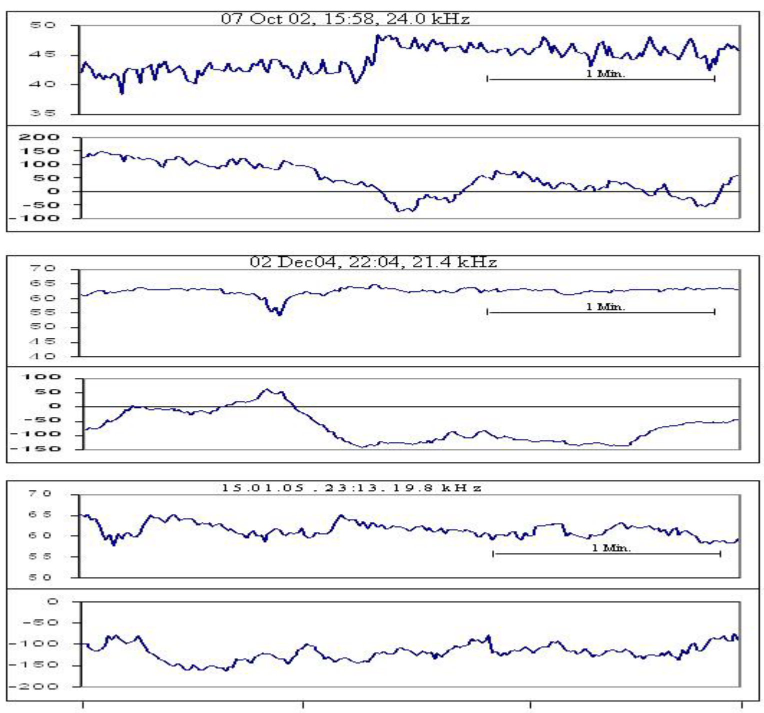

Fig.1 Phase and amplitude changes recorded at Agra station

We have compared the Agra data with those recorded at other mid and high latitudes stations. In particular we have procured some sample data from Budapest, Hungary (J. Lichtenberger and D. Hamar, Personal Communication, October-2005). The details of the comparision are presented in table.2 in which we provide information on date and time of occurrence, onset and relaxation time changes in amplitude and phase, and corresponding references. From this table it may be seen that onset and relaxation times, and change in the amplitude and phase of the Agra data are much higher as compared to others. The characteristics of the data found here are much different from those in Trimpi phenomena, particularly looking at the onset and relaxation times. Especially, two of the three events presented in Fig.1 do not look like classic Trimpi when they are compared with the data received from Budapest. Hence, it is unlikely that the Agra data represent Trimpi phenomena.

Examples of Trimpi like events recorded at low L-shells have been reported earlier but they are associated with Transient Luminous Events (TLE) such as red sprites and elves [9]. Rodger[10] has presented a review on TLE and their association with phase and amplitude perturbation of subionospheric VLF propagation. While such events are generally found to have "fast" onsets, recent observations from the University of Crete have shown that some TLE related perturbations can have slow –onsets as well[11] just as classic Trimpi do. It is worthwhile to note here that Dowden and his co- workers have reported plenty of TLE- related VLF perturbations from Darwin, Australia (L=1.15) whose L value is similar to that Agra [12].

Table-2 A comparison of Agra data with those received at other stations

Date	Time (UT)	Frequency (kHz)	Onset (Sec.)	Relaxation (Sec.)	Reference	Change in Amplitude	Change in Phase
31/10/81	05:10	37.2	~1	~30	Inan et al.,1985	1.5dB	
20/02/97	12:38	19.8	~1	~30	Molchanov and Hayakawa et al, 1998	7dB	30^0
08/10/02	22:40	22.1	~1.1	~35	Budapest	3dB	10^0
08/10/02	22:33	45.9	~1.4	~30	Budapest	1.5 dB	12^0
08/10/02	21:50	22.1	~2.4	~19	Budapest	1.5 dB	10^0
07/10/02	10:28	24.0	~5	~90	Agra	6 dB	86^0
02/12/04	16:34	21.4	~5	~12	Agra	7dB	80^0
15/01/05	17:43	19.8	~5	~41	Agra	5dB	41^0

Since, VLF perturbations due to TLE are caused by scattering from localized regions of ionization enhancements above the active thunderstorms close to the great circle path (GCP), it is worthwhile to examine the locations of lightning and thunderstorms along the GCP of the signals responsible for the Agra data. The studies of these locations are in progress and the results will be reported soon.

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