Ultra- Low- Frequency and total electron content anomalies observed at Agra and their association with regional earthquakes

Birbal Singh[1] and O.P. Singh[2]

1. Department of electronics and communication Engineering, Faculty of Engineering and Technology, R.B.S. College Bichpuri, Agra-283105, India
Telephone: 91 562 2636675, Fax: 91 562 2851288, e-mail: bbsagra@gmail.com

2. Department of Physics, Faculty of Engineering and Technology, R.B.S. College Bichpuri, Agra-283105, India
Telephone: 91 562 2636675, Fax: 91 562 2636718 e-mail: opsagra2003@yahoo.co.in

Abstract

The Ultra Low Frequency (ULF) magnetic field observations and Total Electron Content (TEC) measurements have been carried out at Bichpuri, Agra station in India since 20 April, 2007. The seven months of nighttime data corresponding to the period 01 May-30 November, 2007 have been analysed. Six cases of unusual occurrence of ULF bursts in wide frequency range and corresponding depletion in TEC data have been found. Four cases of ULF burst satisfy the polarization parameter criteria (Z/X>1) and are believed to be caused by earthquakes (M>4.5) that occurred within 600 Km from the observing station.

1. Introduction

It is now widely expected that the earthquake preparation processes consist of not only seismic but also electromagnetic events. Such electromagnetic phenomena could appear in wide frequency range, from DC upto MHz frequencies. However, the frequency band in Ultra Low Frequency (ULF) range (0.01-10Hz) has been found to yield more reliable precursors because of large skin depth, low attenuation rate, and relatively less contamination from other sources[1]. Keeping in view the relative importance of ULF range over others, several workers have studied ULF precursors of earthquakes thoroughly [2-4 and references therein].

The electromagnetic coupling between lithosphere and ionosphere has attracted considerable attention in recent times and several workers have shown ionospheric precursors of earthquakes from ground and satellite based observations [4-6]. Considerable emphasis has been placed on Total Electron Content (TEC) measurements using Global Positioning System (GPS) [7-8]. It has been shown that smooth variation in TEC may be replaced by rapid fluctuation during various geophysical phenomena like solar flares and magnetic storms which may also appear as precursors to large magnitude earthquakes [9-10].

The Agra station in India is equipped with four different types of experiments to study the electromagnetic precursors of earthquakes. These are measurement of vertical electric field emission with borehole antenna, ULF magnetic field observation with a search coil magnetometer, phase and amplitude monitoring of fixed frequency VLF transmitter signals, and TEC measurements with a GPS receiver. In this paper, we present the results of analysis of ULF and TEC data for a period of seven months from 01 May, 2007-30 November, 2007 and show simultaneous ULF and TEC anomalies related to some regional earthquakes which occurred within 600km from Agra station.

2. Experimental Setup

The experimental setup for monitoring of ULF magnetic field emissions consists of three- component search coil magnetometer (f= 0.01-30Hz) procured from Lviv Centre of Space Research, Ukraine. The three sensors of the magnetometer are buried 1m deep under ground in orthogonal directions and the data from each sensor are digitized at a sampling rate of 60 Hz and recorded for offline analysis.

The equipments related to TEC measurements are imported from USA which include L1/L2 GPS antenna (NOVATEL Model GPS702), a GPS receiver and relevant software. The receiver can locate upto 11 GPS signals at a time and the obtained values of TEC are slant TEC which are converted to vertical TEC using suitable mapping

function at different Ionosphere Pierce Point(IPP) locations. The mean ionospheric height of 350km is used for the determination of IPP locations, which is found to validate for elevation angle>50^0 in a low latitude sector.

3. Results and discussion

The ULF data have been analysed for nighttime (1800-0230h, LT) only in view of the fact that local electric and electromagnetic disturbances are low during this time. The analysis of the data for the period of seven months between 01 May, 2007-30 November, 2007 yield ULF anomalies on six occasions where the ULF amplitudes appear as bursts of duration ranging from few minutes to an hour. The frequency time spectrograms of these bursts show that they occur in wide frequency range upto 15Hz. Similar bursts have been reported by earlier workers also [1, 11, 12]. An example of the ULF burst recorded at 28 July, 2007 corresponding to the earthquake of 01 August, 2007 is shown in Fig. 1. In order to determine the sources of these bursts we have carried out polarization analysis of the data [1] which shows that in four of the six cases the sources of the bursts are underground (Z/X>1) whereas in one case the source lies in the ionosphere and magnetosphere (Z/X<1). There is no data corresponding to remaining one case. It is interesting to mention here that in three of the four cases the bursts appear as precursors to earthquakes.

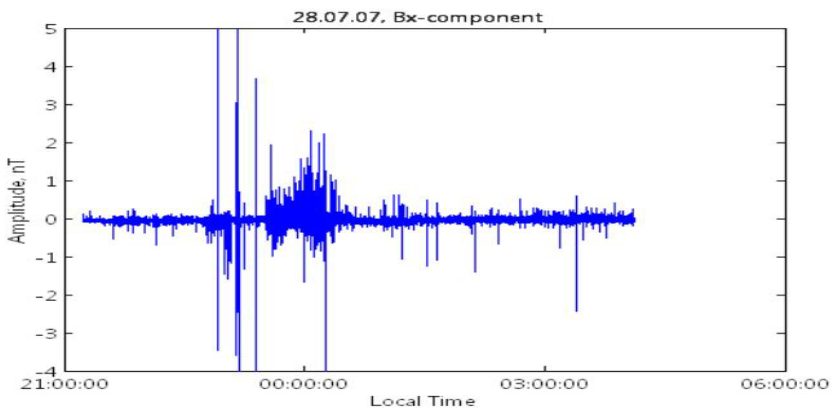

Fig. 1 X - Component of the ULF burst recorded on 28 July, 2007 at Agra

We then analyse the TEC data for the same period of seven months as above. The analysis shows that the TEC values are depleted in all the days during which ULF anomalies are recorded. The TEC analysis is carried out with statistical help in which mean and standard deviation around the mean are calculated and the results are examined graphically. An example of the TEC anomalies corresponding to the earthquake of 01 August, 2007 is shown in Fig.2.

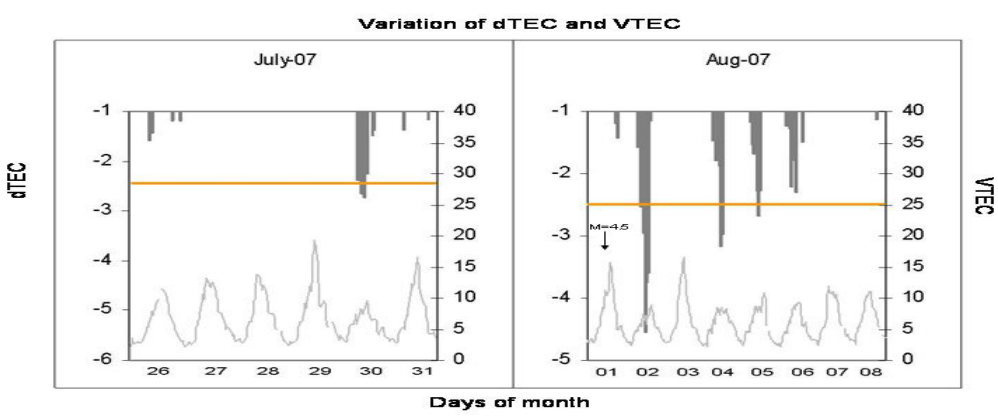

Fig.2 Variation of TEC corresponding to the earthquake of 01 August, 2007 observed at Agra

Since there are no prolonged magnetic storm cases in the months considered above the question arises how did the ULF and TEC anomalies occur? One possibility which is known to cause such anomalies is the occurrence of

earthquake and to examine this possibility we look into the earthquake data obtained from USGS for the period under consideration. We find that there are moderate to major earthquakes around all the days of ULF and TEC anomalies. In table 1 we give the details of these earthquakes along with the ULF and TEC anomalies. The table includes the dates of earthquakes and days of ULF and TEC anomalies.

Table-1 Details of the ULF and TEC anomalies in relation to earthquakes

Date of earthquakes	Magnitude of earthquake and (depth, km)	Distance from observing station (km)	ULF anomalies		TEC anomalies	
			Days before EQ	Days after EQ	Days before EQ	Days after EQ
05 May, 07	6.0 (9)	867	-	3	4(enhancement)	-
22 July, 07	5.1 (19)	408	-	1	5 (depletion)	1-3
01 Aug, 07	4.5 (10)	467	4	-	2 (depletion)	2
09 Aug, 07	4.5 (10)	504	No data	No data	.05(depletion)	
04 Oct, 07	4.6 (10)	628	3	-	3(depletion)	1-2
25Nov, 07	4.7 (10)	172	1	-	7 (depletion)	-

From table 1 it is seen that the precursory periods for the ULF anomalies are between 1 and 4 days whereas the same for TEC anomalies are between 2 and 7 days. In one of the cases the TEC values are found to be enhanced in contract to other days when the values are depleted. This case is on 05 May, 2007, the same on which ULF anomaly appears to have it source in the ionosphere and magnetosphere. Further, all the four cases in which ULF anomalies are observed correspond to the earthquakes whose epicenters are less then 628km and some of them have clear precursors to earthquakes. The TEC measurements also cover the same zone in the ionosphere as these of ULF measurements on the show, and hence there is a great possibility that both the observed anomalies are caused by the same source. The ULF anomalies associated with earthquakes have been discussed by many workers earlier [1,13] and microfracturing of earth crust is attributed to be a possible mechanism for the generation of ULF emissions [14]. The electric field generated during earthquake preparation processes either due to radon emission are due to other reasons including internal gravity waves may penetrate the ionosphere and bring out the TEC anomalies [9,10].

4. Acknowledgements

The authors are thankful to the department of Science and Technology, New Delhi for providing financial assistance for this work. Thanks are also due to senior research fellows Mr. Vinod Kushwah, and Mr. Vikarma Singh, and Junior research fellow Mr. Vishal Chauhan for useful discussions and help with processing of the data .

5. References

1. Y. Kopytenko, V.Ismagilov, M. Hayakawa, N. Smirnova, V. Troyan and T. Peterson, “Investigation of the ULF electromagnetic phenomena related to earthquakes: contemporary achievements and the prospective ”, Annali De Geofisica, 44, 2001, 325-334.

2. M. Hayakawa, and Y. Fujinawa[Eds] , Electromagnetic phenomena related to earthquake prediction, Terra Sci. Pub. Co., Tokyo, 1994, pp. 175.

3. M. Hayakawa [Ed], Atmospheric and ionospheric electromagnetic phenomena associated with earthquakes, Terra Sci. Pub. Co., Tokyo, 1999, pp. 175-215.

4. M. Hayakawa and O.A. Molchanov [Eds], Seismoelectromagnetics, lithosphere-atmosphere-ionsophere coupling, Terra Sci. Pub. Co., Tokyo, 2002, pp. 11-55.

5. B. Singh, V. Kushwah, O.P. Singh, D.R. Lakshmi, and B.M. Reddy, "Ionospheric perturbations caused by some major earthquakes in India" Physics and Chemistry of Earth, 29, 2004, 537-550.

6. S.A. Pullinets, "Strong earthquake prediction possibility with the help of topside sounding from satellites" Advances Space Res., 21, 1998, 455-458.

7. J.Y. Liu, H.F. Tsai, and T.A. Jung, "Total electron content obtained by using the global positioning system", Terr. Atmos. Oceanic Sci., 7, 1996, 107-117.

8. J.Y. Liu, Y.I. Chen, H.K. Jhuang, and Y.H. Lin, "Ionospheric f0F2 and TEC anomalous days associated with M=5.0 earthquakes in Taiwan during 1997-1999", TAO, 15, 2004, 371-383.

9. M. Devi, M.K. Berman, A.K. Babara, and A. Depueva, "Total electron content (TEC) near anomaly crest as precursor of earthquakes" Indian J Radio Space Phys., 30, 2001, 209-213.

10.M. Devi, A.K. Barbara, and A. Depueva, " Association of total electron content (TEC) and f0F2 variation with earthquake events at the anomaly crest region", Ann. Geophys., 47, 2004, 83-91.

11. M. Seto, K. Muriyama, Y.Kitamura, and T. Watabnabe, "Observation of seismo-genic ELF magnetic field variations and seismo-electric currents in a power transmitter system", In Seismoelectromagnetic, Lithosphere-Atmosphere-Ionosphere coupling, Eds. M. Hayakawa and O.A. Molchanov, Terra Sci. Pub. Co., Tokyo, 2002, pp. 69-75.

12. K. Ohta, K. Umeda, N. Watanabe and M. Hayakawa, "Relationship between ELF magnetic fields and Taiwan earthquakes" In Seismoelectromagnetics, Lithosphere-Atmosphere-Ionosphere coupling, Eds. M. Hayakawa and O.A. Molchanov, Terra Sci. Pub. Co., Tokyo, 2002, pp. 233-237.

13. R. Kawate, O.A. Malchanov, and M. Hayakawa, "Ultra- Low –Frequency magnetic fields during the Guam earthquake of 08 August, 1993 and their interpretation" Phys. Earth Planet. Interr., 105, 1998, 229-238.

14. O.A. Molchanov and M. Hayakawa, "On the generation mechanism of ULF seismogenic electromagnetic emissions", Phys. Earth Planet. Interr., 105, 1998, 201-210.