Equatorial Counter-Electrojet and Magnetic Pulsations

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(Received November 27, 1995; Revised May 22, 1997; Accepted August 21, 1997)

The signal amplitudes in the $H_x$ component of magnetic pulsations undergo significant enhancement at the dip equator during intervals of Equatorial Electrojet (EEJ), the enhancement attaining a peak value during prenoon hours. On the other hand, it is shown in this study, that the enhancement peak which occurs during prenoon hours on EEJ days shifts towards noon hours on major counter electrojet (CEJ) days. The observed shift of the peak towards noon hours is interpreted to indicate corresponding change in the diurnal variation of ionospheric conductivity during the CEJ days.

1. Introduction

The geomagnetic signature of the equatorial electrojet (EEJ) is seen as an abnormal rise in the northward horizontal component ($H$) of the normal $Sq$ field in the magnetograms at equatorial sites while that of a typical counter electrojet (CEJ) event is a decrease of $H$ component below night time level, spread over a few hours and occurring mostly in the afternoon hours. The ionospheric currents corresponding to normal EEJ flowing in the dynamo region are known to be widespread and global whereas those representing the CEJ appear to be limited in longitude (Kane, 1976). It is becoming increasingly clear that magnetic pulsations show distinct changes near the dip equator, during the normal electrojet times pointing to the significant role that the equatorial ionosphere plays in modifying pulsation signals.

The enhancement of pulsation amplitudes at dip equator during normal electrojet is fairly well established (Sastry et al., 1979, 1983). However, the nature of influence during intervals of counter electrojet, if any, on these signals is yet to be evaluated. The present study addresses this aspect utilising the simultaneous pulsation records from the pair of pulsation stations in India located at Choutuppal (Gm. Lat: 7°.5) near Hyderabad and the other at Etaiyapuram (Gm. Lat: −0°.6) near the dip equator in Tamilnadu. The La Cour (normal) magnetograms from Hyderabad and Etaiyapuram observatories are used for the purpose of identification and presentation of counter electrojet events.

2. Data Analysis and Results

The magnetic observatories at Hyderabad and Etaiyapuram are equipped with conventional type La Cour system of variometers for analog recording of earth’s magnetic field variations in the three components $H$, $D$ and $Z$ by photographic means at a chart speed of 15 mm/hr.

Induction magnetometer units are used for recording magnetic pulsations and these set-ups at Choutuppal and Etaiyapuram observatories are identical. The recording of pulsations in the three components $H_x$, $H_y$ and $H_z$ at these two stations is carried out by photographic means at two chart speeds of 90 mm/hr and 30 mm/min covering the period ranges 20–1000 sec and 0.5 to 20 sec respectively.

For the purpose of analysis the CEJ days are first identified by a visual inspection of La Cour magnetograms from Hyderabad and Etaiyapuram for all the years from 1976 onwards for which simultaneous records are available. For each one of these days the mean hourly values of the $H$ component are obtained at the two stations for all the hourly intervals. The hourly inequalities on each day are obtained by subtracting the mean of the hourly values of the four hours centered around local midnight from each
of the 24 mean hourly values. Then finally the hourly values of $\Delta H$ representing the variation due to EEJ/CEJ are obtained by subtracting the hourly inequalities at Hyderabad from the corresponding values at Etaiyapuram. Plots of local time variation of $\Delta H$ for the duration 0600 to 2100 hr LT are presented in Fig. 1 for a few typical days exhibiting CEJ phenomenon. The CEJ events occurring mainly during afternoon hours are included in this study as also in this figure and the magnitude of the CEJ events ranges from around 40 to 70 nT.

Simultaneous pulsation records from Choutuppal and Etaiyapuram corresponding to the CEJ days selected are examined for comparison of pulsation signals and their amplitudes at the two stations during these days. For each hourly interval, on all the selected CEJ days pulsations in $Hx$ component which appear identical on both the records are identified and the amplitudes and periods of the pulsation events measured. The periods of most of these pulsations are seen to fall in the Pc4 category. The ratio ($Rx$) of the amplitude of the $Hx$ signal at Etaiyapuram to that of corresponding one at Choutuppal is computed wherever such pulsations are clearly identifiable for each of the hourly intervals. A polynomial fit has been obtained for the $Rx$ values plotted against local time on each of these CEJ days. The curves so obtained are seen to exhibit local time dependence of $Rx$ and some examples are shown in Fig. 2, plots of $\Delta H$-variation representing the CEJ field for the corresponding days are also displayed in this figure.

In order to examine this pattern against a reference, $\Delta H$ variation for a few selected normal electrojet (EEJ) days and the $Rx$ of pulsations for the corresponding days were also computed during different hourly intervals. Figure 3 displays the plot of local time variation of $Rx$ along with the $\Delta H$ variation for a few of these EEJ days. A polynomial fit for these $Rx$ values was obtained as in the case of those for CEJ days. In both Figs. 2 and 3 the curve passing through the crosses represents $Rx$ while the one passing through open circles the $\Delta H$ variation on the same day. From Figs. 2 and 3, a feature of interest that could be immediately noticed is the difference in the local time variation of $Rx$-parameter between the normal and

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**Fig. 1.** A few examples of selected CEJ events.
Fig. 2. Local time variation of $\Delta H$ (open circles: $\bigcirc$) for some of the selected CEJ days and the ratio $Rx$ (explained in the text and shown by crosses: $\times$) for the corresponding days.

Fig. 3. Local time variation of $\Delta H$ (open circles: $\bigcirc$) for a few normal EEJ days and the ratio $Rx$ (crosses: $\times$) for the corresponding days.
counter electrojet days.

In majority of the cases, the $Rx$ value is seen to attain a peak in the prenoon hours on EEJ days thus preceding or coinciding with the normal diurnal peak in $H$ which is around 1100 hr LT. But when we look at the pattern on CEJ days (Fig. 2) the peak in $Rx$ is seen to occur around 1200 hr LT on most of the days of afternoon CEJ, particularly when CEJ magnitude is large, as for example, on 29th January, 1987 as also on 28th February, 1984. Thus the peak in the $Rx$ variation shows a distinct shift from prenoon hours for the normal EEJ days towards noon hours on the counter electrojet days.

3. Discussion

The signal amplitudes in $Hx$ component of pulsations of Pc3, Pc4 class as also the daytime Pi2s are known to show considerable enhancement at the dip equator compared to those observed well away from it. The ratio $Rx$, the enhancement factor on normal EEJ days was shown to attain a peak during prenoon hours ranging from 0900-1100 hr LT preceding or coinciding with the $Sq$ peak (Sastry et al., 1979, 1983).

While the normal electrojet is explained in terms of currents driven by an eastward electric field in the presence of an enhanced cowling conductivity at the dip equator, the counterelectrojet is interpreted in terms of a westward electric field in the equatorial ionospheric dynamo region. For simulation of observed features of counter electrojet several theoretical models based on a combination of global scale tidal wind modes were suggested (Marriott et al., 1979; Hanuise et al., 1983). Recent experimental results carried out on a few consecutive CEJ days during January 1987 (Somayajulu et al., 1993), provided evidence on the nature of zonal winds and amplitude and phase variations of tidal wind components during CEJ events. Thus considering that the $Sq$ field in general is a function of the electrical conductivity of the dynamo region of the ionosphere and the tidal wind velocity, the time of $Sq$ maximum as such depends on the contribution from these two factors.

Concerning transmission of geomagnetic phenomena like SCs, pulsations etc. to the equatorial region, several models including propagation of compressional mode waves as also the earth-ionosphere wave guide modes that transmit electrical fields from polar region to the equator have been proposed (Kikuchi and Araki, 1979b; Saka and Alperovich, 1993). It has been shown that the equatorial ionosphere exercises shielding effect on the incoming compressional mode waves (Kikuchi and Araki, 1979a; Zhang and Cole, 1995). The model proposed by Kikuchi and Araki (1979b), on the other hand, envisages an instantaneous propagation of polar electric fields to the equator through an earth-ionosphere waveguide, setting up east-west electric currents in the dip equatorial $E$-region of the ionosphere. This transmission mechanism was shown by Kikuchi et al. (1996) to be applicable even to DP 2 fluctuations with periods less than one hour. The considerable enhancement of DP2 fluctuations at day side dip equator were attributed to the enhanced ionospheric conductivity there (Kikuchi et al., 1996).

Now assuming that the $E$-fields corresponding to pulsations are uniform over the latitude region under consideration here, the observed peak in $Rx$ (representing an enhancement in signal amplitude at dip equator) on EEJ days around pre-noon hours suggests that the amplitudes of pulsating ionospheric currents (pulsation amplitudes observed on the ground) are governed mainly by the ionospheric conductivity of the $E$-region, which is known to be enhanced several-fold during daytime over a narrow belt around the dip equator. The observed shift of $Rx$ peak towards noon hours and beyond on certain large CEJ days further indicates the persistence of high conductivity in the ionosphere over a longer duration during such major CEJ events. Thus considering that the time dependent changes in $Rx$ for the pulsations clearly correspond to the corresponding changes in electrical conductivity of the dynamo region of the equatorial ionosphere during daytime, the $Rx$ might serve as a useful parameter to monitor the temporal changes of ionospheric conductivity in the equatorial region.

The authors thank Dr. H. K. Gupta, Director, National Geophysical Research Institute for according permission to publish this paper. They also thank Mr. K. Saratchandra for helping in the computations needed in this study. The Editor thanks O. Saka and T. Kikuchi for their kind assistance in evaluating this paper.
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