Appraisal of the Electromagnetic Induction Effects on Geomagnetic Micropulsation Studies

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Geomagnetic micropulsations as recorded by a network of magnetometers are a useful guide to investigate the complex magnetospheric processes in general and to understand the generation and propagation mechanisms of the ULF waves in particular (Hughes, 1994). In these studies, parametrization of the wave polarization properties is inevitably the first step. The geomagnetic field variations as recorded at the Earth's surface are the vector sum of external (source) and internal current systems, the latter resulting from the electromagnetic induction in the electrically conductive layers of the Earth. In the absence of lateral conductivity variations, the internal currents are simply the mirror image of the external current system, in the sense that their magnetic effects in the horizontal (X and Y) field components are in-phase with the inducing external source fields. In this idealized case, the polarization and phase properties of the oscillating external signals are uniquely determined from the recorded total fields. Lateral conductivity variations in the Earth perturb the flow pattern of induced currents, producing local anomalies in the magnetovariational field components at the Earth's surface. The amplitude and phase changes that these perturbations produce in the total fields, make the precise determination of the external source characteristics problematic. The isolation and interpretation of such anomalous parts form the subject matter of the Geomagnetic Deep Sounding (GDS) experiments, aimed at mapping geological structures marked by large electrical contrasts (Gough and Ingham, 1983). In this paper, with the help of a closely spaced array of magnetometers, we present evidence on the contamination of magnetovariational fields related to the micropulsation event by the anomalous induction effects. These induction effects, if not properly scrutinized in the process of quantification of the external source characteristics from geomagnetic data, can lead to deceptive inferences on the propagation characteristics of the ULF waves. Given this observational evidence, useful guidelines to estimate and correct the geomagnetic pulsations data for the induction effects are briefly outlined.

PHYSICAL APPRAISAL OF THE INDUCTION EFFECTS

A 29-station magnetometer array was operated in the Equatorial Electrojet (EEJ) region of the north-northeast Brazil between November, 1990 to March, 1991. Towards the closing phase of the array operation, a globally coherent Pc5 pulsation event that occurred in association with the magnetic storm of March 24, 1991, was recorded by 11 stations. A well developed train of Pc5 pulsations with an average period of 10 min was seen, centered around 13:00 hours. One immediate feature seen was that the amplitudes of the pulsations in the north-south (X) component are considerably enhanced at stations located under the influence of the overhead EEJ currents, centered at the dip equator, showing that the spatial structure of the equatorial enhancement is compatible with the pattern that would result from the increased ionospheric Cowling conductivity. Trivedi et al. (1997) used this evidence to trace the propagation path of the magnetospheric induced polar electric field to the equatorial region through the ionosphere.

An additional feature of this event is that the field variations in the east-west (Y) component at a station (BAC) are considerably large, despite the fact that the other stations with similar locations in relation to the dip equator do not show this anomalous behaviour. A net consequence of this enhanced Y fields is that the polarization ellipse at BAC is enhanced greatly and its azimuth is rotated with respect to the north as well as in relation to the adjoining stations. If only a single equatorial station is available, as often is the case, this anomalous behaviour of the pulsation would not only lead to a highly exaggerated estimate of the equatorial enhancement but would also lead to the conclusion that the enhanced ionospheric conductivity associated with the EEJ also causes the rotation effects in the orientation of the polarization ellipse. This rotational effects may find acceptance in view of the already established results that the ULF waves propagating downwards through the ionosphere undergo azimuth rotation by 90 degrees (Hughes and Southwood, 1976). However, a more careful analysis of the field variations by conventional GDS tools indicated that the Y component at BAC is appreciably enhanced because of its location right over a north-south conductive zone (Arora et al., 1997).

Estimation and elimination of the induction effects. The above example clearly illustrates that if the induction effects are not taken cognizance of in the micropulsation studies, it can lead to erroneous interpretations. If data from more than one station are available, inter-station vertical-field transfer functions, which on physical consideration are more sensitive to the anomalous current concentrations, can be used to simulate the anomalous vertical fields (Schmucker, 1970; Bailey et al., 1974). The corresponding anomalous horizontal fields for the purpose of correcting the induction effects from the pulsation records can then be computed from the simulated anomalous vertical fields using the constraints that the magnetic fields must be derivable from a scalar potential (Banks et al., 1993). However, if data from only a single station are available, one has to basically rely on independent sources for the information on the internal conductivity, such as from the magnetotelluric or conductance map derived from the magnetometer array data itself. In such a case, the nature of the anomalous fields corresponding to the pulsation polarization and magnitude can be estimated numerically. The correction for the induction effects with either scheme to the pulsation event of March 24, 1991 helps to recover the polarization ellipse compatible with the adjoining stations and, thus, justifying its interpretation in terms of the external sources. Given that the internal conductivity distribution is more heterogeneous in the crustal section, micropulsations with right frequency content penetrate to these depths and, hence, are more vulnerable to induction effects. Since the deployment of magnetometer arrays is the common data collection tool, both in micropulsation and GDS studies (Gough and Ingham, 1983; Banks et al., 1993; Yumoto et al., 1995; Menk et al., 1994), a better understanding of the interactions between the internal and external characteristics would permit a more precise interpretation of the magnetospheric process as well as of the internal conductivity distribution.

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