The Perturbation of Alternating Geomagnetic Fields by an Island Near a Coastline: Discussion

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In this paper, Lines and Jones (1973) attempt to apply the finite difference method of numerical analysis to a 3-dimensional model. The only real problem is due to the impossibility of separating the component equations for any direction of polarization. The details of the method appear in Lines (1972). Unfortunately, these methods are in serious error and the problem mentioned above has not been solved. It is therefore certain that the results described in this paper are incorrect, especially near and at structural discontinuities. These are, however, the only regions in which there is any interest.

On page 40 of Line's thesis, equations 3.2, 3.3, and 3.4 give the non-homogenous equations that are to be solved for the components of the electric field. It can be seen that each equation contains derivatives of all three field components. For convenience we will write equation 3.2

$$\frac{\partial^2 E_x}{\partial y^2} + \frac{\partial^2 E_x}{\partial z^2} - \frac{\partial}{\partial x}\left\{\frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z}\right\} = i\eta^2 E_x$$

The difficulty arises when E_y is normal to a surface across which there is a finite discontinuity in σ, the conductivity. As was shown by D'Erceville and Kunetz (1962), this results in a finite discontinuity in E_y. Lines (1972) uses the average value of E_y at the boundary in order to produce the point-wise continuity, which he believes to be necessary for his method. The result is that both the field component and its derivatives are grossly distorted in the region about the boundary. The contributions to the derivatives in equation 3.2 (shown above), especially $\partial E_y/\partial y$, will reflect this distortion, and the effect will be propagated into each of the electric field components. The components of the magnetic field are deduced from the electric field components through Maxwell's equations, and they in turn will also be distorted. Since self-consistency requires that the electric field is, in turn, deducible from the magnetic, one could only arrive back at the improperly continuous electric field by the procedure carried out in this work.

Since both the island and the surrounding oceans in this model are finitely conducting, current lines are distributed throughout both media with their amplitudes diminishing exponentially downward in each medium. A current line at any depth in the less-conducting region must flow upward to a more shallow depth in the more-conducting region due to the well-known skin effect. Figure 7b in Lines and Jones (1973) shows an anti-skin effect. This result is probably a consequence of the erroneous procedures of the authors. Furthermore, had the correct results been obtained, there would have been no reason for the explanation given for the existence and magnitude of E_z at the air surface.

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