# OCEAN-LAND INTERFACES

## Two Alternative Treatments for Geomagnetic Storms and a Synthesis

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***Abstract*— In this presentation, we review two models for calculating the enhancement of geomagnetically-induced electric fields near land-ocean boundaries. The first is a model which requires the solution of an integral equation at each frequency, and the second is a simplified model that only requires Fourier transforms. The mechanism responsible for the differing results is determined, and it is suggested that one of the features of the integral equation model be included in the simplified model. This modification can be made without reducing the computational advantages of the second model.**

***Keywords- Geomagnetically induced current, GIC, magnetic storms, Geomagnetic induction.***

### I. Introduction

At the edge of the ocean, the abrupt change in surface conductivity between the landward side and the seaward side can enhance the geomagnetically-induced electric field on the landward side. This is important for calculations of the response of electric power systems, which often have electrical generating plants near the seashore for cooling purposes In this paper we will compare an integral equation technique and a simplified Fourier transform approach. The major difficulty with the first approach is that it requires the use of integral equations; the major difficulty with the second approach is the neglect of diffusion of magnetic fields from the landward side beneath the ocean. We will propose a technique that modifies the procedure in [2] to include this term.

### II. Models

#### A. Integral equation technique

An integral equation was developed in reference [1] for the horizontal electric field near the land-ocean boundary.

$$\left.\begin{array}{ll} H_0 & x \le 0 \\ H_0 \operatorname{sech}(k_1 d) - Z_1^{-1} E_i \tanh(k_1 d) & x > 0 \end{array}\right\} = \frac{\sigma_0}{\pi} \int_{-\infty}^{\infty} dx' K_0(k_0 |x - x'|) E_i(x') \quad (1)$$

where $H_0$ is the uniform applied magnetic field, $E_i$ is the electric field at the surface of the ground, $x$ is the distance oceanward from the boundary, $k_1$ is the wavenumber in the ocean, $k_0$ is the wavenumber in the ground of conductivity $\sigma_0$, $Z_1$ is the wave impedance in the ocean and $d$ is the local depth.

#### B. Fourier transform technique

In reference [2], a simplified technique was developed that avoided the need for solving an integral equation by using the field diffusing through the ocean to the surface of the ground

$$\left.\begin{array}{ll} H_0 & x \le 0 \\ \dfrac{H_0}{\cosh(k_1 d) + (Z_0 / Z_1)\sinh(k_1 d)} & x > 0 \end{array}\right\} = \frac{\sigma_0}{\pi} \int_{-\infty}^{\infty} dx' K_0(k_0 |x - x'|) E_i(x') \quad (2)$$

As the LHS of the equation was completely specified and the kernel on the RHS could be inverted in Fourier space.

### III. Comparison and a Modification

Figure 1 shows a comparison of the two techniques. The difference is due to the lack in the Fourier transform technique of the landward magnetic field diffusing outward beneath the ocean.

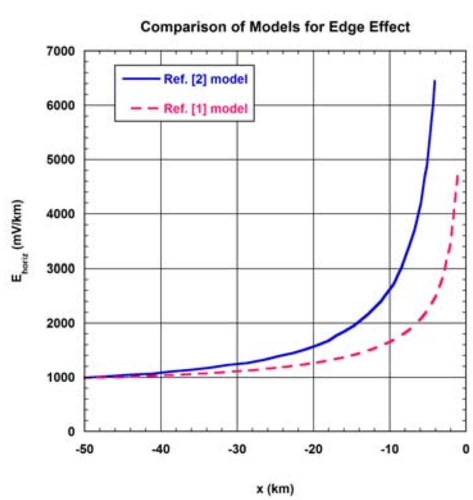


Figure 1. Comparison of techniques.

The Fourier technique may be corrected by adding this diffused field in the left hand side of equation 2. Examples will be shown.

### References

[1] J. L. Gilbert, "Modeling the effect of the ocean-land interface on induced electric fields during geomagnetic storms" in Space Weather, vol. 3, no 4. S04A03, doi: 10.1029/2004SW000120, 2005.

[2] R. Pirjola, "Practical Model Applicable to Investigating the Coast Effect on the Geoelectric Field in Connection with Studies of Geomagnetically Induced Currents," Advances in Applied Physics, vol. 1, no. 1, pp 9-28, 2013.