Wave Propagation along a Thin Wire Antenna Placed in a Horizontally Layered Medium

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Abstract— A theoretical and numerical analysis of the wave propagation along a long thin wire antenna is presented. The wire antenna is assumed to be placed in a horizontally layered medium, where each layer is characterized by an individual conductivity. The current distribution along the wire antenna is derived as the solution of an electric field integral equation which is solved by the method of moments. Numerical results are presented and discussed.

I. Introduction

Electromagnetic wave propagation along a wire antenna in a conductive medium can be used as a method of low frequency communication. Examples of this can be found in the literature, in particular for measurement while drilling systems. F.N.Trofimenkoff[1] studied the downhole to surface communication channel by using a model of a vertical cylindrical perfect conductor in a homogeneous conductive medium. J.R.Wait and D.A.Hill[2] derived the current distribution along a drill rod surrounded by conducting host rock. P. DeGauque and R. Grudzinski[3] studied the current distribution in a homogeneous conductive medium along a drillstring of finite conductivity.

To the best of author's knowledge, an analytical solution of the current distribution along a long metal wire antenna arbitrarily placed (vertical or at an angle) in a conductive inhomogeneous medium is not known in the literature. A 3D model is usually needed since the geometry is not symmetric. However, by dividing the current distribution along the antenna into small segments and decomposing each of them into a vertical and a horizontal electric dipoles, the problem can be addressed as a 2D problem.

II. Theoretical Approach

The current along the wire antenna is divided into small elements, which can be decomposed into a horizontal electric dipole (HED) and a vertical electric dipole (VED). [5] The electric field from each element can then be obtained using the dyadic Green's function. Since a spherical wave from a point source can be expanded into plane waves using the Sommerfeld's identity,[4] the electromagnetic fields from the VEDs and HEDs can be decomposed into transversal electric (TE) and transversal magnetic (TM) waves. In a horizontally layered medium, the z-variation (vertical direction) of the field can be derived by using the theory of multi-reflection.[4] The electric field at an observation point above the surface of the wire antenna is equal to the total field from all the elements along the wire antenna. By applying the boundary conditions at the surface, a relationship between the current in the wire and the field at the wire surface can be obtained, resulting in an electric field integral equation. Moment method was used to solve this integral equation and the solution gives the current distribution along the wire antenna. The poles in the integral equation demand special attention and the errors given by the calculation are discussed.

III. Numerical Results

In Fig. 1, the attenuation of the current along a vertical wire antenna is depicted as a function of frequency. The increased attenuation between 700 and 800 meters is due to a layer of higher conductivity.

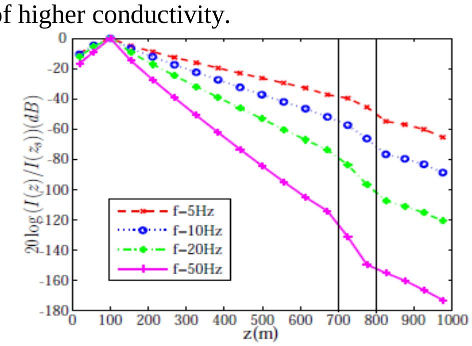

Fig. 1. Current distribution along the wire antenna at different frequencies,f.

IV. Conclusion

In this paper, an analytical solution of the current distribution along a long metal wire antenna arbitrarily located in a horizontally layered medium is presented. The results show that the attenuation in the different layers are almost equal to that of a plane wave propagating in homogeneous medium with the layer's conductivity.

V. References

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