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Effects of Different Rocks Surrounding Monostatic Pulse Radar in a Borehole on the Length of PMC Coating along the Connection Cable

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***Abstract* – The signals of monostatic pulse radar in a water-filled borehole surrounded by horizontally layered rocks are numerically calculated using the finite-difference time-domain method (FDTD). In two cases of horizontally layered rocks, unwanted radar signals caused by interactions between borehole guided waves supported by the connection cable and horizontally layered rocks are calculated. Then, suppression of unwanted radar signal is analyzed here depending on the finite length of perfect magnetic conductor (PMC) coating along the connection cable of the radar.**

***Index Terms* — Borehole, finite-difference time-domain (FDTD), monostatic, pulse radar.**

I. Introduction

For detecting an intrusively dormant man-made tunnel [1], single-borehole monostatic pulse radar was developed by integrating transmitter and receiver modules into one dipole antenna. At a well-suited tunnel test site in Korea, however, the measured B-scan image utilizing developed monostatic pulse radar was severely contaminated by obliquely striped patterns. Numerical simulation results clearly illustrated that unwanted striped patterns were generated due to reflected borehole guided waves supported by a connecting cable of the radar at the horizontal interface of two layered rocks. Experimental results illustrated that unwanted radar signals were suppressed exponentially depending on the length of ferrite cores tightly clamped on the conducting cable of the radar [2].

In general, however, dielectric property of granite in Korea is widely varied. Not only generation of borehole guided wave but also reflection of the borehole guided wave at the interface of layered rocks can be changed. It renders unwanted radar signals to be affected by dielectric properties of surrounding rocks. Hence, suppression of the unwanted radar signals utilizing the finite length of perfect magnetic conductor (PMC) coating can also be varied depending on the electric properties of surrounding rocks. Two cases of layered rocks are considered to investigate the effects of surrounding rocks on the suppression of unwanted radar signals according to the finite length of PMC coating. Instead of field experiments which cannot control the dielectric properties of surrounding rocks precisely, numerical simulations are employed in this paper.

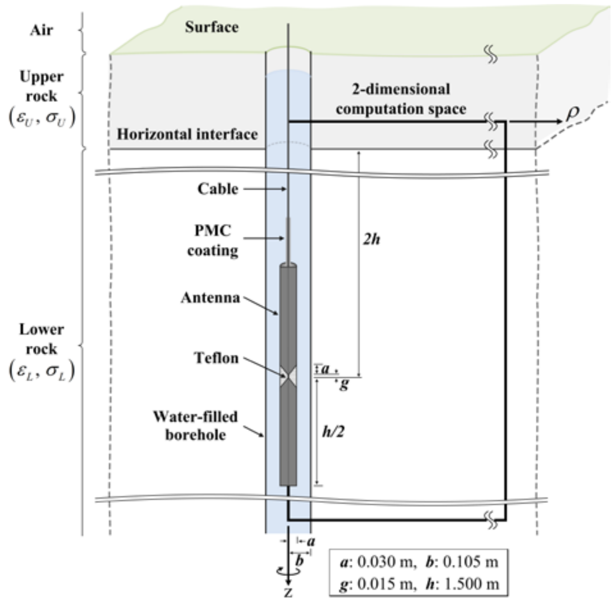

Fig. 1. Monostatic pulse radar in a water-filled borehole surrounded by horizontally layered rocks and 2-dimensional computation space.

TABLE I
Two Cases of Horizontally Layered Rocks in Korea

		Employed dielectric properties	Referred dielectric properties
Upper rock	ε_U	9.722	7.160
	σ_U (S/m)	0.00420	0.00765
Lower rock	ε_L	7.646	6.230
	σ_U (S/m)	0.00146	0.00160

II. Numerical Modeling

Single-borehole monostatic pulse radar with a dipole antenna in a water-filled borehole, surrounded by two horizontally layered rocks, is displayed in Fig. 1. Electromagnetic fields are computed at 2-dimentional computation space of $\rho - z$ plane using the finite-difference time-domain (FDTD) method [3] since the geometry is symmetric in the azimuthal direction. Based on measured electric properties of borehole cores in our laboratory, the underground structure is simplified into two layered rocks with horizontal interface. Employed dielectric properties of the upper and lower rocks are summarized in Table I and

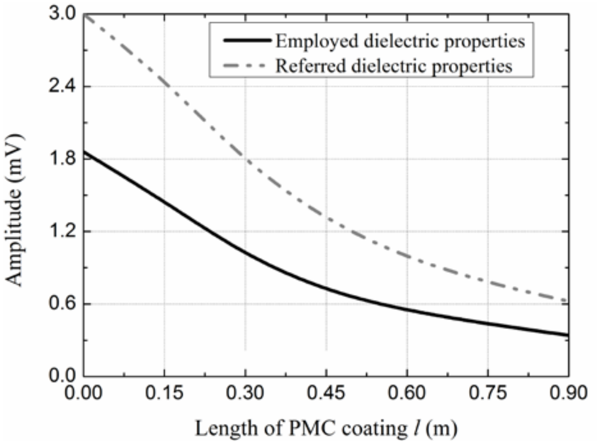

Fig. 2. Amplitude of the maximum positive peaks according to the finite length of the PMC coating by considering employed and referred dielectric properties of surrounding rocks.

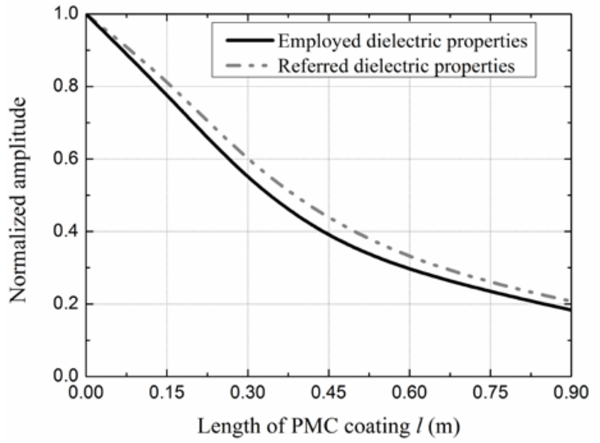

Fig. 3. Normalized amplitude of the maximum positive peaks according to the finite length of the PMC coating by considering employed and referred dielectric properties of surrounding rocks.

referred dielectric properties of two layered rocks are also listed in Table I. The distance between the feeder of the antenna and horizontal interface of two layered rocks is 3 m. Gaussian shaped pulse with the maximum voltage of 1 V and pulse width of 5 ns is excited from the dipole antenna. The spatial resolution $(\Delta = \Delta\rho = \Delta z)$ is uniformly taken by 0.015 m and the time step (Δt) is chosen by 25 ps. Finally, the MUR's boundary condition [4] is set at the outer layer of the 2-dimensional model.

III. Effects of Different Rocks

Induced voltage is computed in progress of time at the gap between two arms of the dipole antenna. To eliminate the common reflections from the imperfectly impedance-matched antenna and the boundary of the water-filled borehole, another voltage computed at the adjacent antenna location which is moved 0.15 m toward the horizontal interface of two rocks is subtracted from calculated voltage [2]. The length of PMC coating *l* is varied from 0.0 m to 0.9 m with the uniform length of 0.15 m. In two cases of horizontally layered rocks, amplitudes corresponding to the maximum positive peaks are extracted from subtracted voltage and displayed in Fig. 2 depending on the length of PMC coating. In Fig. 2, amplitude of the maximum positive peaks decreases gradually depending on the increased length of PMC coating but the amplitude levels of the employed and referred dielectric properties are different as expected.

To compare the degree of suppression affected by different dielectric properties of surrounding rocks, the amplitudes of the maximum positive peaks are normalized by the corresponding value without PMC coating and illustrated in Fig. 3. The normalized amplitude of the maximum positive peak of employed and referred dielectric properties show similar variations depending on the finite length of PMC coating. It leads us to conclude that suppression of unwanted reflected voltages according to the PMC length is not severely affected by varied electric properties of surrounding rocks even though the amplitude levels of reflected voltages are changed depending on the dielectric properties of surrounding rocks.

IV. Conclusion

The effects of different dielectric properties of rocks surrounding monostatic pulse radar on the suppression of unwanted radar signals were numerically investigated depending on the finite length of PMC coating. Reflected borehole guided waves at the horizontal interface of two layered rocks were reduced almost similarly regardless the dielectric properties of surrounding rocks. We are preparing for a more precise FDTD simulation on detecting underground tunnel in multi-layered rock using single-borehole monostatic pulse radar.

Acknowledgment

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