Numerical Modeling and Analysis of a Cylindrical Reflector Antenna for Ground Penetrating Radar

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***Abstract* - Since 1988, we have developed and commercialized various types of impulse ground penetrating radar (GPR) systems for locating buried structures and utility pipes. The performance of GPR systems depends mainly on the characteristics of radar antennas. In this paper, we propose a cylindrical reflector antenna fed by a resistively loaded V-shaped dipole as a new traveling wave antenna for GPR. We construct a numerical model of the antenna and analyze its characteristics using the method of moments based on Rao–Wilton–Glisson basis functions. The analysis results indicate that the new antenna's directivity is sharper and the ringing noise is less than in our commercialized GPR antennas, thus a weight saving can be achieved in the next GPR systems.**

***Index Terms* — Cylindrical reflector antenna, V-shaped dipole antenna, Ground penetrating radar.**

I. INTRODUCTION

We have developed four types of impulse ground penetrating radar (GPR) systems for locating buried structures and utility pipes [1]-[4]. The performance of GPR depends mainly on the characteristics of radar antennas. Two types of development techniques have been used for GPR antennas design. The first consists of empirical design with experimentation and various field tests for pipe detection [1]. The second technique is numerical modeling analysis, which utilizes the method of moments based on the Rao–Wilton–Glisson basis functions (RWG moment method) [5], [6].

A new simulation-based technique has been introduced to develop a traveling-wave antenna for GPR systems. This technique has been applied to a V-shaped dipole antenna with loading resistance and a parabola-shaped reflector antenna [7]. In this paper, we propose a cylindrical reflector antenna which is fed by a resistively loaded V-shaped dipole. A numerical model of this cylindrical reflector antenna is constructed, and some characteristics of this antenna are analyzed by the RWG moment method.

II. ANTENNA DESIGN, NUMERICAL MODEL, AND ANALYSIS RESULTS

This section presents the numerical model and analysis results of the V-shaped dipole antenna with loading resistance for preparation, and describes an antenna design and a numerical model for the cylindrical reflector antenna fed by a resistively loaded V-shaped dipole. Some analysis results of the cylindrical reflector antenna are also provided.

A. V-shaped dipole antenna with loading resistance

The Wu-King (WK) dipole antenna, which is loaded with a distributed internal impedance of proper value, is known to work as a small traveling-wave antenna [8]. By transforming the WK dipole into a V-shaped antenna, the V-shaped dipole antenna with loading resistance of proper value on the elements also works as a traveling-wave antenna [7]. A numerical model of this V-shaped dipole antenna is shown in Figure 1. The directivity pattern of the numerical model is calculated using the RWG moment method. Both the calculated electric field pattern and the measured pattern of the V-shaped dipole antenna are displayed in Figure 2. This type of V-shaped dipole antenna has a high front-to-back ratio.

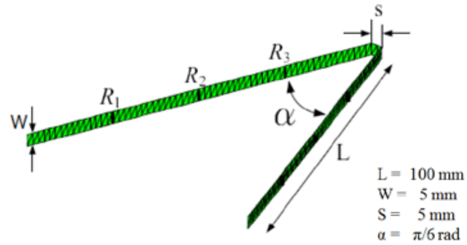

Fig. 1. Numerical model of a V-shaped dipole antenna

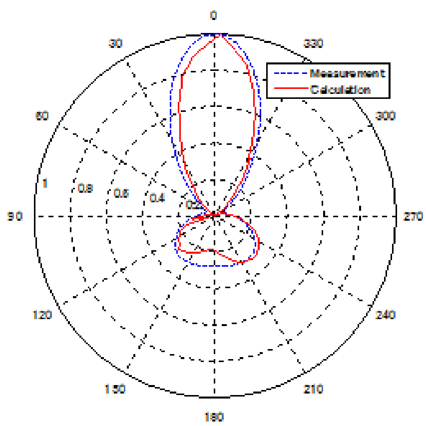

Fig. 2. Calculated and measured electric field patterns of a V-shaped dipole antenna

B. Cylindrical reflector antenna fed by a V-shaped dipole

The cylindrical reflector antenna is configured from a cylindrical reflector and a resistively loaded V-shaped dipole for transmitting and receiving, and the V-shaped dipole is located on a focus point of the cylindrical reflector. A numerical model of this antenna is shown in Figure 3.

Regarding the resistively loaded V-shaped dipole, one side length is 0.1 meter, and the open angle is π/6 radians, as shown in Figure 1. The size of the cylindrical reflector is 0.45 m by 0.3 m (0.45 × 0.3 square meters), and the focal length (F) is 0.2 meters (F = 0.2 m), as shown in Figure 3. That is, the distance between the cylindrical reflector and the V-shaped dipole is 0.2 meters. Resistance is located on the element in contrast, and the three resistance values are fixed at 90 ohm, 200 ohm, and 390 ohm, respectively by means of the function minimization of the three variables (R1 = 90 Ω, R2 = 200 Ω, R3 = 390 Ω).

The RWG moment method [9] is applied for solving the numerical model of the cylindrical reflector antenna fed by a V-shaped dipole. The calculated electric field pattern and the 3D-radiation pattern of the cylindrical reflector antenna are shown in Figure 4(a) and Figure 4(b), respectively. These patterns prove that the front-to-back ratio of the cylindrical reflector antenna is higher than that of the V-shaped dipole antenna despite a relatively simple configuration.

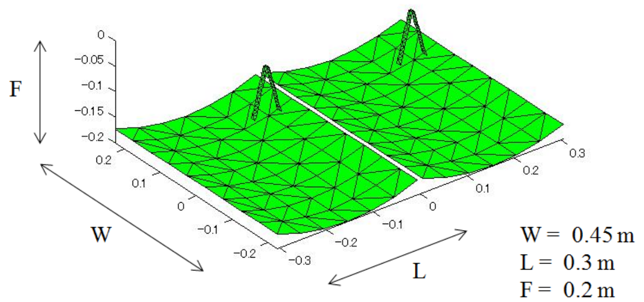

Fig. 3. Numerical model of the cylindrical reflector antennas fed by V-shaped dipoles

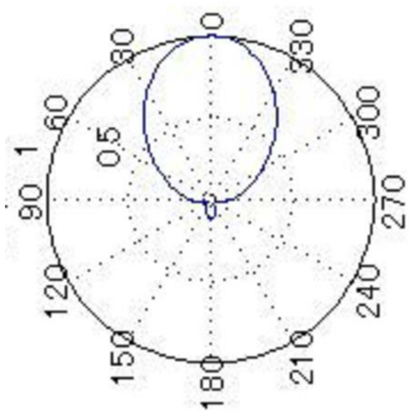

Fig. 4(a). Calculated electric field pattern of the cylindrical reflector antenna

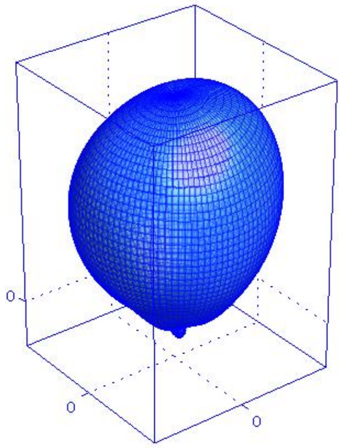

Fig. 4(b). 3D-radiation pattern of the cylindrical reflector antenna

III. Conclusion

In this paper we propose a new traveling wave antenna for impulse GPR systems, which is a cylindrical reflector antenna fed by a resistively loaded V-shaped dipole. A numerical model of this antenna is displayed and analyzed by the RWG moment method. Analysis results indicate that the directivity is sharper and the front-to-back ratio is higher than in the commercialized GPR antennas which we developed. These results prove that the cylindrical reflector antenna improves upon the performance of previous GPR systems with respect to scanning accuracy. It also achieves weight savings when compared to commercial GPR systems.

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