RADAR SYSTEM OF UNDERGROUND OBJECTS

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1. INTRODUCTION

Many research efforts have been made into ways of detecting the location of underground objects like utility pipes, transmission cables and so on [1],[2]. Real-time subsurface radar imaging systems without excavation are strongly desired for locating pipes in advance of construction and maintenance work.

The most significant factors that affect the performance of an underground radar system are antenna design (e.g. radiation pattern), radiation intensity in soil (i.e. attenuation of progressive wave) and extraction of reflected waves from buried targets (i.e. S/N ratio).

In this paper, first we will give an outline of our radar system and then show some numerical results using our newly developed antenna.

2. THE UNDERGROUND RADAR SYSTEM

This radar system transmits base-band pulse waves and receives reflected waves from underground objects. The received signals are amplified and filtered by the antenna control unit and the main control unit, and an underground profile image is displayed on the CRT in real time. The system configuration is shown in Figure 1.

After many trials the three-dimensional tower-shaped antenna with resistive loading was finally developed as shown in Figure 2. It has been experimentally proved that this anntena radiates radio waves with sharper directivity and has fewer unwanted ringing noises compared with conventional cross-dipole antennas[3].

3. NUMERICAL ANALYSIS OF THE ANTENNA

As our first approach to analyzing the three-dimensional tower-shaped antenna, we consider its two-dimensional structure.

The resistively loaded wire antenna geometry under consideration is shown in Figure 3.

The directive properties of the antenna can be determined using the moment method (MM) in the Fourier transform domain. The unknown current I on the wire structure is expanded in a set of N basis functions,

$$I(r) = \sum_{n=1}^{N} I_n J_n(r) \qquad (1)$$

An electric field integral equation is formed by enforcing the boundary condition that the total tangential field must vanish on the wire surfaces. This integral equation is solved using Galerkin MM solution, loading to the following matrix equation,

$$([Z] + [Z_T])[I] = [V] \qquad (2)$$

where $[Z_T]$ is the loading impedance (diagonal matrix) and $[Z]$ is the impedance matrix of the array with elements given by

$$Z_{mn} = \frac{1}{4\pi^2} \iint_{-\infty}^{\infty} \tilde{J}^*_m(k_x,k_y)\ \tilde{\tilde{K}}(k_x,k_y)\ \tilde{J}(k_x,k_y) dk_x dk_y \qquad (3)$$

where $\tilde{\tilde{K}}(k_x,k_y)$ is the dyadic Green's function of the semi-infinite dielectric substrate [4].

Once the unknown complete coefficients In are determined by solving (2), the radiation field can be obtained by the method of stationary phase.

In Figures 4(a) and (b), power gain patterns for non-loaded type ($Z_l = 0\Omega$) and loaded type ($Z_l = 150\Omega$) are shown for $E_r = 4.0 - j\ 0.1$ and $E_r = 10.0 - j\ 0.25$ respectively.

4. CONCLUSION

As an approach to estimating the performance of the underground radar system, especially the radiation characteristics of the three-dimensional tower-shaped antenna, the two-dimensional wire model is introduced and is solved by the moment method.

Finally an output image (B-scope) on our subsurface radar system scanning a road surface is shown in Figure 5.

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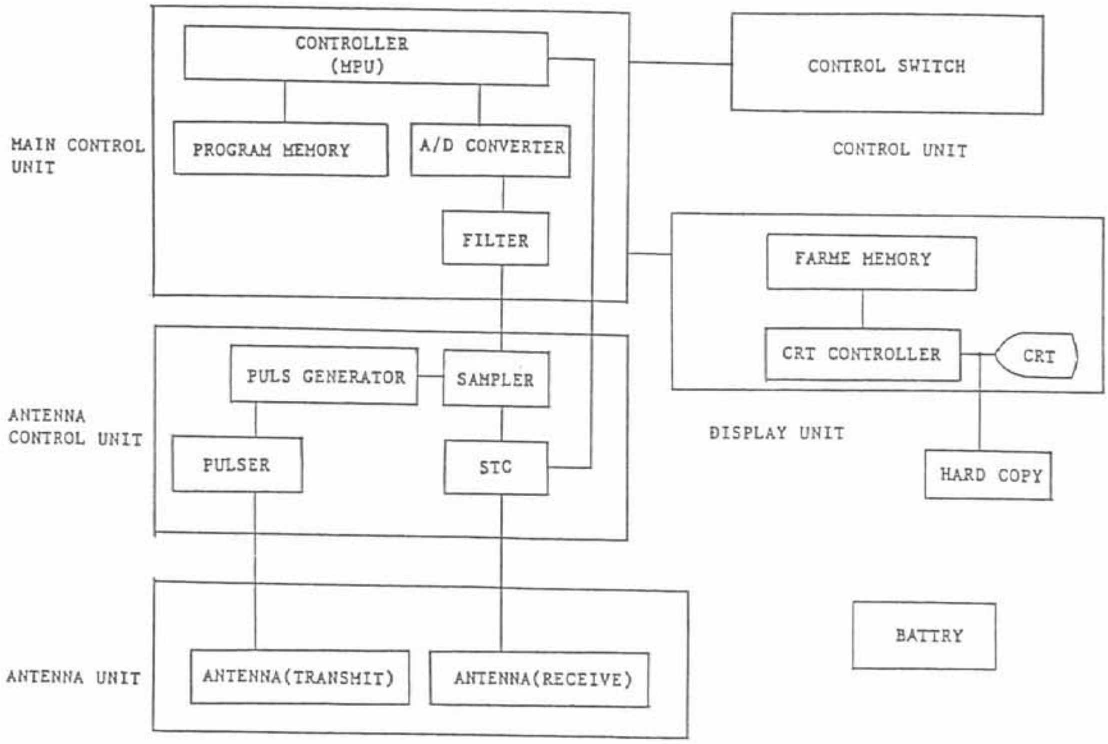


Fig. 1 System configuration

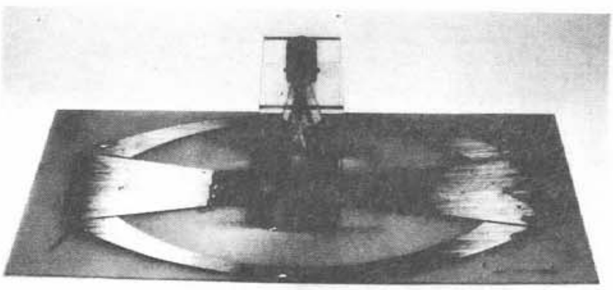


Fig. 2 Three-dimensional tower-shaped antenna

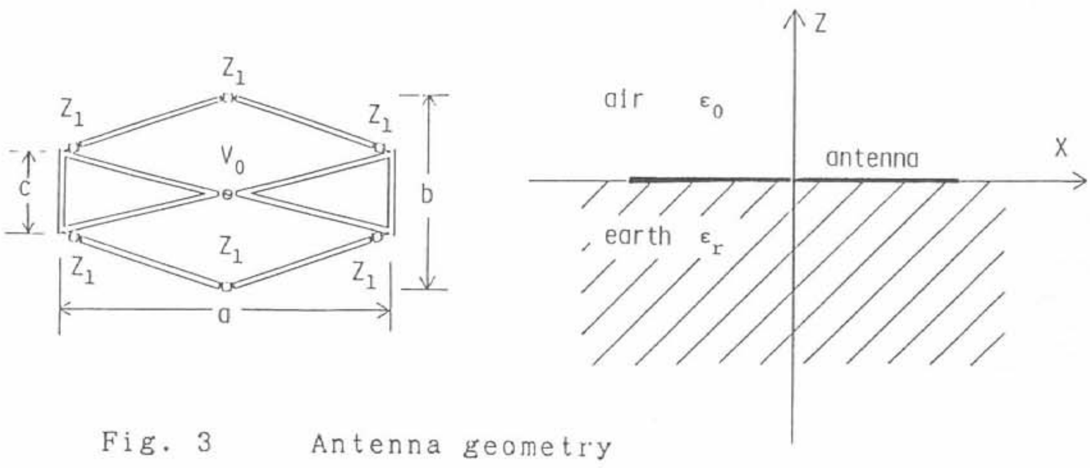
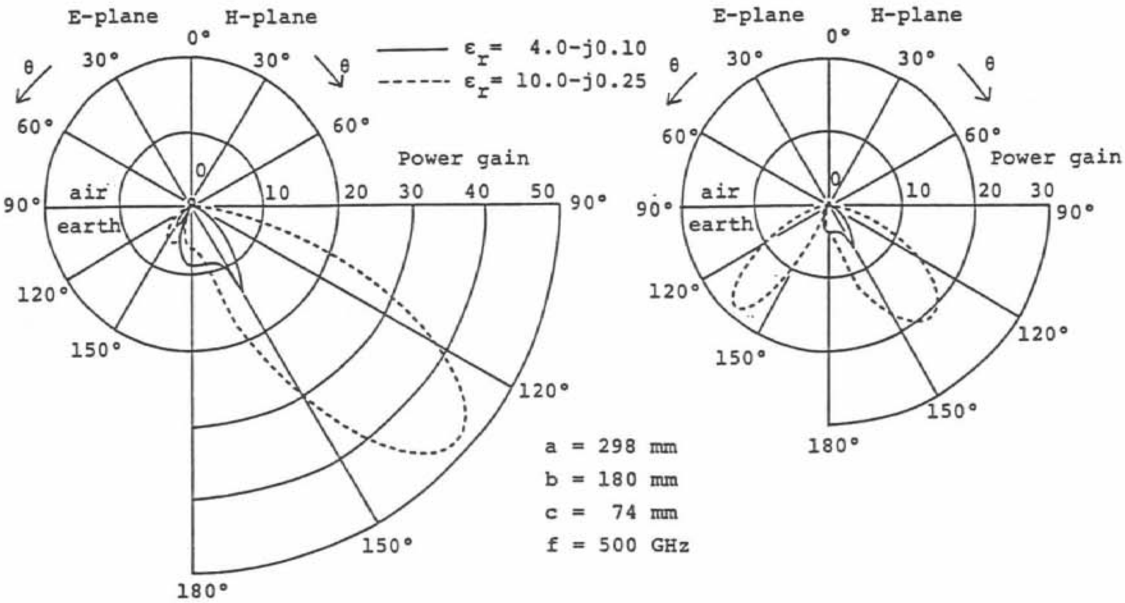


Fig. 3 Antenna geometry



(a) Non-loaded type (Z_1 = 0 Ω)   (b) Loaded type (Z_1 = 150 Ω)

Fig. 4 Radiation pattern

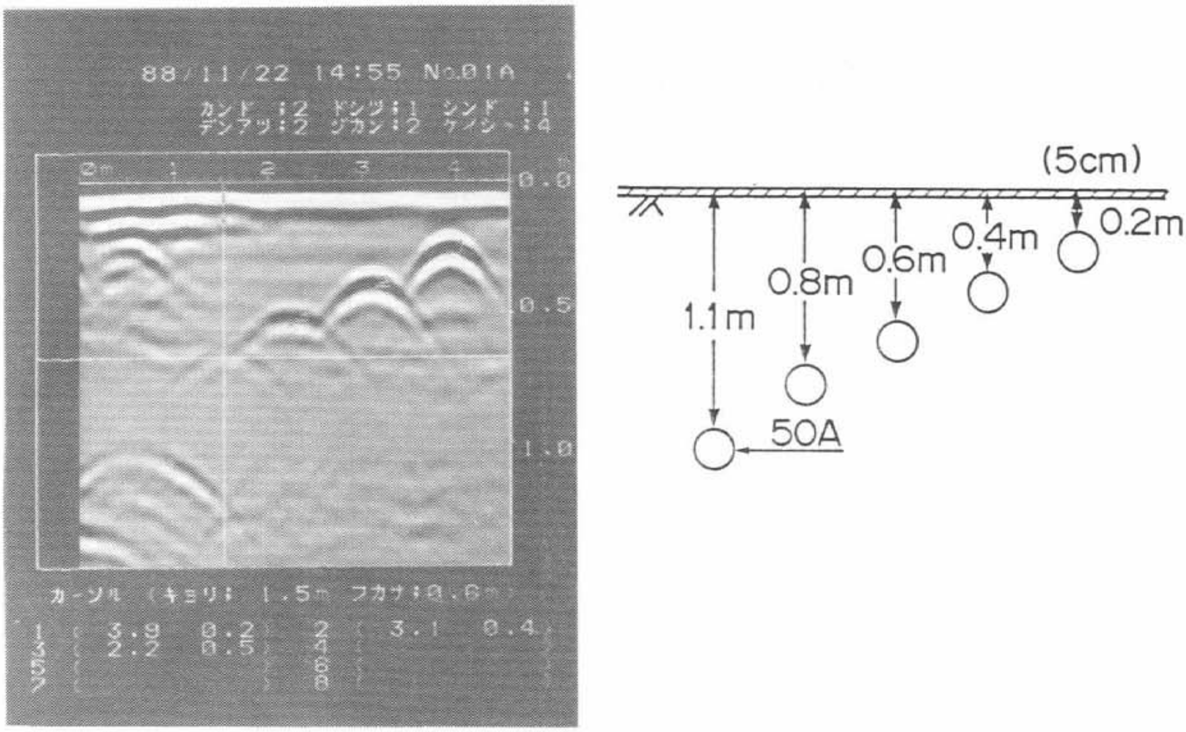


Fig. 5 Output image (B-scope)