ANALYSIS OF RESISTOR-LOADED RECTANGULAR DIPOLE ANTENNA FOR SUBSURFACE RADAR

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1. INTRODUCTION

Ground penetrating radars are widely used to detect the subsurface target [1], such as geological survey, archaeological exploration and detection of mines, buried pipes and voids under pavement. The directly coupled wave between antennas often yield the declination of the detectibility to reflections from shallow underground objects. This is one of problems for ground penetrating radars to be solved. Many techniques have been applied such as subtraction procedures, synthetic aperture techniques, pulse compression techniques and polarimetric techniques to enhance the reflected wave from radar targets.

It is also required to improve the performance of antennas so as to operate for wide frequency range on the ground surface. Most of ground penetrating radars use resistor-loaded bow-tie antennas covered with a ferrite-coated conducting cavity. However, the mobility and flexibility of the antenna arrangement are poor such as array antenna configuration. We have researched a resistor-loaded wire antenna with conducting cavity for a ground penetrating radar antenna [2]. Most of researches on improvement of the antenna is concentrated on development of a wide-band antenna on the ground surface[3] in order to obtain the high resolution radar image. On the other hand, it is noted that the ratio of the amplitude of the directly coupled wave to the reflected wave from a target (Desired to Undesired signal ratio) should be increased in order to broaden the dynamic range of a radar system. The optimal loaded resistor was determined with the D/U ratio. The D/U ratio in the case of the loaded resistor of 200 ohm is improved by 10 dB in comparison with the loaded resistor of 60 ohm. Consequently, the amplitude of the reflected wave is reduced by 10 dB. In order to increase the antenna efficiency, a rectangular dipole antenna is considered instead of the wire antenna. In this paper, it is presented that the rectangular dipole antenna has higher efficiency than the wire antenna, which is demonstrated by FDTD simulations and model experiments. The optimal antenna configuration is further considered with the D/U ratio.

2. ANALYSIS OF OPTIMAL ANTENNA PARAMETER

2-1. Experimental model

Fig. 1 shows the configuration of the resistor loaded rectangular dipole antenna covered with a conducting cavity. The antenna parameters to discuss are the loaded resistor R, the antenna height h , the cavity height t, the element height d and element width w. A 1:4 balun is attached at the feeding point. The model experiment is conducted to obtain the received waveform of the direct coupling and reflected wave. A water tank with the size of 42*42*100 cm is used in order to confirm the antenna characteristics in homogeneous medium. The antennas were set at 2 cm above the water surface. The metallic pipe with the length of 40 cm and the diameter of 3 cm was set at the depth of 40 cm. The transmitter and the receiver are arranged close to each other.

2-2. Loaded-resistor

Here, the optimal loaded resistor which maximize the D/U ratio is analyzed. Fig. 2 shows the relationship between the D/U ratio and the loaded resistor obtained in the experiment. It is found that the maximum D/U ratio appears at 340 ohm in water medium. The FDTD result of the same condition is also shown in Fig. 3. The non-dispersive medium is assumed in the simulation, which has the relative permittivity and the conductivity of 81 and 0.01 (S/m), respectively. However the absolute D/U ratio is slightly different between the experimental data and the FDTD simulation, the optimal resistance corresponds to each other. The FDTD analysis shows the good agreement of the tendency of the D/U ratio with the experiment. The further simulation is done in soil medium as shown in Fig. 3. We assume that the relative permittivity and the conductivity are 25 and 0.02 (S/m), respectively. The presence of the optimal resistance is observed from the maximum D/U ratio. The optimal resistance is found to be around 200 ohm in soil.

2-3. Antenna height

The D/U ratio with the variation of the antenna height h is demonstrated. Fig. 4 shows the D/U ratio obtained in the experimental data and the FDTD simulation for the water tank model. The experiment and simulation results show good agreement. It is observed that the ratio tends to decrease as the proportional to $1/h$. Since the absolute amplitude of the reflected wave is also decreased monotonically as h becomes larger, it is desirable to close the distance between the antenna and the ground as possible.

2-4. Cavity height and element height

Fig. 5 and 6 show the D/U ratio obtained from the FDTD simulation in soil against the variation of t (d = 1 cm) and d (t = 6 cm), respectively. We selected the loaded resistor of 184 ohm. However both results show that the D/U ratio have the maximum, the variation of the D/U ratio is not significantly depend on t and d. Thus, visualizing the antenna efficiency, it is better the element height as 1 cm. The optimal cavity height is determined to be 5 cm.

2-5. Element width

It is expected that the antenna efficiency can be increased by widening the element width. Fig. 8 shows the D/U ratio vs the element width w obtained in the FDTD simulation. The optimal antenna width is more than 6 cm. However, the Q factor of the antenna becomes larger as the width becomes wider from the simulated waveform. It is required to select the adequate element width according to the application.

3. IMPULSE RESPONSE OF RECTANGULAR DIPOLE ANTENNA

Fig. 2 shows the impulse response measured with the rectangular dipole antenna and the wire antenna in water. Here, h, t, d and w are 2 cm, 6 cm, 1 cm and 4 cm, respectively. The optimal loaded resistor of rectangluar dipole antenna is selected as 340 ohm. It is found that the antenna efficiency is increased by 6 dB from the amplitude of the reflected wave. On the contrary, the direct coupling wave is decreased by 6 dB. Thus, the D/U ratio of rectangular dipole antenna is improved by 12 dB.

4. CONCLUSION

The optimal loaded resistor is found to be around 200 ohm for soil and 340 ohm for water. It is desired that the antenna height and element width should shorten and widen as far as possible, respectively. The cavity height and the element height little influence the D/U ratio. It is confirmed that the analyzed rectangular dipole antenna has the higher efficiency and D/U ratio than the wire antenna. It is future work to analyze the mechanism that the D/U ratio have the optimum.

[1] L.Peter,Jr., J. J. Daniels, and J. D. Young, "Ground penetrating radar as a subsurface environmental sensing tool," *Proc. IEEE*, vol. 82, No.12, pp. 1082-1822, Dec., 1994
[2] M. Hirose, Y. Tomizawa, I. Arai and K. Komiyama, "Analysis of antenna characteristics of lorded wire antennas for subsurface radar," *Digest of IEICE Spring Corp.* B-1-1 (1999)
[3] Y. Nishioka, O. Maeshima, T. Uno, aand S. Adachi, "FDTD analysis of resistor-loaded bow-tie antennas covered with ferrite-coated conducting cavity for subsurface radar," *IEEE Trans., Ant & Propag.*,vol. 47, no.6, pp. 970-977, June 1999.

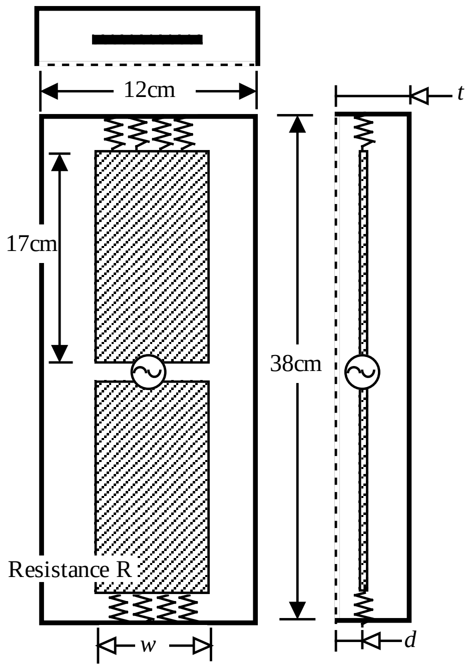

Fig. 1 Configulation of the resistor loaded rectangluar dipole antenna covered with a conducting cavity.

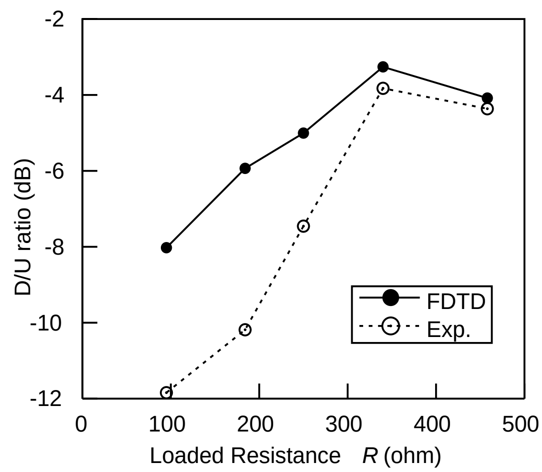

Fig. 2 The ratio of the amplitude of the reflected wave to the directly coupled wave (D/U ratio) measured and simulated for water tank model.
Antenna parameter : *h*=2cm, *w*=4cm, *d*=1cm, *t*=6cm

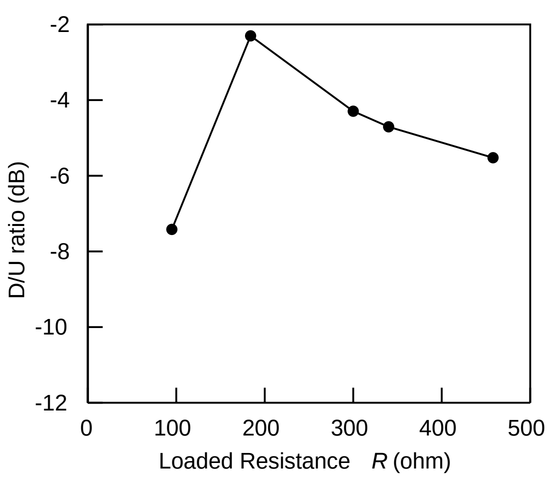

Fig. 3 The D/U ratio simulated for soil model.
Antenna parameter : *h*=2cm, *w*=4cm, *d*=1cm, *t*=6cm

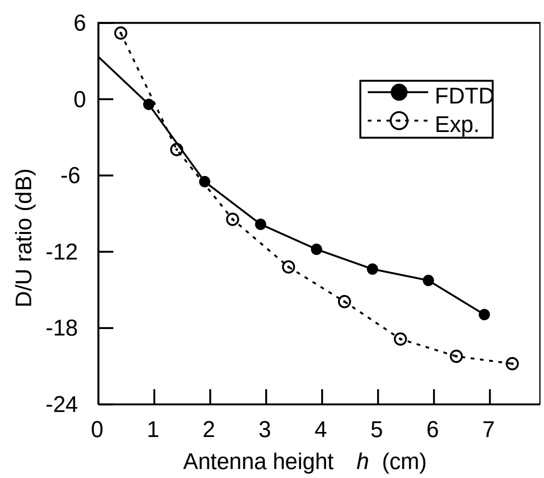

Fig. 4 the D/U ratio vs the antenna height from water surface obtained with the experiment and the FDTD simulation for the water tank model.
Antenna parameter : *R*=184 ohm, *w*=4cm, *d*=1cm, *t*=6cm

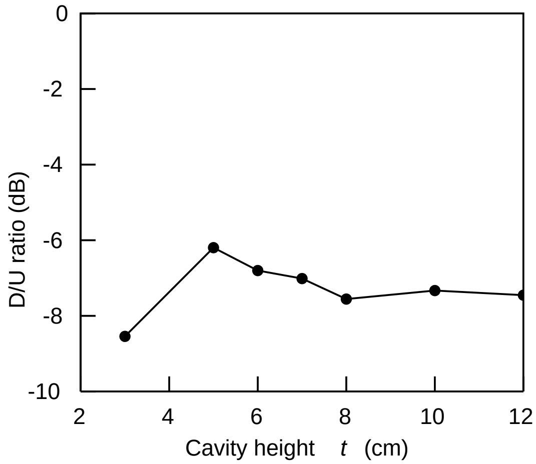

Fig. 5 the D/U ratio vs the cavity height obtained with the FDTD simulation for the soil model.
Antenna parameter :
R=184 ohm, *h*=2 cm, *w*=4 cm, *d*=1 cm

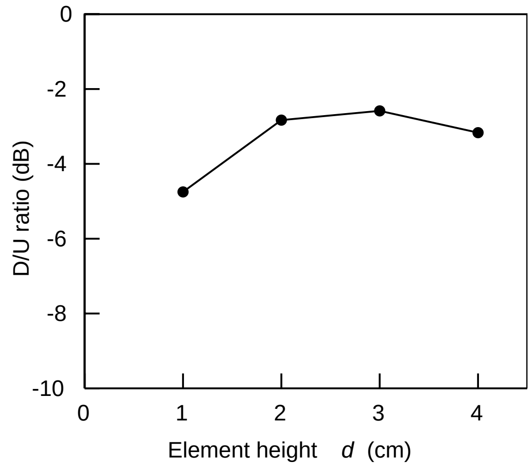

Fig. 6 the D/U ratio vs the element height obtained with the FDTD simulation for the soil model.
Antenna parameter :
R=184 ohm, *h*=2 cm, *w*=4 cm, *t*=6 cm

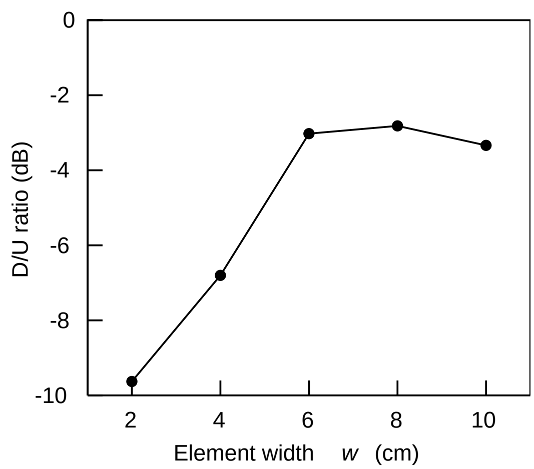

Fig. 7 The D/U ratio vs the element width obtained with the FDTD simulation for the soil model.
Antenna parameter : *R*=184 ohm, *h*=2 cm, *d*=1 cm, *t*=6 cm

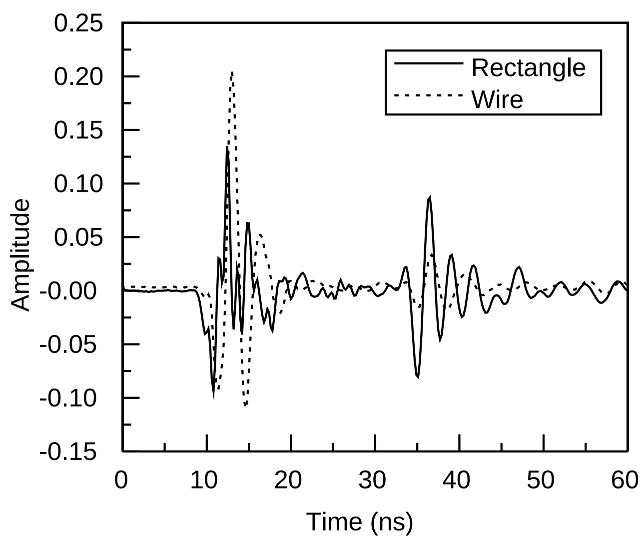

Fig. 8 Radar waveforms measured with the rectangluar dipole antennas and the wire antennas in water model.
Antenna parameter : *h*=2cm, *w*=4cm, *d*=1cm, *t*=6cm, *R*=340 ohm (for rectangle) , 200 ohm (for wire)