# Investigation of Resistive Vee Antennas for a Multi-Static Ground-Penetrating Radar

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## Introduction

A Resistive vee antenna (RVA) is a vee shape configuration of resistively loaded arms [1]. The RVA is usually loaded according to the Wu-King resistive profile, with which the conductivity of the arms is linearly tapered from the feed point to the open end of the antenna. The RVA is very clean in the sense that it has very little self clutter and a very low radar cross section (RCS) to lessen the reflections between the ground and the antenna. These characteristics of the RVA make it advantageous for use in ground-penetrating radar (GPR) applications.

A refined version of the RVA has been designed and implemented for use as an antenna in GPR systems, and its performance has been demonstrated in previous work [2–4]. The arms of the RVA are curved according to a set of equations and loaded according to a modified Wu-King profile to lower the reflections in the feed line at the drive point of the antenna. The antenna is implemented by printing the arms on a 50.8 $\mu$m-thick Kapton substrate and loading each arm with 13 chip resistors, which approximate the continuous loading profile for frequencies less than 8 GHz. The implemented RVA performs well as a GPR antenna.

In this paper, we further improve the implementation of the RVA and demonstrate its use as an antenna in a multi-static GPR system, which is developed to study the potential multi-static inversion algorithms.

## Implementation of the Resistive Vee Antenna

Fig. 1 shows the interior picture of the refined RVA. The arms are printed on a 50.8 $\mu$m-thick Kapton and loaded with 13 chip resistors. A double-Y balun, which is printed on a separate, 0.38 mm-thick FR-4 substrate feeds the antenna [5]. The balun transforms a 50 $\Omega$ coplanar waveguide to a 200 $\Omega$ coplanar stripline. The antenna and the balun are attached to a 0.51 mm-thick FR-4 substrate and then inserted into a U-shaped support made of 0.81 mm-thick G10. The antenna is fed through an SMA connector, which is mounted on the back panel of the support. The back panel is the largest source of the reflection to the incoming wave. The back panel is hidden by the microwave absorber placed at the end of the support. The antenna is modularized by filling the space in the plastic support with polystyrene foam and encasing the entire structure with a thin plastic film.

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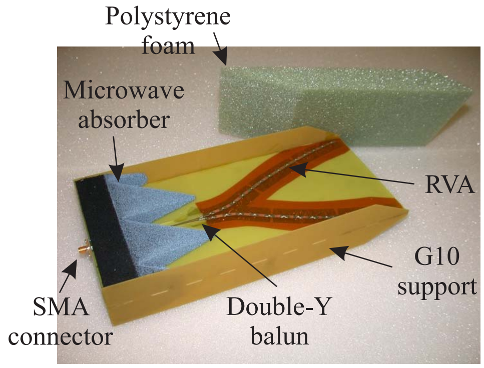



Figure 1: Picture of the antenna assembly. The polystyrene foam is to be placed on top of the RVA.

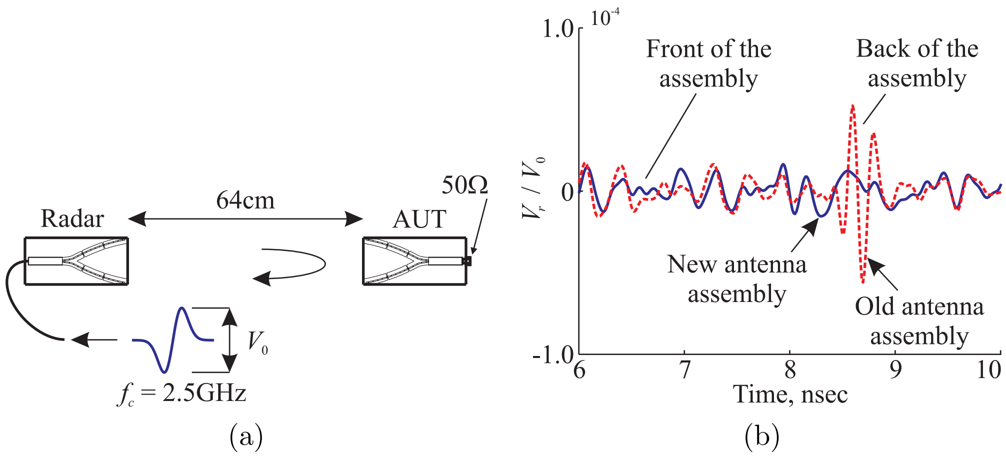
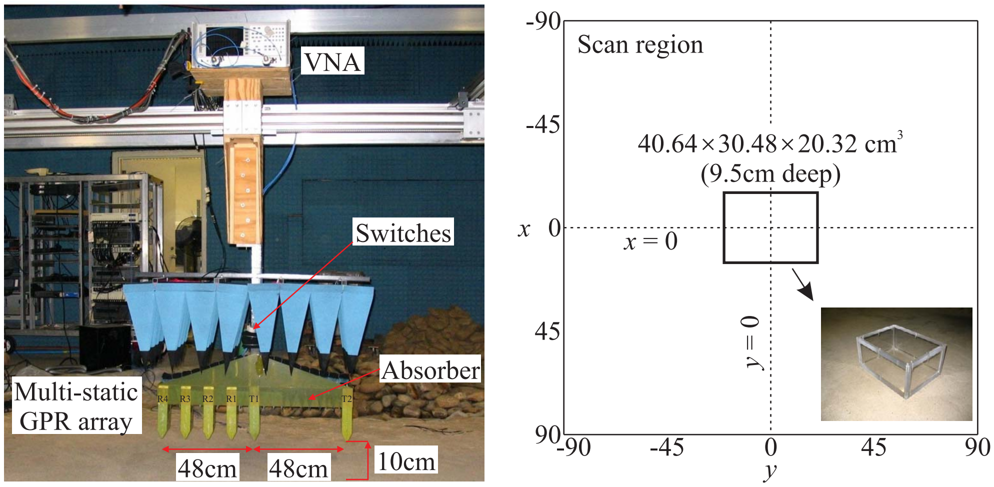



Figure 2: (a) Diagram of the measurement setup. (b) Comparison of the reflections from the old assembly and the new assembly as functions of time.

The reflections from the new antenna assembly is measured and compared with the antenna shown in [3]. Fig. 2 (a) shows the diagram of the measurement setup. A simple monostatic radar is used to measure the signal reflected from the antenna under test (AUT). The radar uses a differentiated Gaussian pulse with a center frequency of 2.5 GHz to excite its antenna. The AUT is terminated with a 50 Ω load for these measurements.

Fig. 2 (b) shows the reflection measured by the radar for both antenna assemblies. The reflections from the front and the back of the assembly appear at approximately 6.7 nsec and 8.6 nsec. The biggest reflection comes from the back of the old assembly. This reflection is primarily due to the back panel of the antenna assembly. The reflection from the back of the new assembly is much smaller due to the addition of the absorber. Note that the reflections from both assemblies are already very small, which make both these antenna assemblies suitable for near-surface GPR applications.




(a) (b)

Figure 3: (a) Picture of the multi-static GPR system. It has four receivers and two transmitters. The spacing between the receiver elements is 12 cm, and the spacing between the transmitter elements is 48 cm. (b) Burial map and the picture of the Plexiglas structure.

## Multi-Static Ground-Penetrating Radar System

A multi-static GPR system has been developed to study the potential of multi-static inversion algorithms. The radar consists of a linear array of 6 RVAs, a network analyzer, and a microwave switch matrix all under computer control. Fig. 3 (a) shows the picture of the multi-static GPR system. The antenna elements in the array are spaced 12 cm apart so the spacing between transmitter and receiver pairs in the measurements are from 12 cm to 96 cm in 12 cm increments. The size of the array is suitable for the land mine detection problem and is also suitable for scaled measurements of the buried structure problem. To lessen the reflections between the array frame and the ground, pyramidal microwave absorber is placed between the antenna elements. In addition, absorber is placed on top of the array to lessen the reflections from the equipment over the array. Because the antennas have a low RCS, and the interactions between the antenna elements are small, we can synthesize various aperture configurations using reciprocity and using scans at different array positions. For example, we can obtain a 192 cm-wide 17-element array aperture, where the antenna in the center acts as a transmitter and the other 16 elements act as receivers. We can also obtain a 96 cm-wide 9-element array aperture, where all elements act as both transmitters and receivers.

The operation of the multi-static GPR system is demonstrated on a buried structure. (Fig. 3 (b)). The structure is a 40.64 cm-wide, 30.48 cm-long, 20.32 cm-high box that is made of 2.54 cm-thick Plexiglas. The structure is buried 9.5 cm deep at the center of the 1.8m × 1.8m scan region. The array is scanned 10cm high over the scan region. In Fig. 4, the responses of four transmitter-receiver pairs along $x = 0$ line and the $y = 0$ line are shown in a 40dB scale. The vertical axes of the graphs represent the time. The horizontal axes represent the locations of the array in $y$-coordinate for

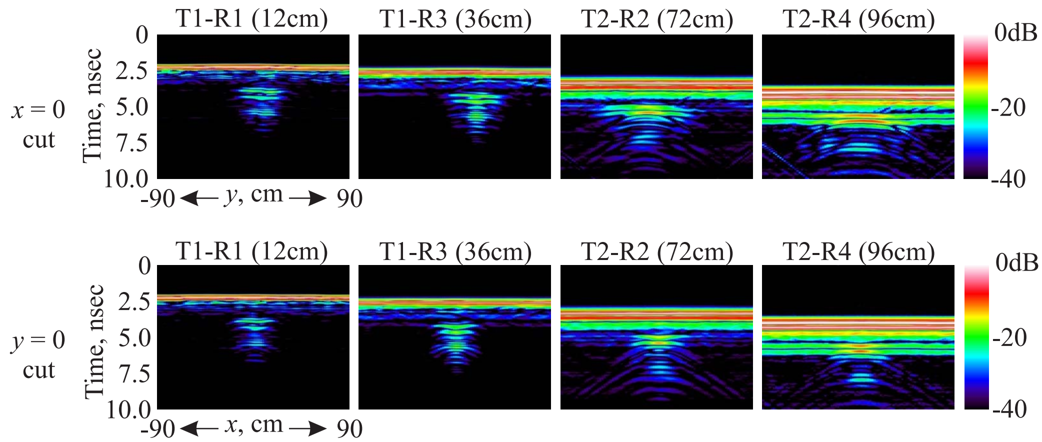



Figure 4: The responses of the buried structure for four transmitter and receiver pairs. The numbers in the parentheses are the distance between the transmitter and the receiver. The responses on the top row are those measured across the $x = 0$ line, and responses on the bottom row are those measured across the $y = 0$ line.

the graphs on the top row and in $x$-coordinate for the graphs on the bottom row. The first horizontal responses are the reflections from the surface of the ground. The reflections from the top and bottom of the structure are clearly visible in both cuts. In graphs for T2-R2 pair and T2-R4 pair, the hyperbolic nature of the target responses are evident.

## References

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