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Design Considerations for a Half Impulse Radiating Antenna

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614 Paseo Del Mar NE
Albuquerque, NM 87123

January 1996

Final Report

PHILLIPS LABORATORY
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13. ABSTRACT *(Maximum 200 Words)*
Recently developed pulsers have the capability to generate approximately 100GW of peak power with an impulse width of about 150 ps Full Width Half Max, and with a repetition rate of about 1 kHz. However, all these hydrogen-gap pulsers produce output into a coaxial waveguide, which is a single-ended configuration. This configuration is difficult to match to an antenna, since most free-space antenna designs require a balanced feed. One can convert the signal to a balanced configuration with a coaxial unzipper or point geometry converter, but there may be losses associated with these transitions. An alternative is to feed the signal into half a reflector Impulse Radiating Antenna (IRA). For this project, we developed the design principles of half reflector IRAs, and we calculated the radiated far field. We also provided a design for the lens that converts a coaxial Transverse Electromagnetic (TEM) mode to a spherical wave on the feed arms. Finally, we provided measurements of a ground-plane model of a half reflector IRA. The results of this project have already been summarized in two Sensor and Simulation Notes and a Prototype IRA memo, so we only very briefly summarized their contents.

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PREFACE

Many helpful discussions were held with Carl E Baum, James P O'Laughlin, and C Jerald Buchenauer, of Phillips Laboratory. Their assistance is gratefully acknowledged.

1.0 INTRODUCTION

Recently developed pulsers have the capability to generate approximately 100 GW of peak power with an impulse width of about 150 ps Full Width Half Max, and with a repetition rate of about 1 kHz. However, all these hydrogen-gap pulsers produce output into a coaxial waveguide, which is a single-ended configuration. This configuration is difficult to match to an antenna, since most free-space antenna designs require a balanced feed. One can convert the signal to a balanced configuration with a coaxial unzipper [1] or point geometry converter, but there may be losses associated with these transitions. An alternative is to feed the signal into half a reflector Impulse Radiating Antenna, as first suggested in [2]. For this project, we developed the design principles of half reflector Impulse Radiating Antennas, and we calculate the radiated far field. We also provided a design for the lens that converts a coaxial TEM mode to a spherical wave on the feed arms. The results of this project have already been summarized in two Sensor and Simulation Notes, so here we very briefly summarize their contents.

1l E. G. Farr, et al, Design Considerations for Ultra-Wideband, High-Voltage Baluns, Sensor and Simulation Note 371, October 1994.

2. C. E. Baum, Variations on the Impulse Radiating Antenna Theme, Sensor and Simulation Note 378, February 1995.

2.0 GENERAL DESIGN

We consider here a strategy for radiating a high-power single-ended transient source using a Half-Impulse Radiating Antenna (Half IRA). An example of a source we might wish to radiate with such an antenna is the HASP or H4 pulser currently being developed by Phillips Lab. The output of the H4 is a pulse with about 100 GW of peak power into a coaxial line. The pulse width is approximately 150 ps Full Width Half Max, and the source has a repetition rate of about 1 kHz.

A sketch of the proposed antenna is shown in Figure 1. For simplicity, we have assumed an *F/D* of 0.25. The feed impedance of the two arms combined is 100 ohms in air. Note that these arms are the same angular width (±4° from the cone center) as would be normally used in standard full IRA configurations, in which a single pair of arms with a full reflector has an impedance of 400 Ω. The lens is designed using the principles contained in [3]. An oil cap may or may not be used be used, depending upon dielectric breakdown considerations near the feed point. Configurations both with and without the oil cap are shown in Figure 2.

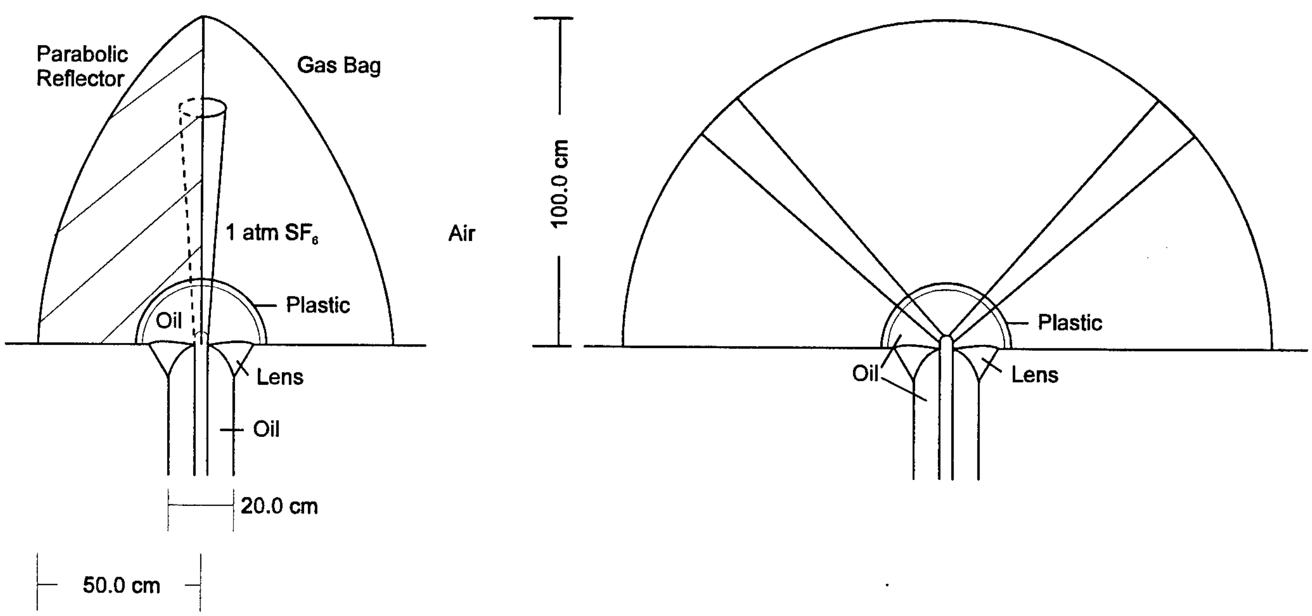

Figure 1. A sketch of the Half IRA, shown here with an oil cap.

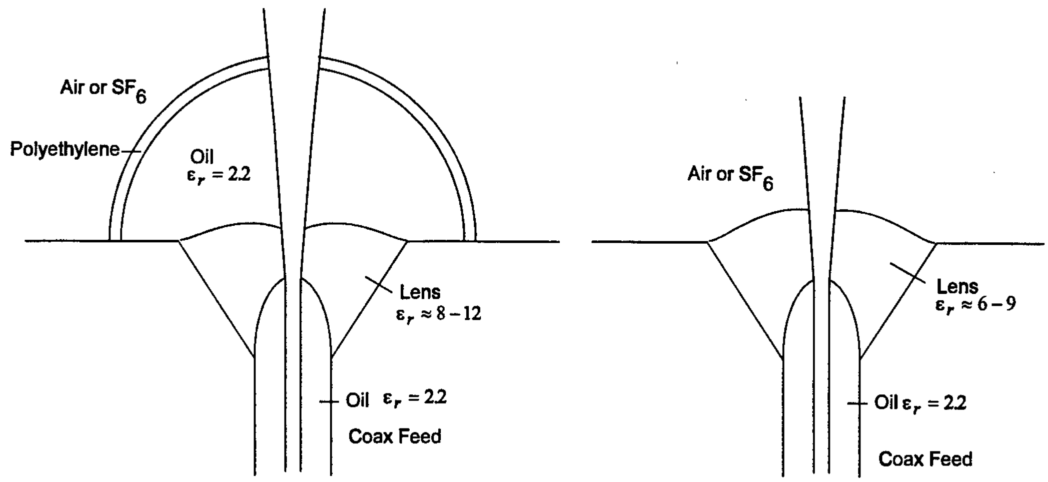

Figure 2. Two lens designs, with an oil cap (left) and without an oil cap (right).

3.0 LENS DESIGN PRINCIPLES

A key problem in the design is how to convert the coaxial wave mode to a spherical wave. We have developed a solution to this problem in [3]. The equations are derived in [3], so we simply show here a sample solution to the equations, as shown in Figure 3. This lens converts a coaxial mode on the left, to a spherical wave on the right.

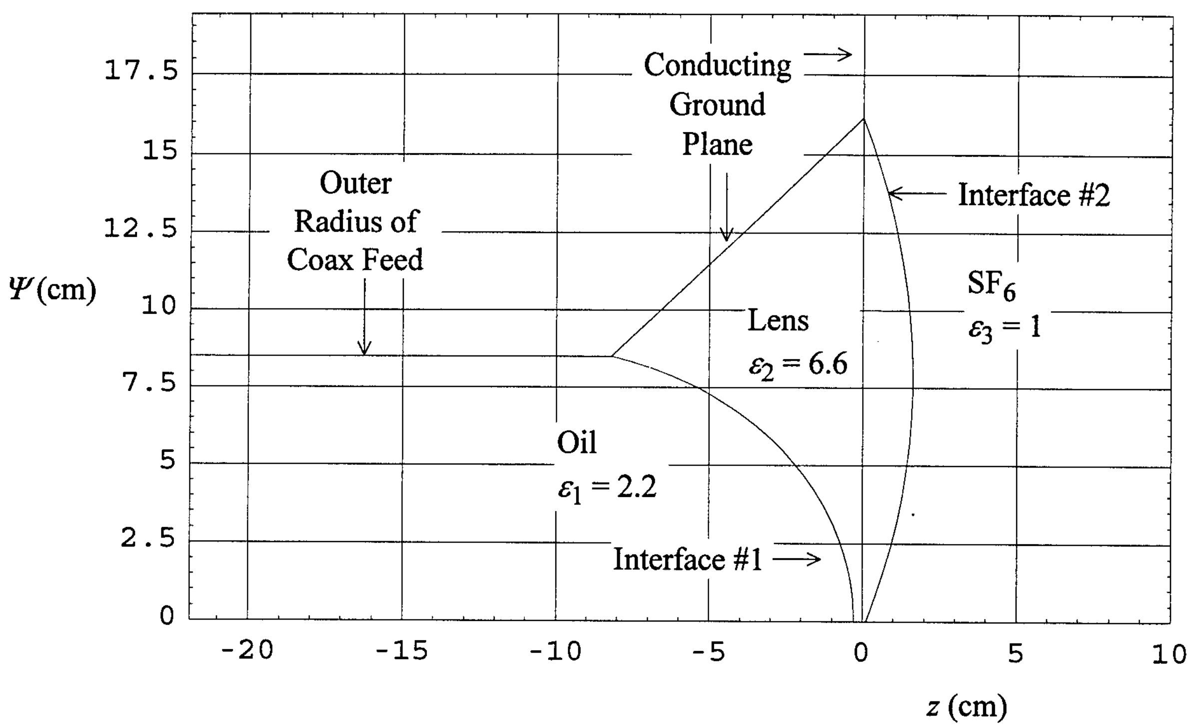

Figure 3. Improved oil-lens-air design using $\Delta\theta_1 = 43°$, and $\Psi_2/\Psi_1 = 2$.

3. E G. Farr and C. E. Baum, Feed-Point Lenses for Half Reflector IRAs, Sensor and Simulation Note 385, November 1995.

4.0 RADIATED FIELDS

The principles behind the field radiated from a half IRA were also developed. We adapted earlier calculations of a full IRA to that of a half IRA. An example of the boresight radiated field is shown in Figure 4. Furthermore, the radiated field as a function of angle off-boresight in the H- and E-planes is shown in Figure 5. We leave the details of the calculation to [4].

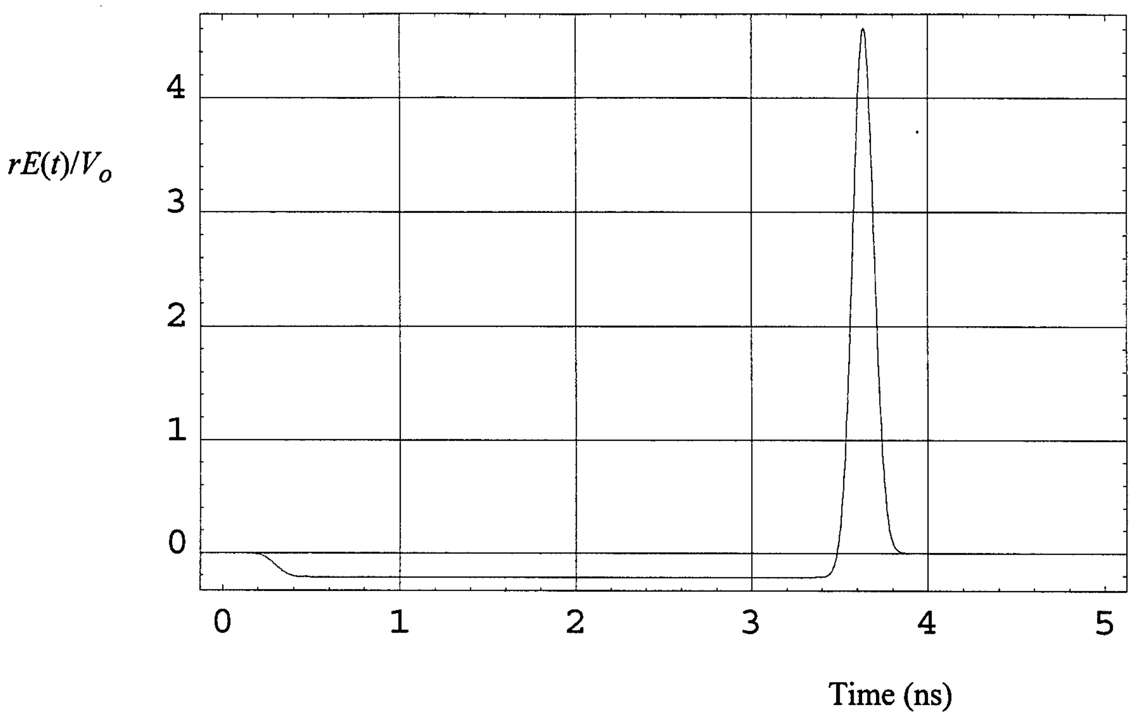

Figure 4. Radiated field on boresight for a 2 m diameter half IRA driven by a 150 ps risetime source. The peak is 4.6, with a t_{FWHM} of 139 ps.

4. E. G. Farr and G. D. Sower, Design Principles of Half Impulse Radiating Antennas, December 1990.

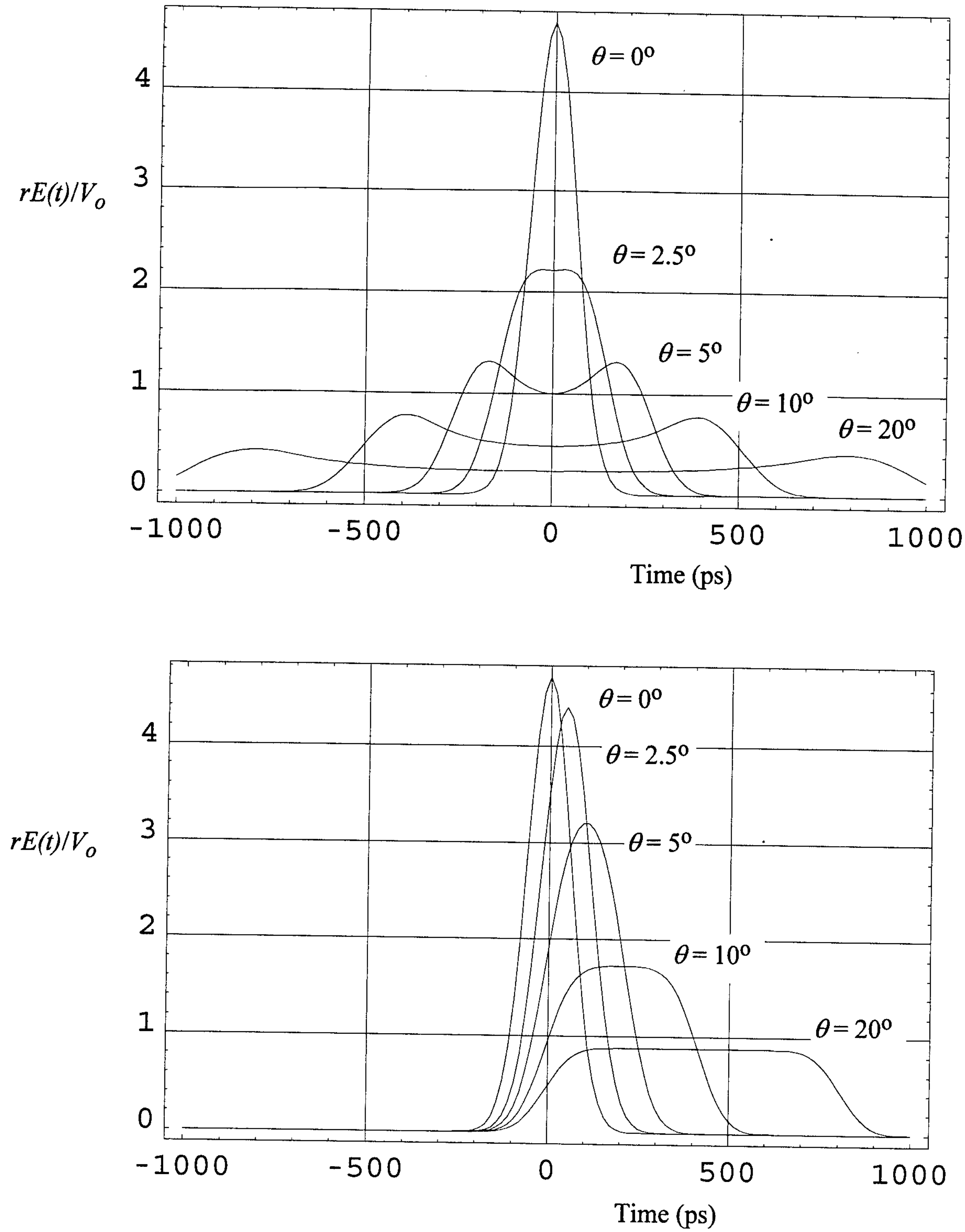

Figure 5. Fast part of the H-plane (top) and E-plane (bottom) radiated field for the half reflector IRA.

5.0 MEASUREMENTS

Antenna pattern and TDR measurements were carried out on a ground plane model of a half reflector IRA. The antenna was 12 inches (30.5 cm) in diameter, with an F/D of 0.25. The radiated field was measured, and comparisons were made to theory. A summary of this work appears in [5].

From TDR measurements, it was found that the impedance of the feed arms was not a uniform 100 Ω with perfectly conical arms. The impedance started out at 100 Ω, and then became lower as the feeds arms approached the edge of the reflector. This was attributed to the proximity of the reflector. To raise the impedance to a more uniform 100 Ω, the feed arms were tapered in various ways as they approached the edge of the reflector. In doing so, one can see an improvement in the uniformity of the feed impedance on the TDR measurement. The peak radiated field was also improved somewhat.

Experiments were also conducted which varied the impedance of the termination of the feed arms to the reflector. A matched load, a short circuit and an open circuit were considered. It was found that the matched load had some effect in damping out late-time oscillations, when compared to the other two termination impedances. Little effect was seen in the prepulse or in the magnitude of the radiated impulse.

Comparisons in the radiated field were made between the measurements and theory for both on- and off-boresight directions in the H-plane. The measured fields off-boresight demonstrated the double-hump characteristic in the impulse portion of the radiated field, as has been predicted by the theory. Furthermore, the measured beamwidth (peak field down by 0.707 of the boresight value) were in general agreement, with a measured value of 6 degrees, and a calculated value of 5 degrees. The magnitude of the peak measured field on boresight was about half of what was predicted by the theory, as plotted in Figure 6. This is roughly consistent with the results obtained in [6], where the measured field was 0.53 times the predicted field. This might be attributed to any of a number of factors, including no correction for feed blockage in the theory, and imperfections in the geometry at the feed point.

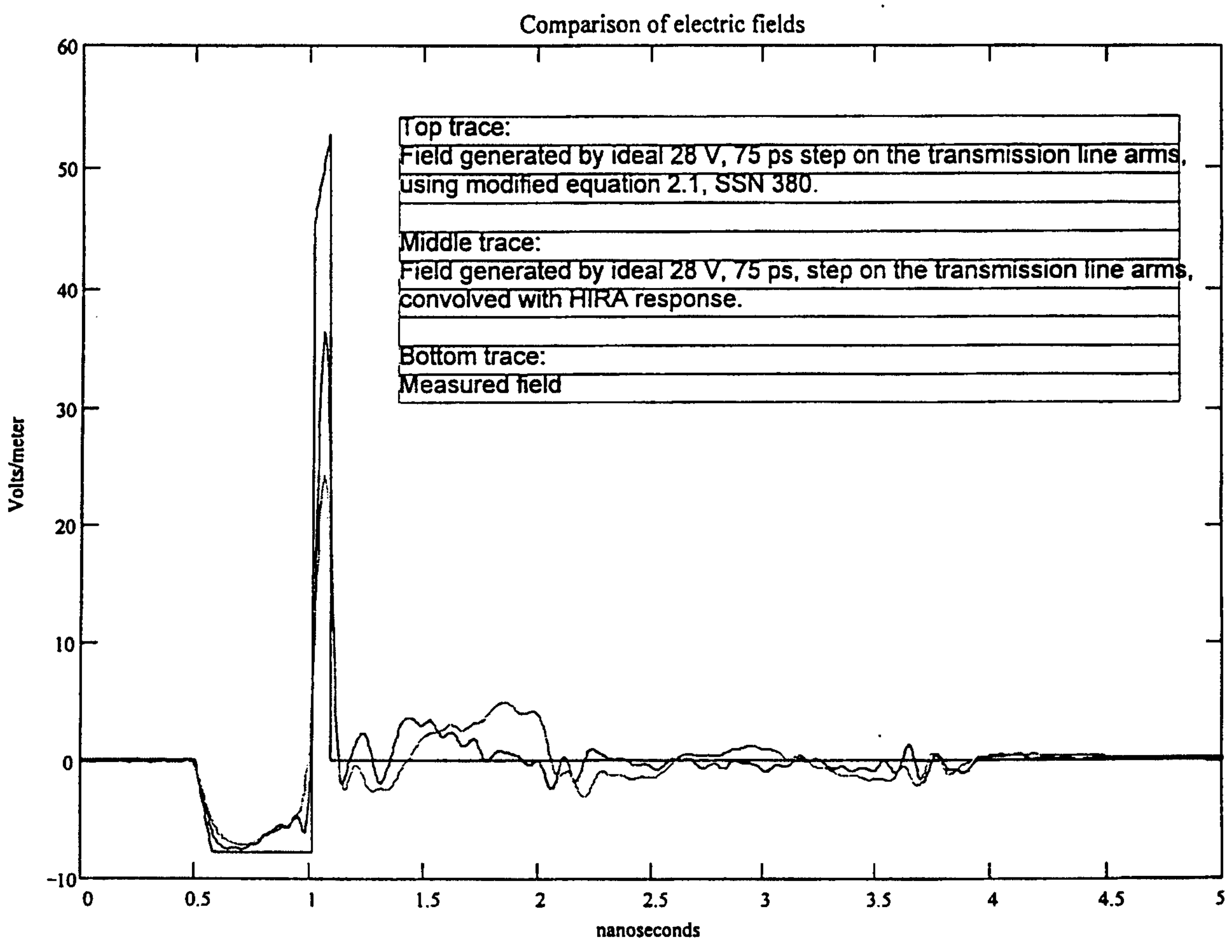

Figure 6. A comparison of the boresight predicted and measured fields for a Half IRA.

5. L. M. Atchley, G. D. Sower, and E. G. Farr, Scale-Model Ground-Plane Measurements of a Half IRA, Prototype IRA Memo 6, January 1996.
6. E. G. Farr and C. A. Frost, "Compact Ultra-Short fuzing Antenna Design and Measurements," Sensor and Simulation Note 380, June 1995.

6.0 CONCLUSIONS

We have summarized here the most important results from our recent work in developing the half reflector IRA. We have provided a design for the lens, and we have calculated the field radiated from a typical aperture. Finally, we have provided measurements of ground-plane measurements of a half IRA. Additional details can be found in the notes that have been cited.

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