

# WIPL-D Results and Time Domain Response for an Impulse Radiating Antenna (IRA)

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**Abstract:** WIPL-D was used to model and simulate an Impulse Radiating Antenna (IRA) with a 46cm diameter paraboloidal reflector and 45 degree feed arms. Model views are shown and the results of frequency domain simulation up to 20GHz are plotted for the two cases of the IRA as transmitter and as receiver. The simulated frequency domain data is inverse Fourier transformed to obtain the time domain response to a Gaussian pulse input. The integral of the pulse input response gives the step response, which compares well with the theorized step input response of the IRA.

**Keywords:** WIPL-D, Impulse Radiating Antenna, IRA

## 1. Introduction

The Impulse Radiating Antenna (IRA) was first theorized by Carl Baum in 1989 [1]. Since that time, numerous papers have filled out the knowledge of the IRA [2-4] and several versions of the IRA with different diameters of reflector and various feed arm configurations have been built and tested by Everett Farr and others [4-6]. The objective of this document is to show simulation results both in the frequency and time domain of the electrical characteristics of the IRA modeled using the electromagnetic analysis code WIPL-D [9]. Since this code uses entire domain basis functions over large subsectional patches it is possible to analyze electrically large structures on a desktop pc using modest computational resources. In this paper, we introduce a WIPL-D model which is based on design information provided by E. Farr for an IRA-2 with an 46cm diameter reflector and 30 degree feed arms [7]. However, instead we use the basic 45 degree feed arms configuration of the original IRA-1. We show the frequency domain results of the simulation for the two cases of the IRA as transmitter and as receiver. The frequency domain data are transformed to time domain and the time domain plots are also shown. The results of this IRA model are compared to published measurements on similar IRA versions which were built and tested [4].

## 2. WIPL-D Model and Simulation Results for the IRA

The IRA structure consists of a 46cm diameter paraboloidal reflector and four feed arms with 45 degree spacing. Figure 1 shows the front and side views of the IRA modeled in WIPL-D. The segmentation for the paraboloidal reflector is set by the parameter  $n = 16$  which defines 16 segments per quarter circumference of the reflector. The plates which make up the feed arms are automatically discretized by WIPL-D into appropriate meshing for a maximum frequency of 20GHz.

# Report Documentation Page

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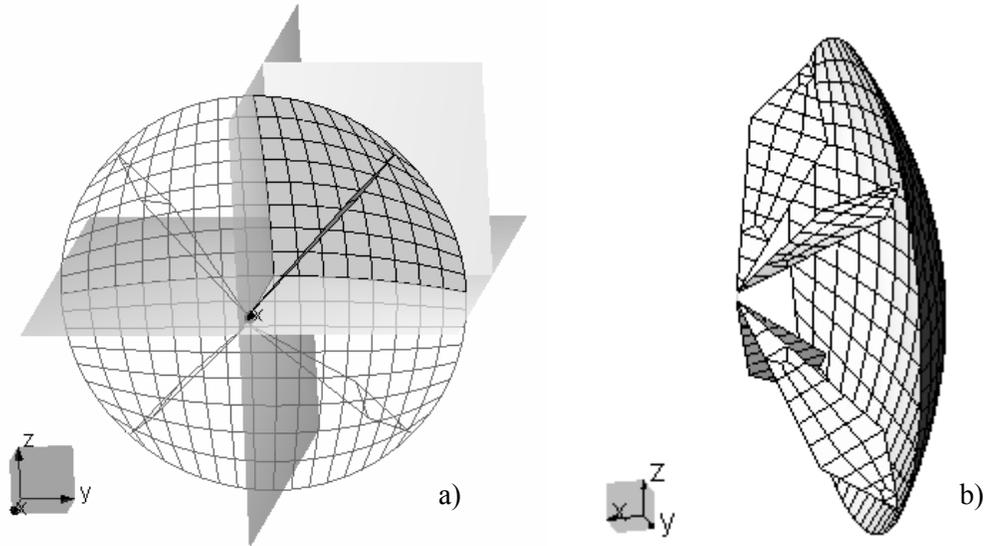


Fig. 1. a) Front view with quarter symmetry, b) side view with feed arm discretization.

The frequency domain results of the WIPL-D simulation are shown in Figs. 2 and 3. The two simulations were run from a starting frequency of 20MHz to a stop frequency of 20GHz, with a 20MHz step size, for 1000 data points total per simulation.

Fig. 2 shows the  $E_{\theta}$  radiation vs. frequency for the IRA as a transmitter with a delta gap generator feed located at the focal point of the reflector, where the four feed arms meet. The IRA as a receiver is simulated with a plane wave incident on the antenna and monitoring the current on the feed wire at the focal point. The magnitude of the current vs. frequency, which is proportional to the received field, is plotted in Fig. 3 below.

Fig. 4a shows the dB gain vs. frequency from WIPL-D which agrees well with the shape and peak gain found in the measurements documented by Bowen et al [4] for the IRA-1 with  $30^{\circ}$  feed arms and the IRA-2 with  $45^{\circ}$  feed arms. Fig. 4b shows the Bowen results.

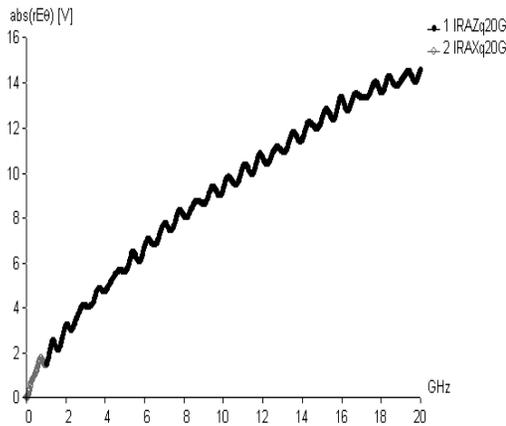


Fig. 2. Magnitude of  $E_{\theta}$  vs. Frequency

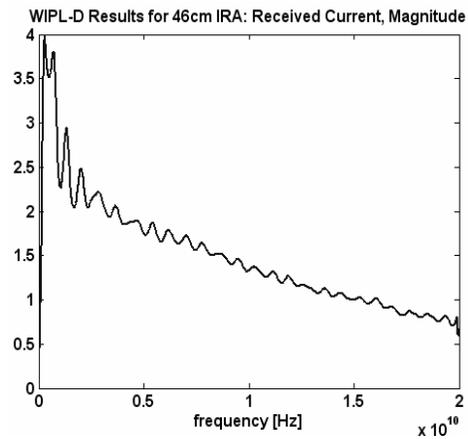


Fig. 3. Received Current Magnitude vs. Freq

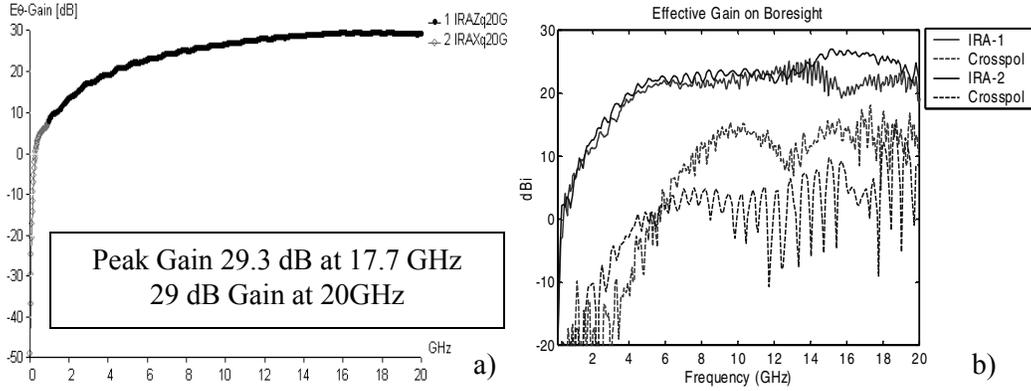


Fig. 4. a) WIPL-D dB Gain vs. Frequency, and b) Published Measurements [4, Fig. 3.5]

### 3. Time Domain Response

The time domain response is obtained from the frequency domain data calculated in WIPL-D. The response vs. frequency data is weighted by a Gaussian window of approximately 16GHz bandwidth and the result is inverse Fourier transformed to generate the time domain response. Table 1 summarizes the parameters used.

| Parameter  |                          | Value           | Description          |
|------------|--------------------------|-----------------|----------------------|
| $\Delta f$ | set by simulation        | 20 MHz          | frequency resolution |
| N          | select                   | $2^{11} = 2048$ | sequence period      |
| $f_s$      | calc: $f_s = N\Delta f$  | 40.96 GHz       | sampling frequency   |
| $\Delta t$ | calc: $\Delta t = 1/f_s$ | 24 psec         | sampling interval    |
| $T_0$      | calc: $T_0 = 1/\Delta f$ | 50 nsec         | record length        |

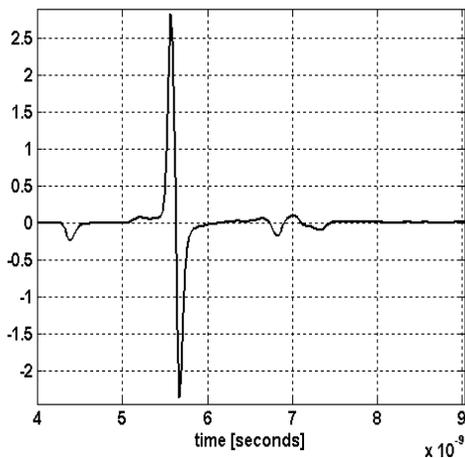
TABLE 1: List of signal processing parameters

The time domain response of the IRA as a transmit antenna is obtained from the radiated field vs. frequency calculated in WIPL-D. Figure 5 shows the transmit time domain response of the IRA to a Gaussian input pulse. The IRA acts as a differentiator on transmit and will differentiate the input pulse, producing a pulse doublet in the far field.

The time domain response of the IRA as a receive antenna is obtained from the incident field vs. frequency, which is proportional to the current monitored on the IRA's central feed wire. Figure 6 shows this result. The relationship between the transmit and receive waveshapes is noted by observing that the receive response to the incident plane wave, which is wideband in frequency and an impulse in time, is the integral of the transmit far field time domain response due to a pulse input.

The designed operation of the IRA is to produce an impulse in the far field. This is achieved with a step input to the transmitter, which the IRA differentiates on transmit. To generate the response of the IRA to a step input, we recognize that the desired step input is the integral of the pulse, and therefore take the integral of the time domain radiation response due to the pulse input. This results in the transient response due to a step input and is the same shape as the receive response due to an incident plane wave, shown in Fig. 6, because of the integral relationship between time domain transmit and receive.

TD IRA 46cm: Time domain response,  $T=0.25\text{ns}$  (16GHz),  $t_0=5\text{ns}$



TD 46cm IRA: Rx Current (BW=16GHz, delay=5ns)

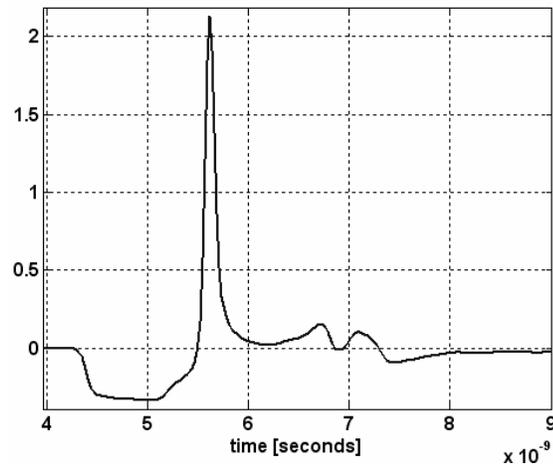


Fig. 5. Time Domain Response on Transmit Fig. 6. Time Domain Response on Receive

#### 4. Conclusions

In this paper, we have presented a model and simulation results for a 46cm diameter IRA using the electromagnetic analysis code WIPL-D. The frequency domain results from WIPL-D have been shown for the cases of the IRA as a transmitter and as a receiver. The frequency data have been transformed to the time domain using a Gaussian window and inverse Fourier transform. The IRA on transmit time domain plot shows the transient response due to a Gaussian pulse as the input. Integration of this result gives the transient response due to a step input, which is the radiated impulse for which the antenna was designed. Future work includes using this IRA in scattering scenes with other antennas and various configurations of targets and ground planes.

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