WIPL-D Model and Simulation Results for a 6ft Diameter Impulse Radiating Antenna (IRA)

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Abstract: WIPL-D was used to model and simulate an Impulse Radiating Antenna (IRA) with a 6ft diameter paraboloidal reflector and 45 degree feed arms. Model views are shown and the results of frequency domain simulation up to 2GHz 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. This far-field transient response is integrated to obtain the response to a step input, 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, additional papers have filled out the knowledge of the IRA [2, 3] and several versions of the IRA with an 18 inch diameter reflector and various feed arm configurations have been built and tested by Everett Farr and others [4]. The objective of this document is to introduce a larger scaled IRA model and show simulation results both in the time and frequency domain of the electrical characteristics of the larger antenna using the electromagnetic analysis code WIPL-D [6]. Since this code uses entire domain basis functions over large subsectional patches it is possible to analyze electrically large structures and configurations 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 18inch (46cm) diameter reflector and 30 degree feed arms [5]. However, instead we have scaled up a 6ft diameter reflector and 45 degree feed arms. 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 transient response is also shown. The results of this larger antenna are comparable to published measurements on other IRA versions with a smaller diameter reflector [4].

2. WIPL-D Model of 6ft Diameter Impulse Radiating Antenna (IRA)

The IRA structure consists of a 6ft 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 = 8 which defines 8 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 2GHz.

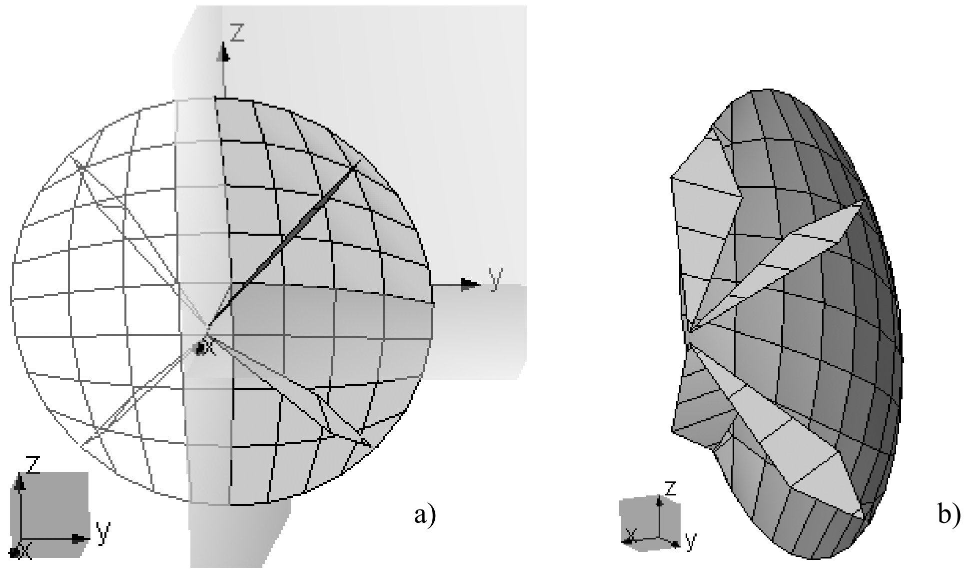

Fig. 1. a) Front view with half symmetry and b) side view with feed arm discretization.

3. WIPL-D Simulation Results

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 1MHz to a stop frequency of 2GHz, with a 1MHz step size, for 2000 data points total per simulation.

Fig. 2a shows the far-field 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. Fig. 2b shows the dB gain vs. frequency from WIPL-D which agrees well with the general shape and peak gain found in the measurements documented by Bowen et al [4] for the IRA-1 with 30° feed arms and the IRA-2 with 45° feed arms.

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.

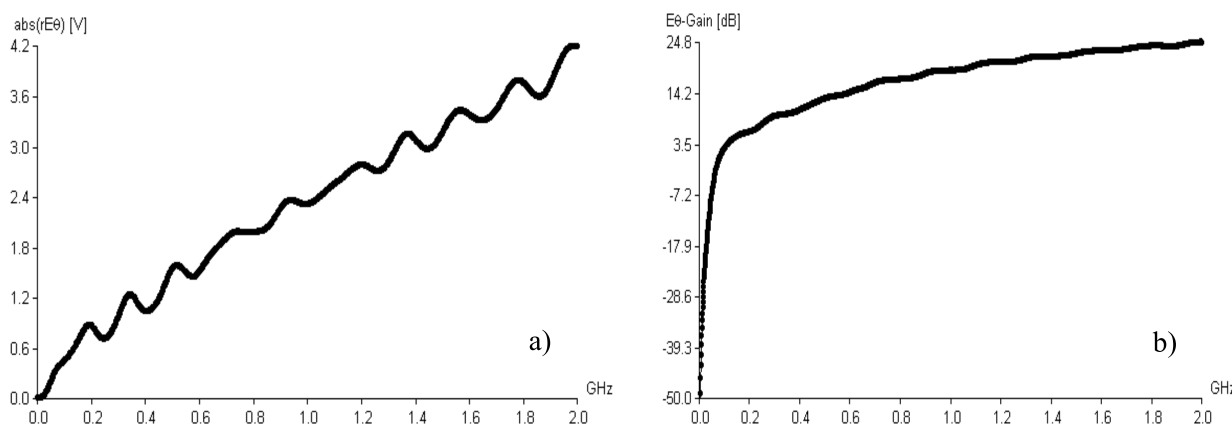

Fig. 2. Transmit IRA: a) Far-Field Radiation vs. Frequency and b) Gain vs. Frequency.

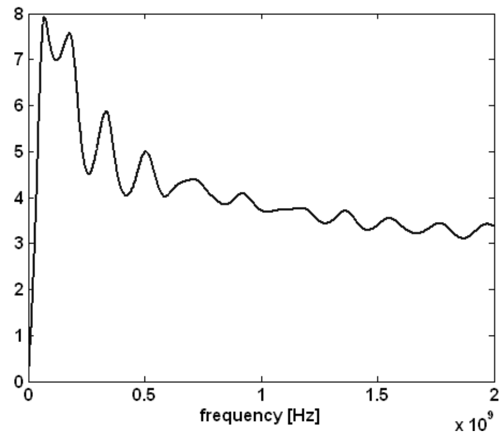

Fig. 3. Receive IRA: Magnitude of Received Current vs. Frequency.

4. 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 2GHz bandwidth and the result is inverse Fourier transformed to generate the time domain response. Table 1 summarizes the parameters used in the processing.

Parameter		Value	Description
Δf	set by simulation	1 MHz	frequency resolution
N	select	$2^{12} = 4096$	sequence period
f_s	calc: $f_s = N\Delta f$	4.096 GHz	sampling frequency
Δt	calc: $\Delta t = 1/ f_s$	244 psec	sampling interval
T_0	calc: $T_0 = 1/\Delta f$	1000 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 far field radiation vs. frequency calculated in WIPL-D. Figure 4a 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 4b 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 simulated far-field radiation response due to the pulse input. This results in the far-field transient response due to a step input and is the same shape as the receive response due to an incident plane wave, because of the integral relationship for time domain transmit and receive.

The shape of simulated transmit pulse agrees with the theoretical shape [1]. The pre-pulse extends from about 6ns to 11ns, which approximately corresponds to the time 2F/c = 4.87nsec, or the time for the excitation to travel from the source at the focal point F to the reflector and back to the focal plane which forms a circular aperture from which it radiates as a plane wave.

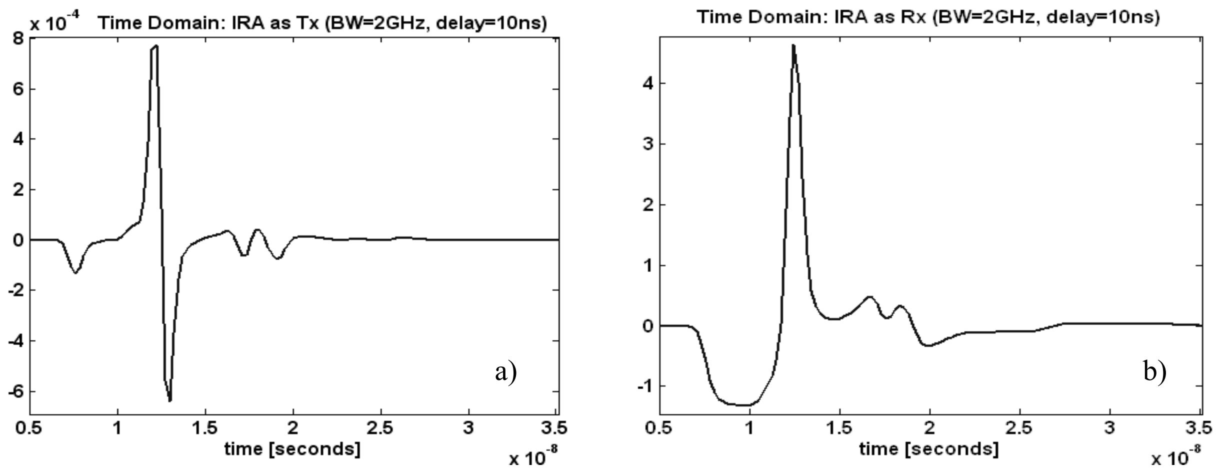

Fig. 4. a) Time Domain Response on Transmit, b) Response on Receive

5. Conclusions

In this paper, we have presented a model and simulation results for a 6ft 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.

References

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