EM Implosion Memos

Memo 4

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Numerical Calculation for the Focal Waveform of a Prolate-Spheroidal IRA

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Abstract

This paper is based on a numerical attempt to reproduce the analytical results for the waveform of a prolate-spheroidal IRA with two feed arms.

1 Introduction

This paper is a numerical calculation of a prolate-spheroidal IRA that is based on [1],[2],[3],[4]. The waveform at the second focus of a prolate-spheroidal reflector is reproduced.

2 Description of the calculation method

CST MICROWAVE STUDIO (CST MWS) is a specialist tool for the 3D EM simulation of high frequency problems. CST is based on Finite Integration Technique (FIT). This numerical method provides a universal spatial discretization scheme, applicable to various electromagnetic problems, ranging from static field calculations to high frequency applications in time or frequency domain.

CST Applications include the expanding areas of: Mobile Communication, Wireless Design , Signal Integrity, and EMC. The broadly applicable Time Domain solver and the Frequency Domain solver simulates on hexahedral as well as on tetrahedral grids[5].

3 Description of Geometry

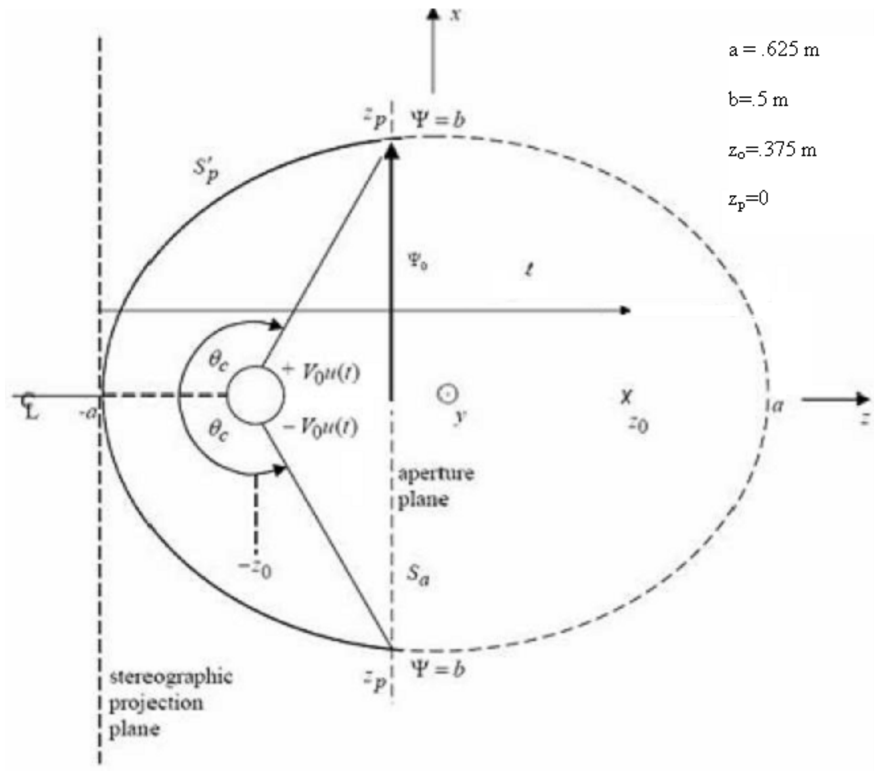

Figure 3.1 IRA Geometry

The prolate-spheroidal IRA's geometry parameters are [2]

$$z_p = 0,\ b = \Psi_0 = .5\,\text{m},\ a = .625\ \text{m},\ z_0 = .375\,\text{m},\ \ell = 1\,\text{m} \tag{3.1}$$

Our design has two 90^o TEM feed arms and the dimensions of these arms determined by $400\,\Omega$ Pulse Impedance.

Z_{line}	$b'_2 - b'_1$	$\phi_0(deg)$	h_a/R - COS	h_a/R - ideal	*increase*	R/R_0
200	0.916	75	0.726	0.730	0.42%	0.96
200	0.521	60	0.736	0.750	1.80%	1.11
200	0.275	45	0.648	0.687	6.00%	1.16
200	0.130	30	0.480	0.559	16.63$	1.14
200	0.061	15	0.254	0.355	39.94%	1.16

Table 3.1: Increase in the aperture height due to the ideal contour shaping and increasing the aperture radius relative to the circle of symmetry. The column gives the width of the electrode in the aperture plane when b' = 1, the column h_a/R-COS gives the normalized aperture height when the entire circle of symmetry is focused, the column h_a/R-ideal gives the highest computed normalized aperture height with corresponding increase and value of R/R_0 at which the maximum occurs [7]

We know that [6]

$$
\begin{aligned}
& b'^2 = b_1' b_2' \\
& (b_1' - b_2')/b' = 0.275 \\
& \beta_o = \arctan(.5/.375) \cong 53.1^o \qquad \textbf{(3.2)} \\
& \beta_1 = 2\arctan\left[\sqrt{b_1'/b_2'}\tan(\beta_o/2)\right] = 47^o \\
& \beta_2 = 2\arctan\left[\sqrt{b_1'/b_2'}\tan(\beta_1/2)\right] = 59.6^o
\end{aligned}
$$

Where b', b_1', b_2' were defined in [6].

β_o is the angle from the z – axis to the electrical center
β_1 is the angle from the z – axis to the first edge
β_2 is the angle from the z – axis to the second edge

From (3.1)&(3.2) and table 3.1 we can find the locations and dimensions of the feed arms.

The feed arms are symmetric and the upper fed arm has three corners located at

x	y	z
0	0	-37.5
0	50	-8.2
0	50	8.99

Table 3. 2 Upper feed arm corner locations in cm

4.Focal Waveform

An accurate analytic result is

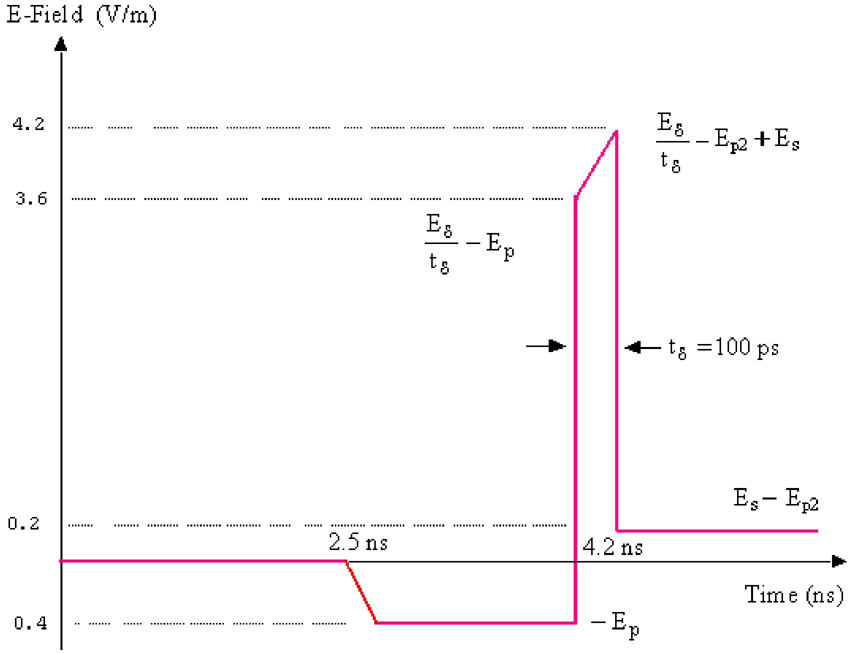

Figure 4.1 Analytic Waveform at the Second Focus [4]

4.1 3 GHz vs 5 GHz

Calculated simulation results for 3 GHz and 5 GHz for different mesh size (lines per wavelength (LPW))

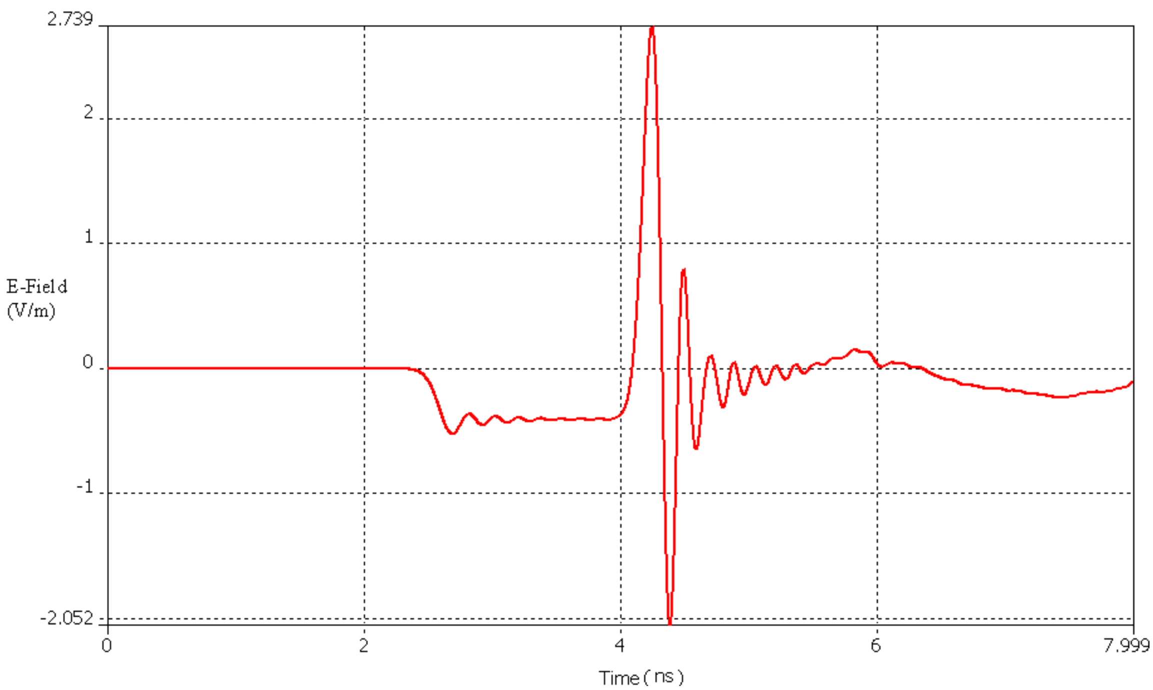

Figure 4.2 Numerical Waveform at the Second Focus at 3GHz & LPW=8

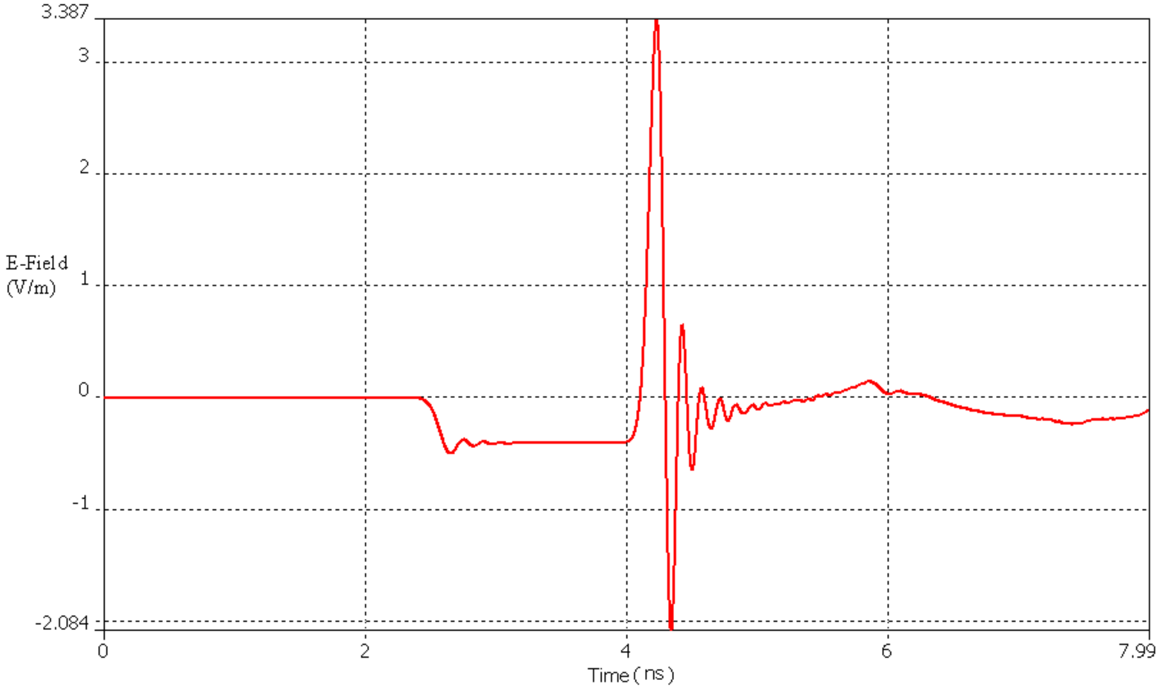

Figure 4.3 Numerical Waveform at the Second Focus at 3GHz & LPW=12

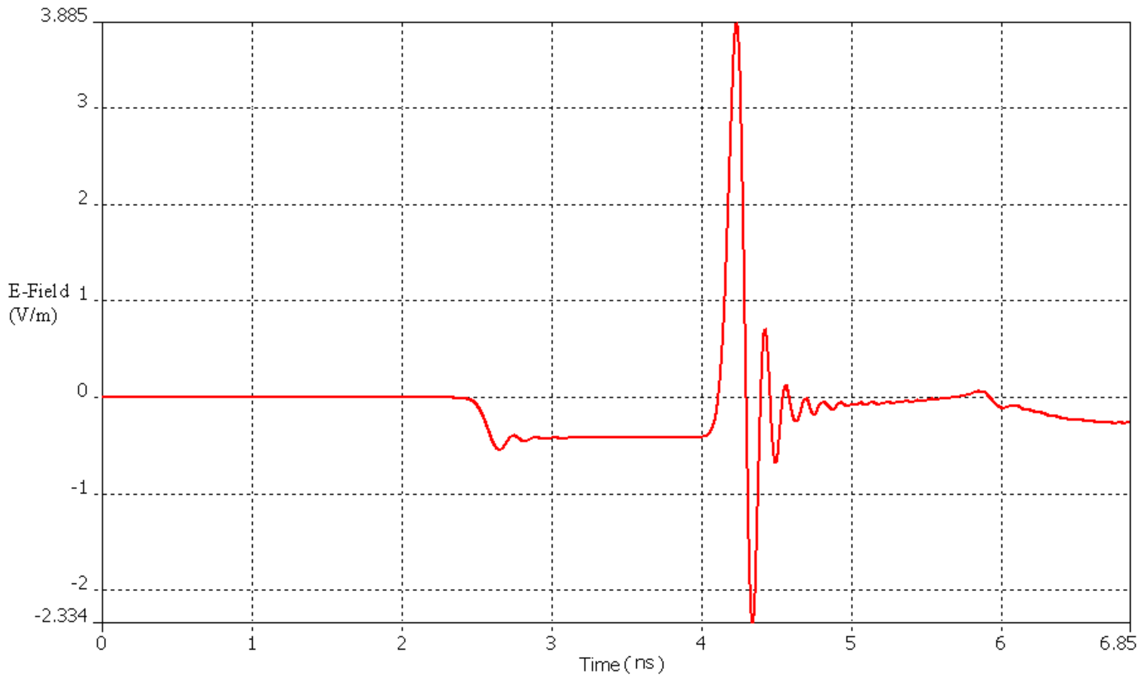

Figure 4.4 Numerical Waveform at the Second Focus at 5GHz & LPW=8

As expected, if we keep the mesh size the same we are getting better results by including higher frequencies. If we decrease the mesh size, we are getting better results for the 3GHz case.

As one can see, the prepulse is essentially the same as the analytical result and the impulse approaches to this value. The postpulse is not reproduced at all well.

4.2 Smoother Rise for Excitation

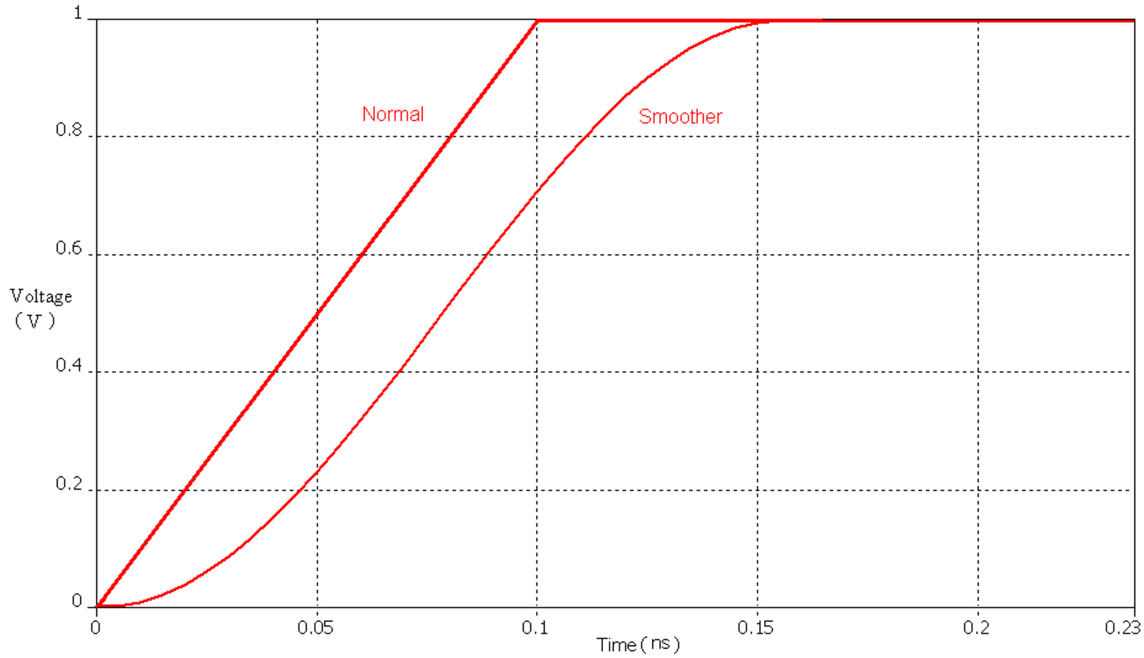

Figure 4.4 Normal&Smoother Excitation

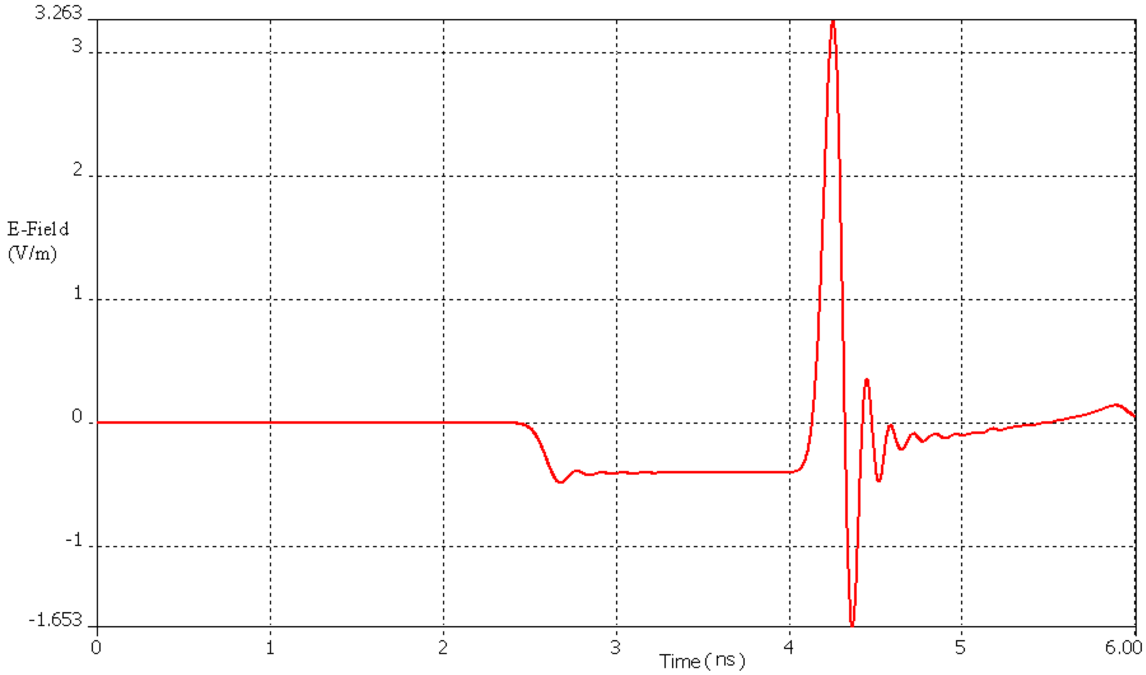

Figure 4.5 Waveform for Smoother Excitation at 5GHz

From Fig. 4.5 we can see that since the Fourier spectrum falls off faster at higher frequencies, it is trying to suppress 2nd harmonic of the upper frequency used.

Smoother rise excitation should approach to the analytic result more than normal rise excitation , but if we compare Fig. 4.3 with Fig. 4.5 we cannot see that. So we are hoping to see these in our future experimental results. We can see lower oscillations in the postpulse but we have also lower peaks for the impulse.

4.3 100ps vs 200ps

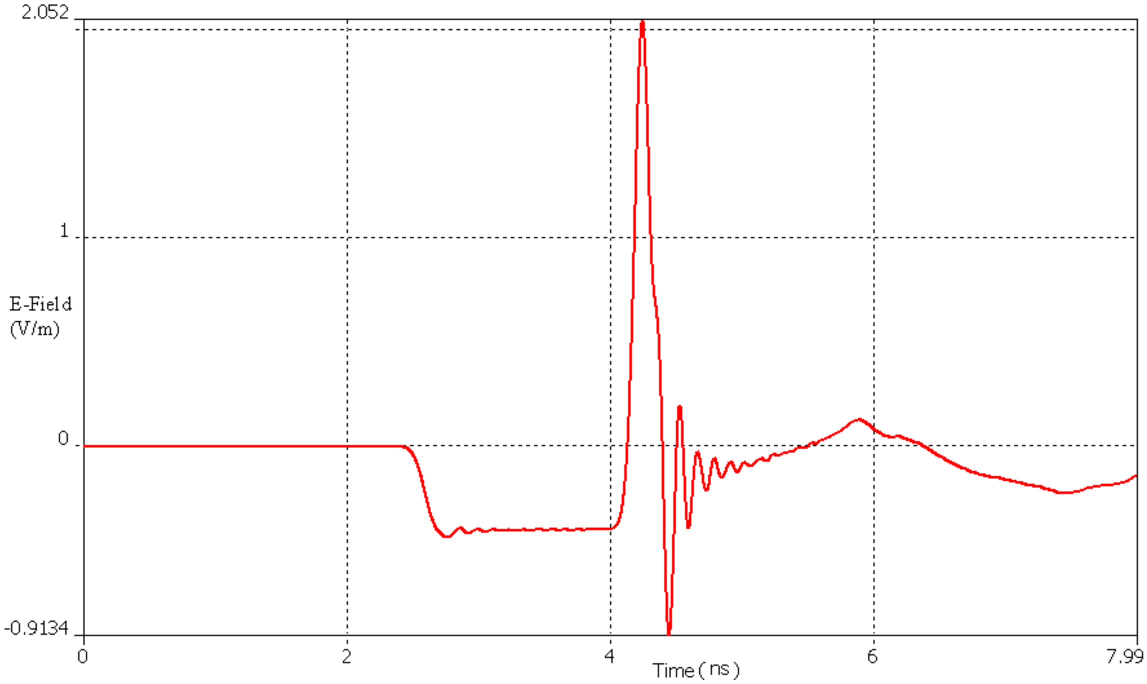

Figure 4.6 Waveform for 200ps at 5 GHz

$$E_i = \frac{E_\delta}{t_\delta} \tag{4.1}$$

So the impulse should be 2.1 V/m and as one can see Figure 4.6 approaches to the analytical results better than Figure 4.3. This is due to less requirements on the high frequencies. It also has lower ringing after Impulse.

5 Effect of Terminations

5.1 Resistive Termination

What is going to happen if our TEM feed arms does not touch the reflector and we have a $200\,\Omega$ resistive termination?.

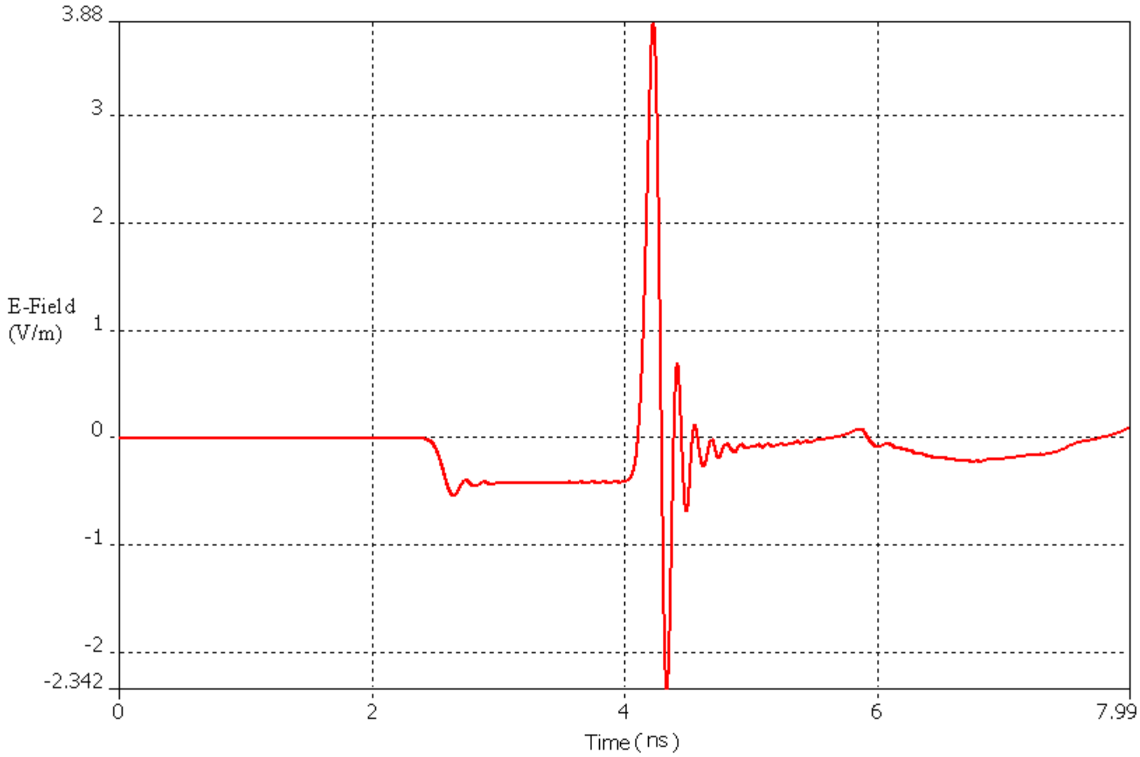

Figure 5.1 Waveform for $200\,\Omega$ Resistive Termination

If we have $200\,\Omega$ resistive terminations we are expecting to see a better approach but we cannot see that.

5.2 Parallel RC Termination

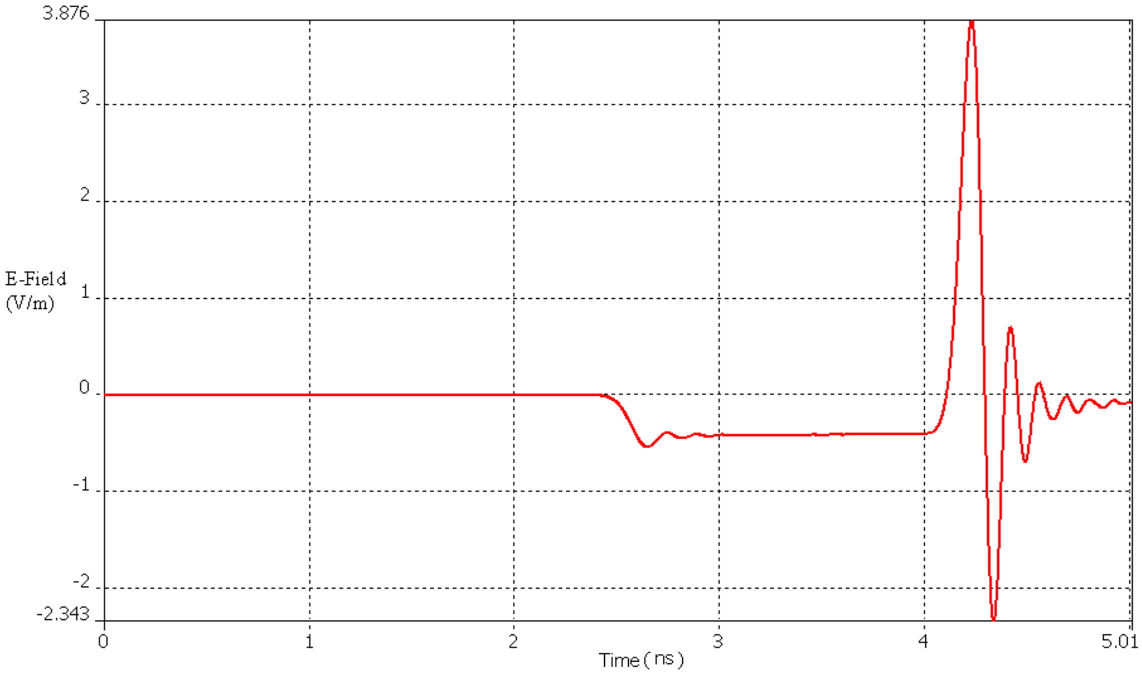

Figure 5.2 Waveform for $200\,\Omega$ resistive and 1pF Parallel RC Termination

We are expecting to see a better approach if we have $200\,\Omega$ resistive and 1pF parallel RC terminations but we cannot see it. We may be able to see it in our experiment results.

6.Conclusion

Numerical results for the prepulse term are basically the same as the analytical results. In general the impulse term is approaching the analytic one from below. But especially for the postpulse the numerical computation is inadequate, perhaps due to mesh size and frequency limitations .

We are expecting to get more reasonable results with our experiments.

References

1. C. E. Baum, “Focal Waveform of a Prolate-Spheroidal IRA”, Sensor and Simulation Note 509, February 2006.
2. S.Altunc and C.E.Baum. “Parameter Study for Prolate-Spheroidal IRA”,EM Implosion Memos, Memo 1, May 2006.
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6. J. Scott Tyo “Optimization of the Feed Impedance for an ArbitraryCrossed-Feed-Arm Impulse Radiating Antenna”, SSN 438, Nov. 1999.
7. M. J. Baretela and J. S. Tyo, “Improvement of prompt radiated response from impulse radiating antennas by aperture trimming,” *IEEE Trans. Antennas Propagat.*, vol. 51, pp. 2158 – 2167, 2003.