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Analytical and Numerical Calculation for the Focal Waveform of a Four-Feed Arms Prolate-Spheroidal IRA

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Abstract

Numerical and Analytical results for the waveform of a prolate-spheroidal IRA with four 45^{o} and 60^{0} TEM feed arms are calculated .

1 Introduction

This paper is a analytical and numerical calculation of a prolate-spheroidal IRA . Numerical and analytical results for the waveform of a prolate-spheroidal IRA with four 45^0 and 60^0 TEM feed arms is calculated and compared.

2 Description of Geometry

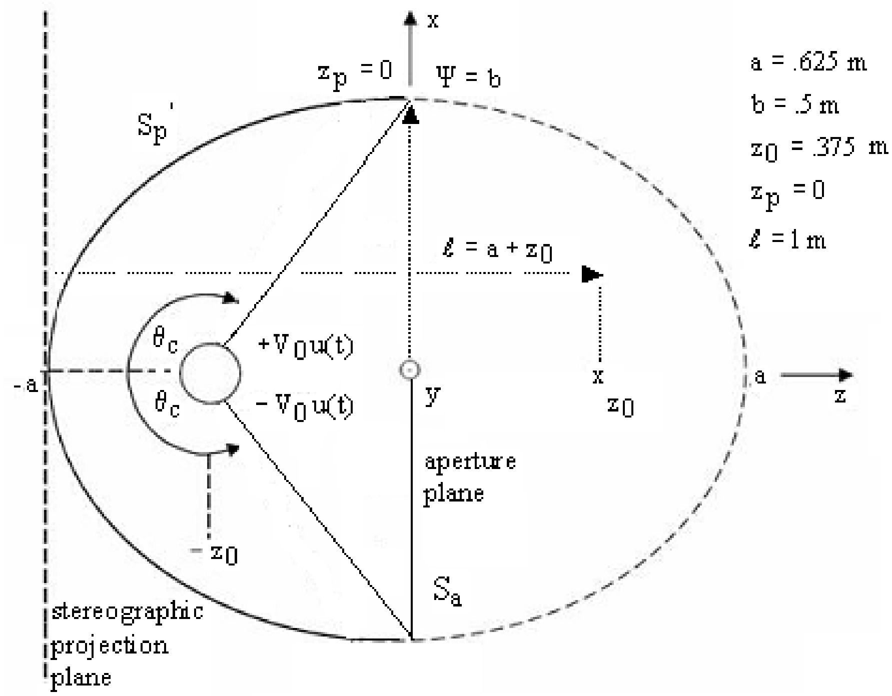

Figure 2.1 IRA Geometry [1]

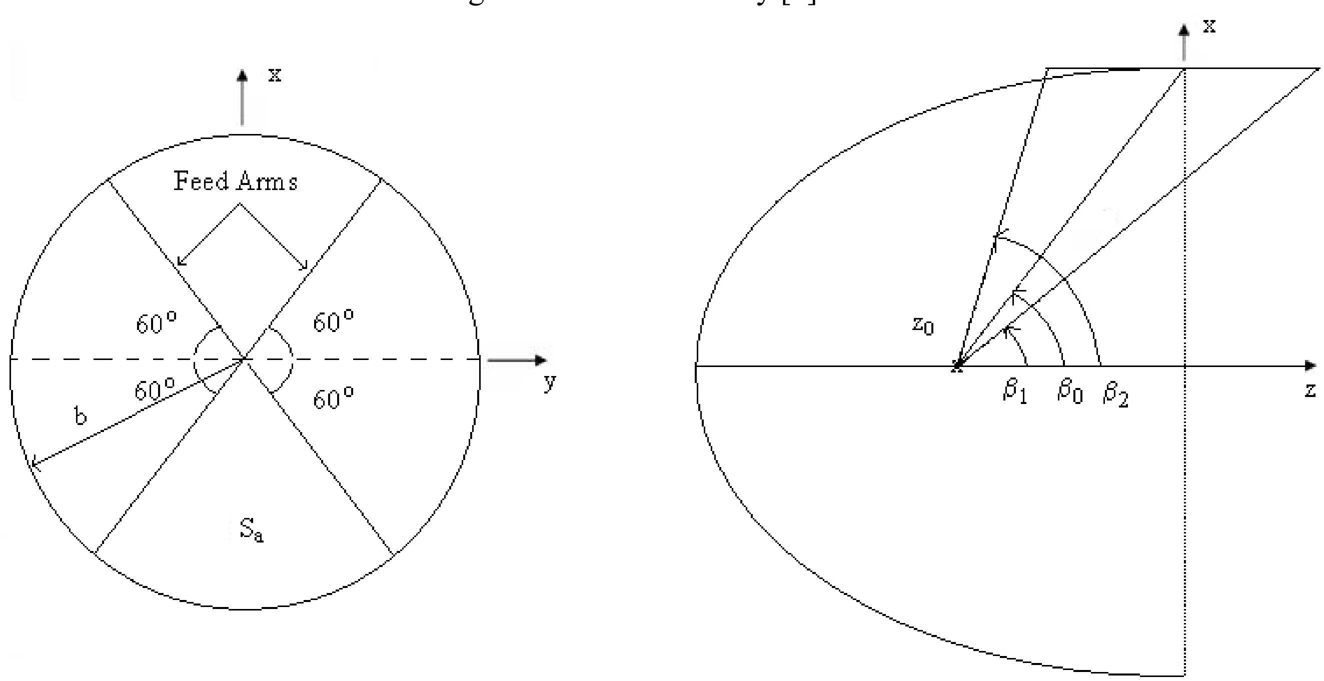

Figure 2.2 IRA's Feed Arm Geometry

This design has four 60^{o} TEM feed arms and the dimensions of these arms determined by $200\,\Omega$ Pulse Impedance. We can calculate [3]

$$b'^2 = b_1' b_2'$$

$$(b_1' - b_2')/b' = 0.521$$

$$\beta_o = \arctan(.5/.375) \cong 53.1^{o} \qquad (2.1)$$

$$\beta_1 = 2\arctan\left[\sqrt{b_1'/b_2'}\tan(\beta_o/2)\right] = 42.23^{o}$$

$$\beta_2 = 2\arctan\left[\sqrt{b_1'/b_2'}\tan(\beta_1/2)\right] = 65.77^{o}$$

where b', b_1', b_2' were defined in [3].
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 (2.1) and table 1[2], we can find the locations and dimensions of the feed arms.

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

Right			**Left**		
X_1	Y_1	Z_1	X_2	Y_2	Z_2
0	0	-37.5	0	0	-37.5
43.3	25	-15	43.3	-25	-15
43.3	25	18	43.3	-25	18

Table 2.1 Upper feed arms corner locations in cm

Now let us find how much the field increases at the second focal point with four 60^{0} TEM feed arms. Farr introduced the voltage normalized gain as [6],[7].

$$G_v = \frac{h_a}{f_g} \qquad (2.2)$$

and this can be used for comparison to the radiation from two different antennas that have the same input power. Here h_a is the aperture height and $f_g = Z_c / Z_0$ is the impedance factor which relates transmission-line to free space impedance.From table 1 of [2] we can easily define

$$G_{v_1} = \frac{.736}{200/377} = 1.387\ ,\ G_{v_2} = \frac{.648}{200/377} = 1.221 \qquad (2.3)$$

G_{v_1} and G_{v_2} are the voltage gain for four 60^o and 45^o (times .707 for two arm, $400\,\Omega$, case by symmetry) TEM-feed-arms case. If we divide G_{v_1} by G_{v_2} we will have how much increase we have in field if we use 60^0 instead of 45^0. So we have

$$G_{v_1} / G_{v_2} = 1.135 \tag{2.5}$$

We know that we will have $\sqrt{2}$ increase in fields if we have a four 45^0 TEM feed arms instead of 2 arm case, by symmetry. So we should have [1]

$$\left[G_{v_1} / G_{v_2}\right] \sqrt{2} = 1.606 \tag{2.6}$$

increase in fields using the 60^0 TEM-feed-arm case as compared with the 2 arm case.

For 45^o 4-TEM feed arms case the feed arm geometry is the same but it is just tilted 45^o from the y-axis [8]. In our design we used the 60^o case because the voltage gain maximize for 60^o (Table 1 of [2].)

3.2 45^o 4-TEM feed arms case

The analytic result is [4]

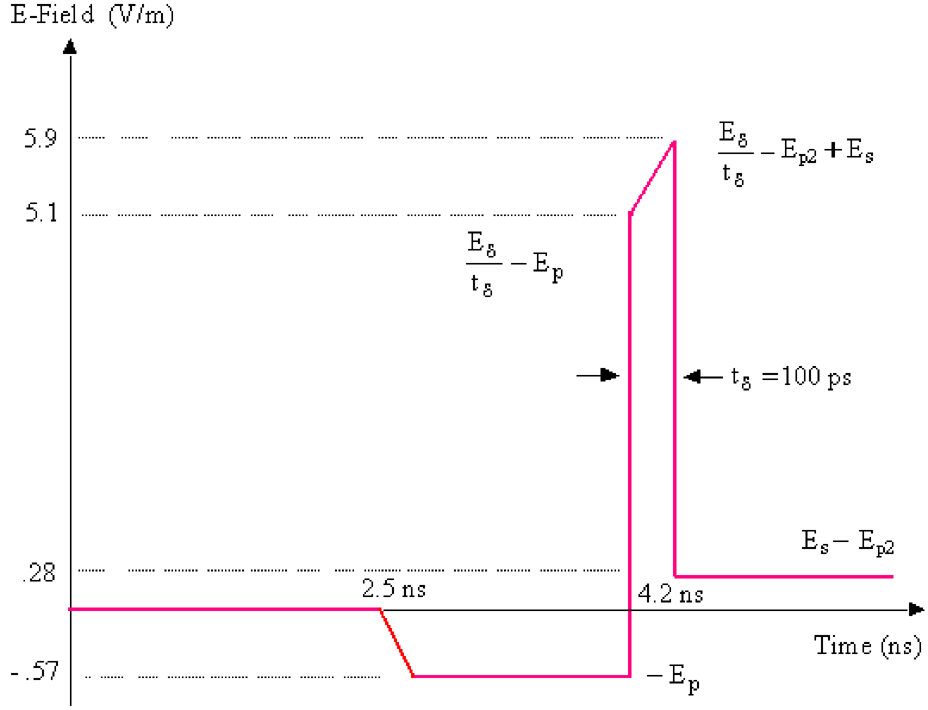

Figure 3.3 Analytic Waveform at the Second Focus for 45^o 4-TEM Feed Arms

The numerical Result is

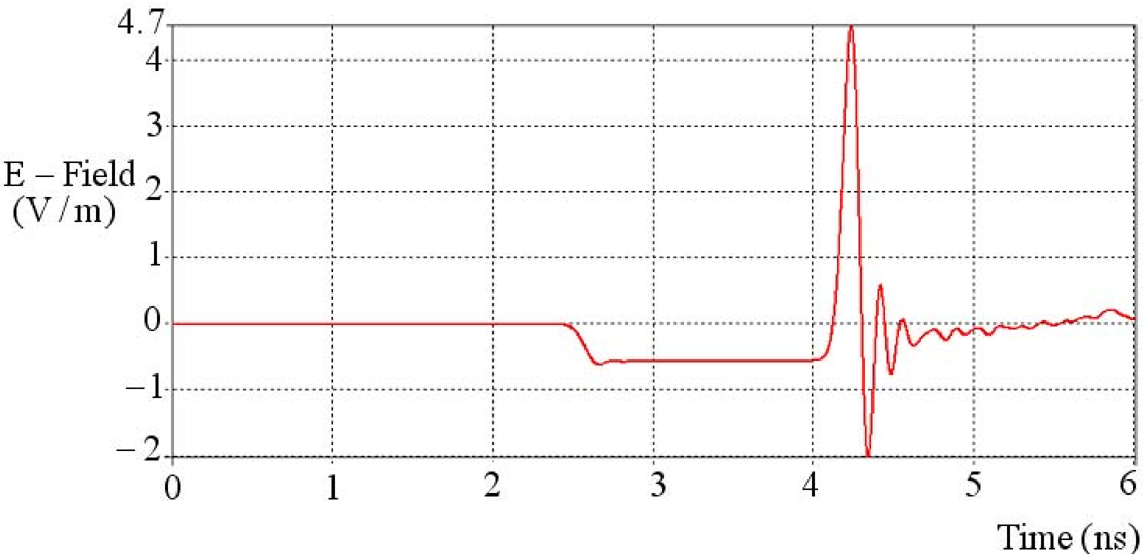

Figure 3.4 Numerical Waveform at the Second Focus 45^o 4-TEM Feed Arms

3 Focal Waveform

3.2 60° 4-TEM feed arms case

The analytic result is [4]

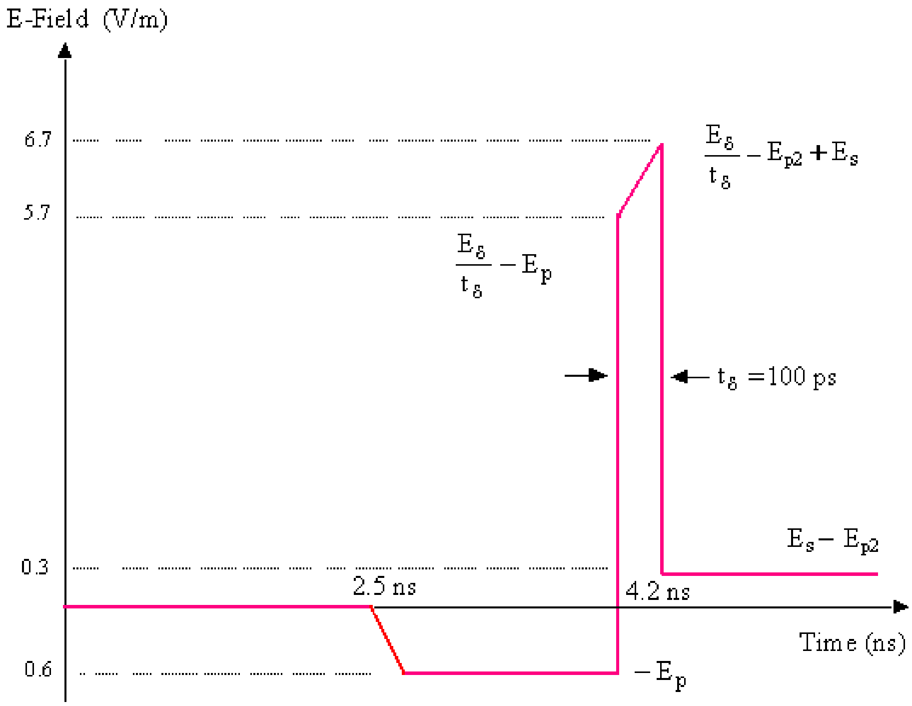

Figure 3.1 Analytic Waveform at the Second Focus

The numerical Result is

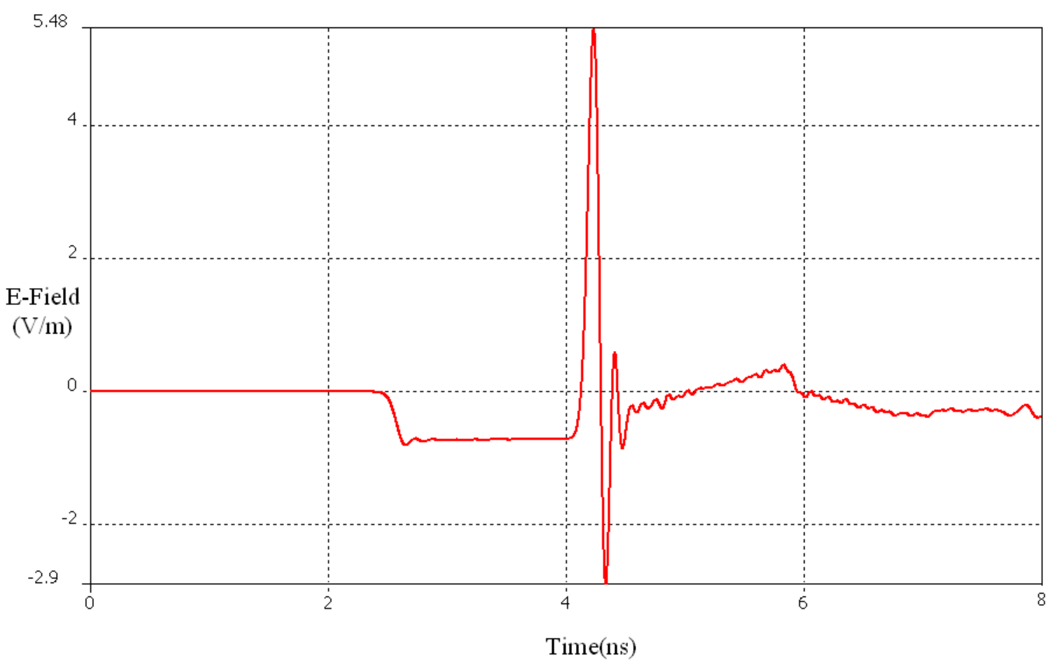

Figure 3.2 Numerical Waveform at the Second Focus

4.Conclusion and Errors

For the 2-arm and 4-arm-45^0 cases the prepulse of –0.4 agrees very closely between the analytical and numerical cases. For the 4-arm-60^o case the analytic prepulse is -0.6 while the numerical case is -0.7 (some error). The impulse part shows less agreement, between analytical and numerical, approaching the analytical value from below, likely due to the high-frequencies required. Analytical errors can be classified into two groups. First of all, analytical calculation does not account for feed arm width, and it is a little different from [4]. Secondly, when calculating the aperture integrals we have used the uniform-field part all the way to $\Psi = \Psi_p$ but the feed arms intersect partly into S_a for $\Psi < \Psi_p$. So the aperture integrals are correct up to $\Psi < \Psi_p$. Note that 60^0 arms are much wider than 45^0 arms for the same 200Ω impedance.The analytical waveform, while simple, is still good, but not perfect.

The numerical calculations also have errors. There are errors in the numerical technique(e.g., spatial dispersion). The prepulse is rather good. The impulse is trying to approach the analytical shape and value, but the postpulse has no relation to the physical case. Finally, there is also the plane-wave approximation on S_a for calculating G_v numerically. The wave is spherical, introducing some errors. G_v is calculated in [6] for a planar wave. It may be a little different for a spherical wave when accounting for the plate widths. This would require more detailed calculations.

References

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