

# **Analysis of Impulse-Radiating Antennas with Centered and Offset TEM Feed Structures**

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## **I. Introduction**

A variety of applications require an antenna that radiates ultra-wideband electromagnetic pulses. One candidate for such applications is the reflector-type impulse-radiating antenna (IRA), which consists of a parabolic reflector and a conical transverse electromagnetic (TEM) feed structure [1], [2].

Typically, the apex of the TEM feed structure is placed on the rotational axis of the circular paraboloidal reflector. In this center-fed geometry, the existence of the TEM feed structure causes aperture blockage [3]. The effects of the aperture blockage may be grouped into two categories. The first category is related to the reduction in the amplitude of the radiated impulse. The second category is concerned with the multiple reflections between the TEM feed structure and the reflector; this effect appears in the waveform following the impulse.

Conical coplanar plates are widely used for a TEM feed structure because they have no optical blockage. However, they still partially block the aperture because of the scattering from the TEM feed structure. To further reduce the blockage, an offset reflector may be used. In this geometry, the apex of the feed structure is still located at the focal point of the reflector, but the feed structure is placed off the path of the reflected waves, resulting in essentially no blockage.

In this paper, two IRAs are numerically modeled. They are a center-fed IRA with a circular parabolic reflector and a conical coplanar feed and an offset IRA with an offset parabolic reflector and a conical feed with curved plates. The numerical model has been developed using the method of moments as implemented in the electromagnetic interactions generalized (EIGER) code suite [4].

## **II. Models of the IRAs**

The geometries for the two IRAs are shown in Fig. 1. The reflectors are portions of a paraboloid with a focal length  $F/D = 0.5$ , resulting from the intersection of the

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paraboloid with a cone whose apex is located at the focal point of the paraboloid [5]. The axis of the cone lies in the  $x$ - $z$  plane, and it makes angles  $\beta = 0^\circ$  for the center-fed IRA and  $\beta = 82.9^\circ$  for the offset IRA with the  $z$ -axis.

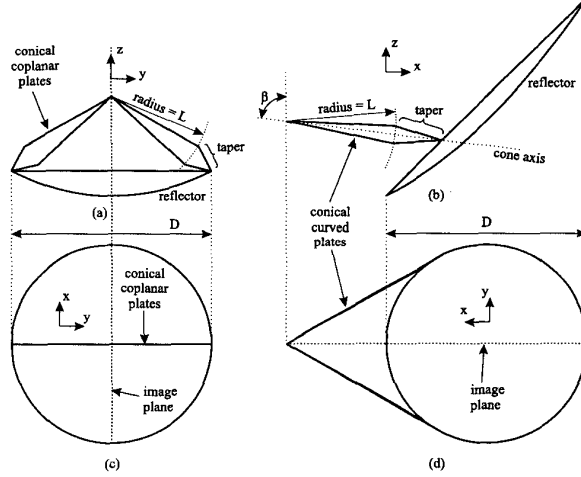


Fig. 1. Geometries of the IRAs. The diagrams in the left column are those for the center-fed IRA, the ones in the right column are those for the offset IRA. The three-dimensional geometries are projected onto (a)  $y$ - $z$  plane, (b)  $x$ - $z$  plane, and (c), (d)  $x$ - $y$  plane.

Each IRA is excited at the apex of the feed by a delta-gap voltage source. The angles associated with the feed arms are such that the characteristic impedance of the feed arms is  $400\Omega$ . The arms are linearly tapered and eventually connected to the reflector through  $200\Omega$  resistors, which are used as low frequency matching circuits. The distance  $L$  is chosen to be equal to the distance from the apex to the closest point on the reflector in an attempt to minimize the reflected voltage by allowing the first signal from the taper to cancel the first signal from the reflector [6].

The PEC symmetry in the geometry is utilized and only a half of the geometry is meshed. The edges of the arms are densely meshed because those are the places where the current density is high. The mesh for the center-fed IRA contains 9255 triangle elements and the mesh for the offset IRA contains 10516 triangle elements.

### III. Analysis

The frequency domain results are transformed into the time domain using a step-like pulse incident through a  $400\Omega$ -transmission line. The step-like pulse is defined as:

$$V(t) = \frac{V_0}{\tau_p} \int_{-\infty}^t e^{-\pi(\tau/\tau_p)^2} d\tau, \quad t_{10-90\%} \simeq 1.023\tau_p \quad (1)$$

where  $V_0$  is the amplitude of the pulse, and  $\tau_p$  is the pulse parameter. The pulse parameter is related to  $t_{10-90\%}$ , which is the 10% – 90% rise time of the step-like pulse.

In Fig. 2, the reflected voltage in the feed transmission line is shown for both antennas as a function of normalized time,  $t/\tau_a$ , where  $\tau_a = D/c$  is the time for light to travel the length of the aperture diameter  $D$ . The input pulse rise time is  $t_{10-90\%} = 0.1\tau_a$ . In the figures, small reflections are seen at around  $t = 0$ . This reflection is due to the approximation of the apex geometry in the numerical model.

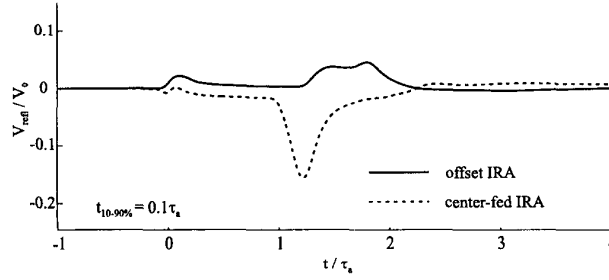


Fig. 2. Reflected voltage in the feed transmission line as a function of normalized time for  $t_{10-90\%} = 0.1\tau_a$ .

The later reflections ( $t/\tau_a > 1$  for the center-fed IRA and  $t/\tau_a > 1.25$  for the offset IRA) are due to the interactions of the TEM feed structure and the reflector. For the center-fed IRA, a negative signal from the reflector surface and a positive signal from the feed arm taper begins at  $t/\tau_a \simeq 1$ . A positively diffracted signal from the reflector edge begins at  $t/\tau_a \simeq 1.25$ . For the offset IRA, all three signals begin at  $t/\tau_a \simeq 1.25$ . The pulse near  $t/\tau_a \simeq 1.81$  is a signal from the reflector edge that is coupled to the feed arms. Note that the amplitude of the reflected voltage for the offset IRA is lower than that for the center-fed IRA. Recall that the arms in both IRAs are linearly tapered so that the reflected signal from the taper will approximately cancel the reflected signal from the reflector. The cancellation is seen to be more effective in the offset IRA than in the center-fed IRA.

In Fig. 3, the radiated electric field in the direction of maximum radiation is shown for both antennas as a function of normalized time,  $t/\tau_a$ , for a step-like pulse with  $t_{10-90\%} = 0.1\tau_a$ . The prepulse and the impulse are very similar for both antennas. The prepulse height of the center-fed IRA is slightly higher than that of the offset IRA due to the difference in the TEM feed structure and the observer angle with respect to the axis of the TEM feed structure. Note that the distortion of the prepulse near the impulse is due to the radiation from the feed arm taper.

The tail waveforms are very different. The tail waveform of the center-fed IRA is bigger and more complicated than that of the offset IRA. Unlike the center-fed IRA, in the offset IRA, there is negligible blockage in the aperture by the TEM feed structures. Thus, the multiple reflections between the feed structure and the reflector are small, and therefore

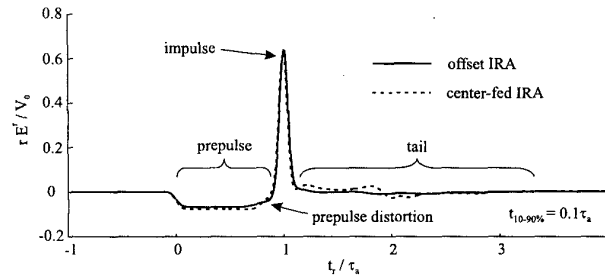


Fig. 3. Radiated electric field as a function of normalized time for  $t_{10-90\%} = 0.1\tau_a$ .

the tail waveform is small and simple.

#### IV. Conclusion

An offset IRA and a center-fed IRA have been numerically modeled and analyzed. The reflected voltages in the feed transmission line and the radiated electric field in the direction of maximum radiation have been graphed as functions of normalized time.

The amplitude of the reflected voltage was lower for the offset IRA than it was for the center-fed IRA. The tail waveform of the offset IRA was smaller and simpler for the offset IRA because the multiple reflections are smaller.

#### References

- [1] C. E. Baum and E. G. Farr, "Impulse radiating antennas," in *Ultra-Wideband, Short Pulse Electromagnetics*, H. Bertoni *et al.*, Eds. New York: Plenum, 1993, pp. 139-147.
- [2] E. G. Farr, C. E. Baum, and C. J. Buchenauer, "Impulse radiating antennas, part II," in *Ultra-Wideband, Short Pulse Electromagnetics 2*, L. Carin and L. B. Felsen, Eds. New York: Plenum, 1995, pp. 159-170.
- [3] Y. Rahmat-Samii and D. V. Giri, "Analysis of blockage effects on TEM-fed paraboloidal reflector antennas (Part II: TEM horn illumination)," C. E. Baum, Ed. Albuquerque, NM: USAFPhillips Lab, Nov. 1992, Sensor and Simulation Notes #349.
- [4] R. M. Sharpe, J. B. Grant, N. J. Champagne, W. A. Johnson, R. E. Jorgenson, D. R. Wilton, W. J. Brown, and J. W. Rockway, "EIGER: Electromagnetic interactions generalized," in *IEEE AP-S Int'l Symp. Digest, Quebec, Canada*, Jul. 1997, pp. 2366-2369.
- [5] V. Jamnejad-Dailami and Y. Rahmat-Samii, "Some important geometrical features of conic-section-generated offset reflector antennas," *IEEE Trans. Antennas Propagat.*, vol. AP-28, no. 6, pp. 952-957, Nov. 1980.
- [6] C. E. Baum, "Some topics concerning feed arms of reflector IRAs," C. E. Baum, Ed. Albuquerque, NM: USAFPhillips Lab, Oct. 31, 1997, Sensor and Simulation Notes #414.