OFF-BORESIGHT, SPATIO-TEMPORAL NEAR AND FAR FIELDS OF A REFLECTOR TYPE OF AN IMPULSE RADIATING ANTENNA

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ABSTRACT

In this paper, we are concerned with the electric fields on and off the boresight of a reflector type of an impulse-radiating antenna (IRA), both in the near and far filed regions. The IRA is a paraboloidal reflector fed by one or two pairs of conical transmission lines. It is a non-dispersive antenna since the reflector is fed by a spherical TEM wave. This is now a well established antenna system with significant contributions from many researchers. The near field on and off the boresight axis, is useful in some of the many applications of IRAs.

INTRODUCTION

A reflector type of an IRA under consideration is schematically shown in Fig. 1.

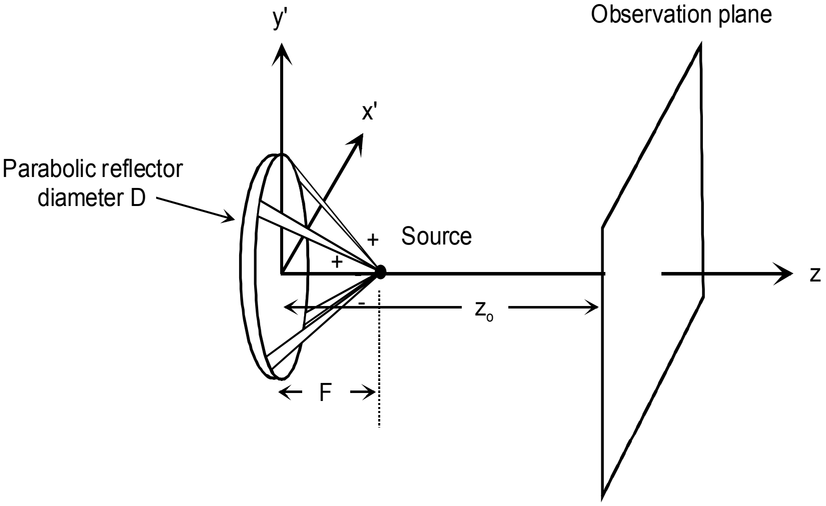


Fig. 1. Schematic diagram of a reflector type of IRA

IRAs have many potential applications in both military and civilian sectors. Some of these applications are listed below:

1) Detection and identification or aerospace objects , 2) buried object detection and identification (land mines and UXOs) 3) periscope detection, 4) wideband jammers, 5) wideband source for vulnerability studies via transfer function measurements , 6) electrical characterization of materials (wave propagation in materials such as rock, concrete etc), 7) industrial applications (e.g., detecting leaky or defective pipes underground), 8) law-enforcement applications (seeing visually obscured objects) etc.

In some of these applications, a precise knowledge of the near fields is useful and we have estimated the near and far fields of a nominal 1m IRA, both on and off the antenna axis. The analyses and measurements for this type of a radiating system have generally been in the far field. The far field being defined to start from a radial distance where the clear time of the antenna becomes small (say, a third) compared to the risetime of the transient pulse launched on the reflector. Two different approaches are available in the literature [1,2] for estimating the near and far fields on and off boresight of IRAs. Reference [1] takes the approach of imaging the conical transmission line feeding the reflector in the paraboloidal mirror. The image of the focal point in the reflector is located at infinity on the negative boresight axis. The original problem of a reflector fed by one transmission line is replaced by two transmission lines (or two V antennas), one of which has a vanishing expansion angle and compute fields, on and off the boresight axis, both near and far. The limitation of this approach is that it is valid only in a cylindrical volume in front of the reflector, the diameter of the cylinder being the diameter of the reflector. Baum [2] takes the approach of aperture integration. The aperture fields are approximated by the TEM fields of a cylindrical transmission line, which are then integrated over the aperture to have closed form expressions in the intermediate ranges. In this paper, we evaluate the fields for a canonical case IRA. The reflector diameter D = 0.9 m, F/D = 0.37, and an applied voltage of 9.5 kV rising in 100 ps, or a maximum rate of rise of 0.95 x 10^{14} V/s. Such a reflector and a pulse generator are commercially available and hence the canonical IRA system is practical and in fact been built at the TNO Laboratory, The Hague in Netherlands. For this example, the measurements are available only on boresight, which compare well with the estimated fields. Having validated the calculational models with the measured boresight fields, we proceed to estimate the off boresight fields using both approaches. The results are presented and physical implications are examined in this paper.

REALISTIC ANALYTICAL MODEL FOR THE PULSER

Transient pulse generators are typically specified with three numbers. They are: peak amplitude, the (10-90)% risetime and the FWHM. Such a characterization is inadequate in the context of an impulse radiating antenna, where the far field is proportional to the maximum rate of rise of the voltage waveform launched on the antenna. This voltage could be different from the voltage out of the pulser owing to the presence of other dielectric media at the feed point. It then becomes important to assess the maximum value of the voltage rate of rise. So, instead of the usual double exponential model, we have used the following analytical model. The pulser voltage, its derivative and the Fourier transform are given by:

$$V(t) = \begin{cases} V_o \; e^{-\frac{\beta t}{t_d}} \left[\left(\frac{1}{2}\right) erfc\left(\sqrt{\pi}\,|t|/t_d\right) \right] & t < 0 \\ V_0 \; e^{-\frac{\beta t}{t_d}} \left[1 - \left(\frac{1}{2}\right) erfc\left(\sqrt{\pi}\; t/t_d\right) \right] & t > 0 \end{cases} \tag{1}$$

$$\frac{dV(t)}{dt} = \frac{V_0}{t_d}\, e^{-\beta\left(\frac{t}{t_t}\right)} \; e^{-\pi\left(\frac{t}{t_d}\right)^2} - \frac{\beta}{t_d} V(t) \qquad ; \qquad \tilde{V}(\omega) = \frac{V_0\, t_d}{(\beta + j\omega t_d)}\, e^{\left[\frac{1}{4\pi}(\beta + j\omega t_d)^2\right]} \tag{2}$$

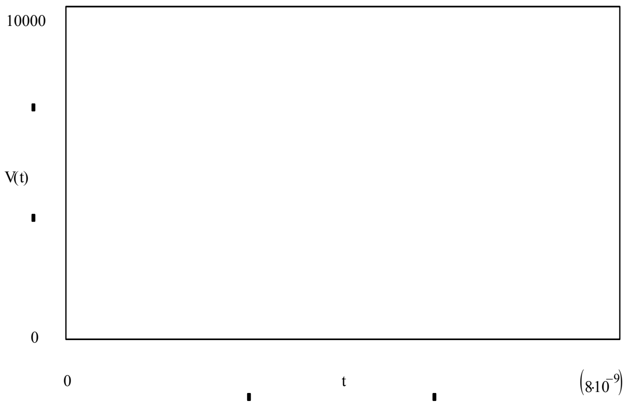


Fig. 2. The voltage waveform

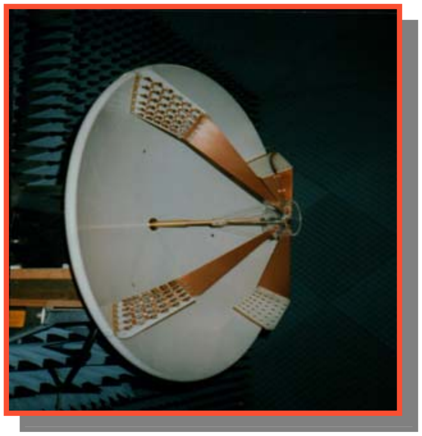


Fig. 3. TNO-IRA (0.9m dia. with F/D =0.375)

NEAR AND FARFIELDS ALONG THE TRANSVERSE AXIS [1]

The above described pulser voltage is applied to the TNO IRA which has a diameter D of 0.9m and a focal length of 0.3375m. This IRA is fed by a pair of conical transmission lines, as shown in Fig. 3. For an applied risetime of ~ 100ps, the far field for this antenna starts at about 8m, where the clear time becomes roughly a third of the risetime. Initially the boresight near and far fields are estimated based on the analysis in [1], and cross checked with available measurements [3]. We have also estimated the off-boresight, near field at 1m and far field at 10m, as plotted in Figs. 4 and 5. Note that in Figs. 3 and 4, x is the transverse coordinate, y is the axial and z is the vertical coordinate, to conform to the coordinate system in [1], and it is different from Fig.1.

Fig. 4. Near field along a transverse line at a distance of 1m.

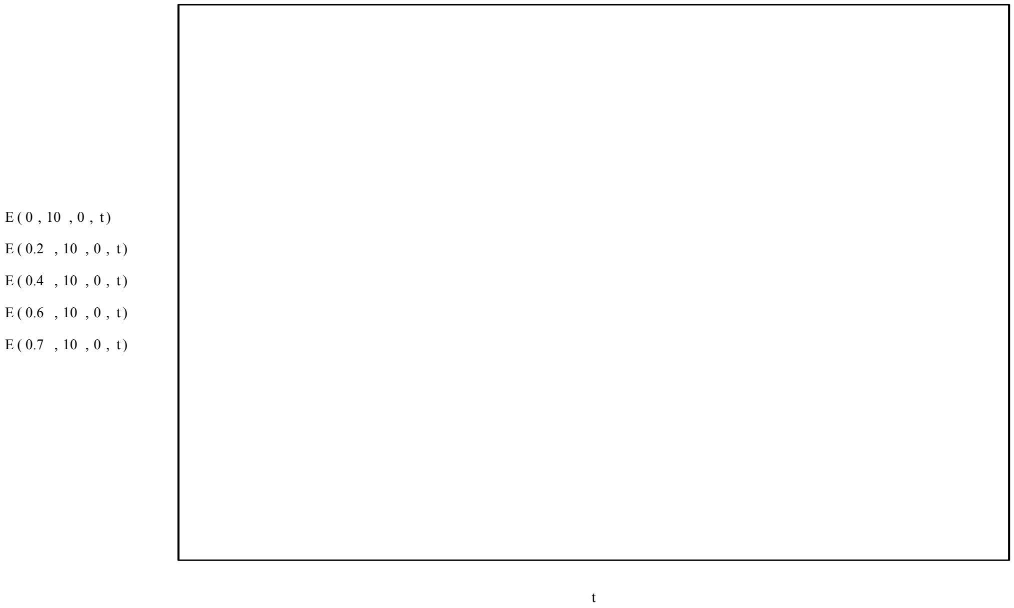


Fig. 5. Far field along a transverse line at a distance of 10m

NEAR AND FARFIELDS BASED ON APERTURE INTEGRATION

A severe restriction in the analysis presented in [1] is that it is valid only in a cylindrical volume in front of the reflector, with the diameter of this cylinder equal to the reflector diameter. One can go as far as one reflector radius from the boresight axis. A second approach [2, 4] is to use the aperture integration and a complete Greens function. These results are presented for a nominal 1m antenna, with a 10kV, 100ps pulse. The results are presented in Figs. 6 and 7 in time domain and at three spot frequencies. The rectangular coordinates (x, y, z) are defined in Fig.1.

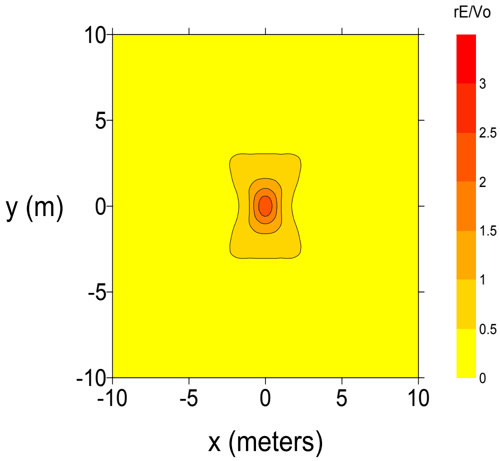


Fig. 6A. Contour plot of normalized filed

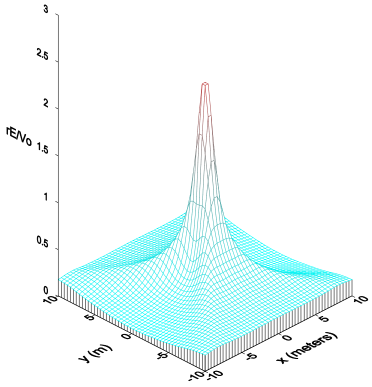
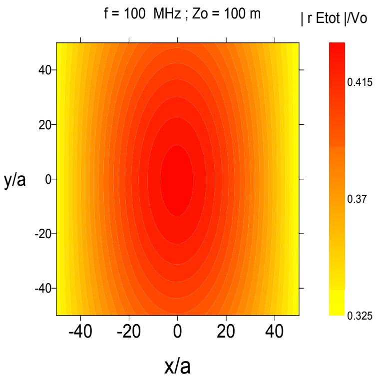
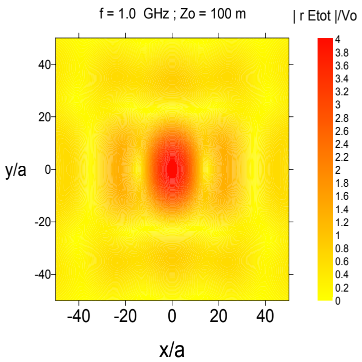


Fig. 6B. Surface plot of normalized field





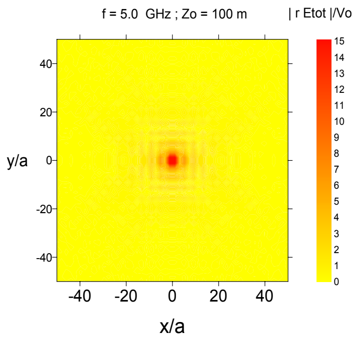


Fig. 7A. Frequency = 100 MHz

Fig. 7B. Frequency = 1 GHz

Fig. 7C. Frequency = 5 GHz

In presenting the off-boresight fields, all three components are calculated and the magnitude of the total field is used in the plots. It is observed in Fig. 7 that the main beam narrows as the frequency increases. In conclusion, it is noted that the near and far fields can be obtained very efficiently by integrating the aperture field distribution and can be plotted in time domain or at spot frequencies of interest. Such calculations can provide physical insights into the performance of such antennas and also help in the understanding of coupling of the radiated fields to chosen targets.

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