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Combining Multiple Prolate Spheroidal Reflectors as a Timed Array With a Common Near-Field Focus

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Abstract

Continuing from a previous paper, the present paper considers an array of such antennas all focused at a common target position. Each antenna, as before, uses a prolate-spheroidal reflector. Now, an array of such antennas introduces the problem of switch spread, since we need the pulses from nearly all the antennas to arrive at the target location at essentially the same time.

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1. Introduction

A recent paper [5] discusses a technique for producing fast-transient, very large electromagnetic fields in a small region of space. This is accomplished by a reflector comprised of a sector of a prolate spheroid. This, having two focii at $\pm z_0$, has the feed arms (as in a reflector impulse-radiating antenna (IRA)) emanating from the first focus and concentrating a focused field at the second focus. This type of IRA, which focuses in the near field, (instead of at infinity), might be called an "implosion" IRA. The reader should have a copy of [5] at hand while reading the present paper for a fuller description.

An alternate approach to focusing a transient wave is with a timed array. One can take a set of N reflector IRAs (of the usual type), point them each at the same target, and trigger them so that the N pulses all arrive at the target at the same time. This has technological problems concerning the timing accuracy with which one can trigger all N IRAs. The timing error needs to be small compared to all times of interest in the waveform from a single IRA at the target.

These two approaches are not incompatible. One can have an array of N "implosion" IRAs (IIRAs, pronounced (aye)(ee)ras) to further increase the field at the target.

2. Timed Array

Let us then consider an IIRA array as illustrated in Fig. 2.1. In this hexagonal example we have 7 IIRAs, number zero in the center, and numbers 1 through 6 in a hexagonal pattern around this. While the feed arms are indicated at $\phi_0 = 45^\circ$ with respect to a horizontal plane [3], other choices such as the recently popular $\phi_0 = 60^\circ$ are possible. Of course, antennas 1 through 6 are canted inward so that all add at the target focus (say $\vec{r}_0 = z_0 \vec{1}_z$) with each polarization parallel to the *yz* plane Note that the source region, discussed in [5], is not depicted here.

Considering the symmetries of such an array, the *xz* and *yz* planes are symmetry planes ($R_x \otimes R_y$ symmetry). The diagram is suggestive of C_{6a} symmetry (6-fold rotation axis with 6 axial symmetry planes) but not exactly. If we choose $\phi_0 = 60^\circ$ and place two more (dummy feed arms on the locally horizontal plane ($\phi_0 = 0^\circ$, 180°) this would complete this type of symmetry. One can consult [8] for discussion of such rotation symmetry in the context of a different kind of high-power source.

The inward canting of the individual antennas is illustrated in Fig. 2.2 which gives a cross section on the *yz* plane. Note that all the IIRAs need not have the same focal distances, as long as they all have the same target focus $\vec{r}_0$. While the feed arms here are shown as "inside" S'_p (the reflector), this need not be the case. There is some optimization to be done in this regard.

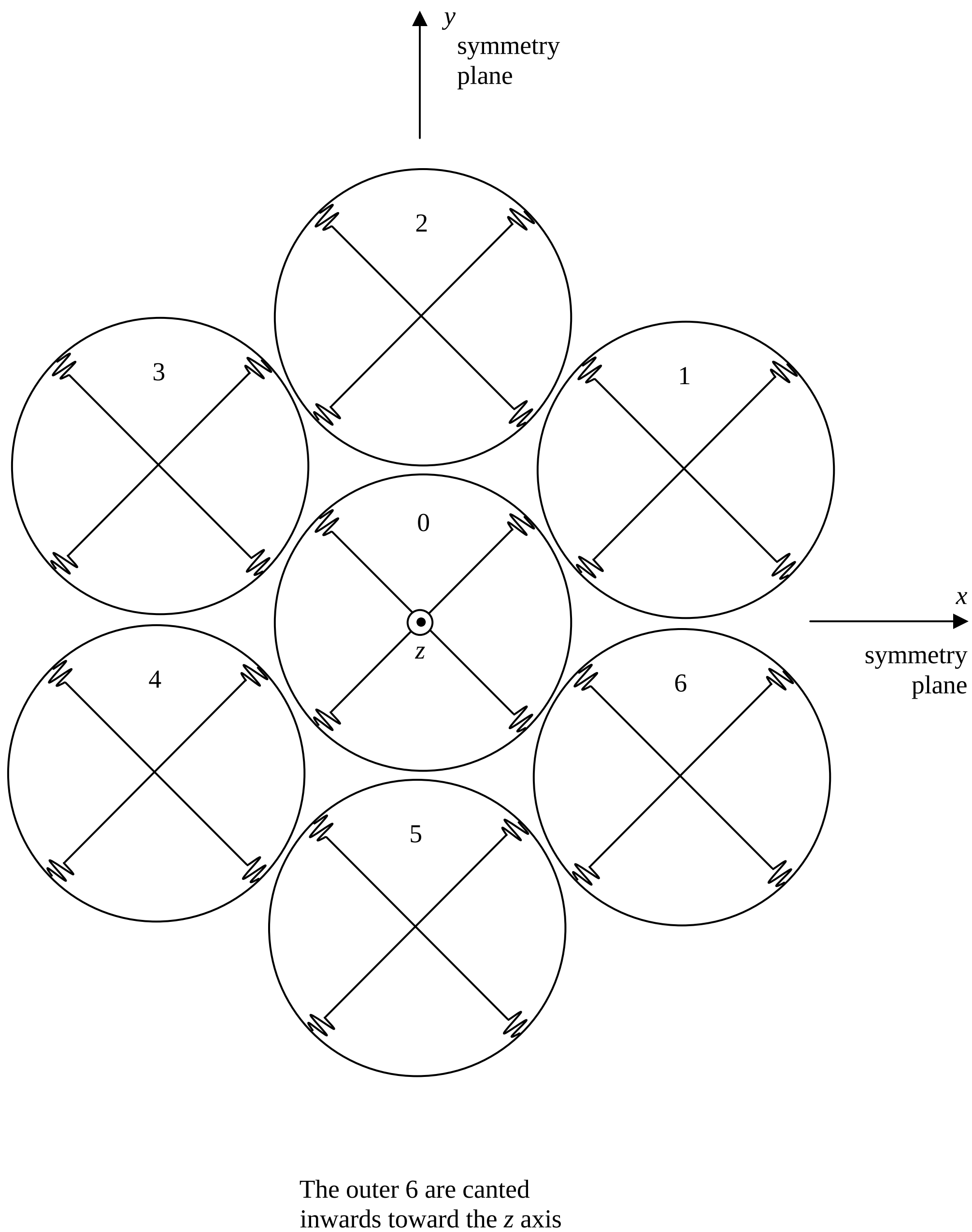

Fig. 2.1 IIRA Array, Front View

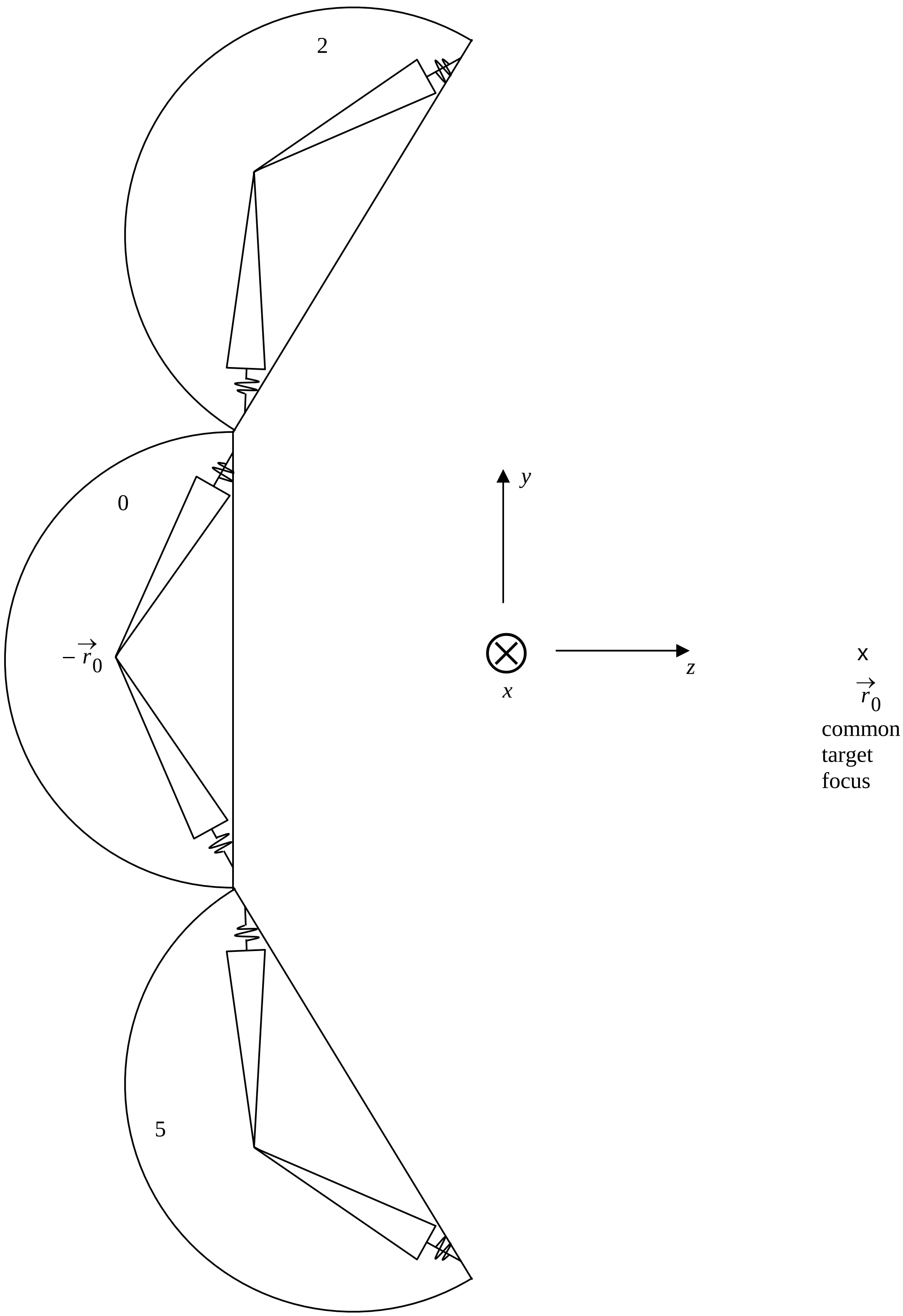

Fig. 2.2 Cross-Section View of Array

3. Timing Accuracy

Timing the launches of the N waves, later converging on $\vec{r}_0$, is critical. The key concept is *switch spread* [6]. By this we mean a time window of width t_s, centered (roughly) on t_0, during which some very large fraction (say 90%) of the pulses begin. This is several times the *jitter* (a standard deviation), depending on the actual distribution function of beginning times of the pulses.

For fast-rising, step-like pulses launched into the reflector, the focusing near $\vec{r}_0$ has a time-derivative, giving a narrow pulse with width given by the risetime (t_{mr}) of the original pulse [1]. The amplitude is inversely proportional to t_{mr}. If we have N waves arriving at $\vec{r}_0$, we need all N waves to arrive at the "same" time, i.e., within a spread which is small compared to t_{mr} (in the 100 ps range [2]), if we want the individual field amplitudes to add for maximum field in a short pulse.

There is some information regarding switch spread in the 100s of kV range [4, 7], for a timed-array application (of TEM horns in this case). One might achieve a smaller spread at lower voltages with solid-state technology, but smaller voltages give smaller fields on target. Achieving a sufficiently small spread for the antenna triggering is a significant technological challenge.

4. Concluding Remarks

Extending our consideration of an array of IIRAs, we can potentially greatly increase the amplitude of a fast pulse incident on a small target in the near field. This however, is accompanied by significant technological problems, specifically switch spread.

References

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