Analyzing Impulse Radiating Antenna Performance Using Space-Time Beam Summation

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Impulse radiating antennas (IRAs) are a class of focused aperture antennas that are known to generate and radiate extremely wide bandwidth pulses [C.E. Baum, *et al.*, "Review of Impulse-Radiating Antennas," *Review of Radio Science*, W. R. Stone, Ed., Oxford U. Press:New York, pp. 403–439, 1999]. IRAs operate by using a conical TEM transmission line to launch a spherical wave into a focusing optic, usually a reflector or a lens. The focusing optic converts the spherical wave into a plane wave in the near field, and aperture theory can be used to compute the radiated far-field in the time or frequency domains. For the clear time of the antenna, which is the time that it takes for diffraction effects to be seen by the observer, the time domain physical optics is *exact*, and this very simple theory can produce extremely accurate predictions of the radiated fields for the early time, especially on boresight. Recent adaptation to the theory have extended excellent results to off-boresight angles and allowed the consideration of non-ideal IRAs, e. g. IRAs that are slightly defocused.

The time domain aperture theory does an excellent job of predicting the early time radiation into free space, but there are limitations to the theory. The most important limitation is that the antenna cannot be located close to other objects. In applications such as ground penetrating radar (GPR) and through-wall sensing, there are objects that are in the near field of the IRA for some frequencies, and hence will perturb the theory. Furthermore, the physical optics theory fails to properly consider the effect of aperture blockage by the feed arms, which leads to a reduction in the early time effective height and corrupts the late time fields.

Shlivinski, *et al.*, have recently developed a space-time beam summation formulation for analyzing ultra wideband (UWB) radiation from apertures [A. Shlivinski, *et al.*, "A phase-space beam summation formulation for ultrawide-band radiation," *IEEE Trans. Antennas Propagat.* **52**:2042 – 2056 (2004)]. Their theory improves upon physical optics by using expansion functions that are localized in space and time. This spatiotemporal localization makes the beam summation method ideally suited to computing the interaction of the IRA with objects in the near field, including scattering and diffraction effects from the feed arms.

In this paper, we adapt the methods of Shlivinski, *et al.*, to the specific case of radiation from an IRA, and we compare the performance of the new methods to the existing physical optics theory and experiments. We then consider the application of the beam summation formalism to the study of an IRA in a complicated environment.