Antenna Impulse Response and the Generalized Antenna Scattering Matrix

Everett G. Farr
Farr Fields, LC, Albuquerque, NM, 87123, http://www.farr-research.com

We address here the problem of characterizing antenna performance in the time domain as simply as possible. Currently, no standard terms have been defined, and this can be a problem for buyers and sellers of wideband antennas. This problem becomes apparent if one imagines attempting to describe antennas in the frequency domain without a widely accepted definition of gain. In this work, we recast the time domain antenna equations into a simple form. This allows us to very naturally extend into the time domain a collection of commonly used antenna terms, including gain, realized gain, antenna factor, radar cross section, and scattering cross section.

An earlier attempt at this (E. G. Farr, A Standard for Characterizing Antenna Performance in the Time Domain (With Corrections)," Sensor and Simulation Note 555, September 2011.) was limited to the case of an antenna situated in free space, with a 50-ohm load. Here, we extend that theory to a number of new cases. The new theory applies to antennas of all load impedances and feed types, including waveguide feeds, and it applies to antennas embedded in any medium.

The approach is analogous to the use of generalized scattering parameters to describe circuits. In that theory, one establishes relationships between incident and scattered "power waves" at each port, each of which is associated with a port impedance. We extend that concept by describing the incident plane-wave field as a "power flux density wave," and the radiated far field as a "radiation intensity wave." We identify receiving and transmitting impulse responses, and prove that the two are always related by a simple rule. We suggest that the receiving impulse response be designated as the "impulse response" of an antenna, because it has a simpler form, and because specifying the transmitting impulse response adds no new information. We show how the impulse response is related to gain, realized gain, and antenna factor.

We also identify a scattering impulse response that can be applied to either an antenna or an arbitrary scatterer. We show how this is related to radar cross section and scattering cross section. From these various quantities we build a Generalized Antenna Scattering Matrix (GASM), which provides a formalism that allows one to calculate antenna response under a variety of situations, including mismatched source and/or load impedances.

The ultimate goal of this work is to get a number of terms entered into the antenna definitions standard (*IEEE Standard Definition of Terms for Antennas*, IEEE Std. 145-1993, 1993), in order to more completely characterize antenna performance.