Forum for Electromagnetic Research Methods and Application Technologies (FERMAT)

Comments on the paper "A Power Wave Theory of Antennas." By Everett G. Farr; Published in FERMAT (www.e-fermat.org) / Articles / 2015 Vol7.

Keywords: Antenna Characterization, Frequency Domain, Time Domain, Antenna Impulse Response, Scattering Impulse Response, Generalized Antenna Scattering Matrix (GASM), Antenna Equation.

Author Response:

Here I begin responding to comments on my recent paper [1]. I address here Comment #2 [2], which was written anonymously.

1. I do not find anything new or exciting.

There are two major advances made here. First, there are currently no terms in the antenna definitions standard [3] that describe antenna performance in the time domain. Imagine that you worked your entire career without a widely accepted definition of antenna gain. Communication would be clumsy, to say the least. That is precisely the situation in which UWB antenna engineers find themselves, since many interesting antenna features are seen only in the time domain. This paper resolves the issue.

Second, even in the frequency domain, the description of antennas in the antenna definitions standard [3] is incomplete. Antenna gain is magnitude only – it has no phase. However, my antenna transfer function includes both magnitude and phase. Similarly, RCS has no phase information, but my scattering coefficient includes both magnitude and phase.

While antennas are commonly characterized by their phase, no standard definition can be found in the antenna definitions standard [3]. I leave it to others to speculate why that is the case, but my formulation resolves the issue.

2. You just made some well-established concepts complicated.

I presume that the commenter is referring to eqn. (3.1), where I define the various forms of power waves.

$$
\begin{aligned}
\tilde{a}_1 &= \tilde{\Pi}_{src} = \frac{\tilde{V}_{src}}{\sqrt{Z_{o1}}} &&= \text{source power wave} \\
\tilde{b}_1 &= \tilde{\Pi}_{rec} = \frac{\tilde{V}_{rec}}{\sqrt{Z_{o1}}} &&= \text{received power wave} \\
\tilde{a}_2 &= \tilde{\Sigma}_{inc} = \frac{\tilde{E}_{inc}}{\sqrt{Z_{o2}}} &&= \text{incident power flux density wave} \\
\tilde{b}_2 &= \tilde{Y}_{rad} = \frac{r\,\tilde{E}_{rad}}{\sqrt{Z_{o2}}} e^{\gamma r} &&= \text{radiated radiation intensity wave}
\end{aligned}
\quad . \tag{3.1}
$$

Using these parameters the antenna response can be expressed in a remarkably elegant form, which I refer to as the antenna equation. From eqn (6.1) we have

$$
\begin{aligned}
\begin{bmatrix} \tilde{b}_1 \\ \tilde{b}_2 \end{bmatrix} &= \begin{bmatrix} \tilde{S}_{11} & \tilde{S}_{12} \\ \tilde{S}_{21} & \tilde{S}_{22} \end{bmatrix} \begin{bmatrix} \tilde{a}_1 \\ \tilde{a}_2 \end{bmatrix} \\
\begin{bmatrix} \tilde{\Pi}_{rec} \\ \tilde{Y}_{rad} \end{bmatrix} &= \begin{bmatrix} \tilde{\Gamma} & \tilde{h} \\ s\,\tilde{h}/(2\pi v) & \tilde{\ell} \end{bmatrix} \begin{bmatrix} \tilde{\Pi}_{src} \\ \tilde{\Sigma}_{inc} \end{bmatrix}
\end{aligned}
\quad . \tag{6.1}
$$

The matrix in this equation, the Generalized Antenna Scattering Matrix, is a simple and complete description of antenna response, including both magnitude and phase. (Obviously, this treats only boresight performance and dominant polarization, but this can be extended to the general case as shown in my paper.) Of particular interest is the simple relationship between the antenna's receive and transmit characteristics (the off-diagonal elements). In my paper I refer to 18 papers (references [2-19] in [1]) that previously treated this problem – none found such a simple form.

The antenna definitions standard [3] defines almost all terms with words only. It seems to be an unwritten rule that equations are strongly discouraged. At first, this might seem to be an arbitrary constraint, but it has the positive effect of forcing us to use the simplest possible expressions.

Based on eqns. (3.1) and (6.1), we can draft the following definitions for antenna transfer function, $\tilde{h}$, and antenna impulse response, $h(t)$.

Antenna transfer function – In reception, the ratio of the received power wave to the incident power flux density wave. Alternatively, in transmission, the ratio of the radiated radiation intensity wave to the derivative of the source power wave, multiplied by $2\pi v$, where v is the velocity of propagation in the surrounding medium.

Antenna impulse response – The inverse Laplace transform of the antenna transfer function.

To be complete, we will have to extend the above to include polarization information, as is done with gain, but that is straightforward.

One alternative to using these power wave definitions would be to cast eqn. (2.11) into words,

$$
\begin{aligned}
\frac{\widetilde{E}_{rad}}{\sqrt{Z_{o2}}} &= \frac{s}{2\pi v} \frac{e^{-\gamma r}}{r} \widetilde{h} \frac{\widetilde{V}_{src}}{\sqrt{Z_{o1}}} \\
\frac{\widetilde{V}_{rec}}{\sqrt{Z_{o1}}} &= \widetilde{h} \frac{\widetilde{E}_{inc}}{\sqrt{Z_{o2}}}
\end{aligned}
. \tag{2.11}
$$

I challenge you to put the above two equations into words. I actually tried it – the result wasn't pretty. Other formulations in [1, refs. [2-19]] are no better.

3. It is suggested that you work out the following simple example to enhance the educational value of the paper. As you know, any practical antenna system has a matching network and/or balun between the antenna proper and its load, like the Impulse Radiating Antenna (IRA).To indicate the effect this has on the received voltage at a load, take IRA and work out the problem and show how much this matching network reduces the received load voltage, or the ratio of the load voltage to the Voc at the antenna

The only examples I can think of similar to this are either too simple to be useful, or more complicated than I prefer. Instead, I direct your attention to Comment 1, which requested two examples. I'll have those examples posted very soon.

References

1. Everett G. Farr, "A Power Wave Theory of Antennas," Published in FERMAT (www.e-fermat.org) / Articles / 2015 Vol7.

2. Comments on the paper "A Power Wave Theory of Antennas." By Everett G. Farr; Published in FERMAT (www.e-fermat.org) / Articles / 2015 Vol7. Com-Farr-2015-Vol7-Jan_Feb-002 A Power Wave Theory of Antennas.

3. IEEE, *IEEE Standard for Definitions of Terms for Antennas*, IEEE Std. 145-2013, Institute for Electrical and Electronics Engineering, Inc., New York, December 2013.