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On the Accuracy of Finite-Order Reaction Models for the Analysis of Array Antennas

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Extended Abstract

Typical figures of merit for array antennas are the far-field characteristics and the element coupling (near-field region of the aperture). Regarding the latter, the main issue is to evaluate the quantity commonly referred to as reaction [1]

$$\langle i,j\rangle = \iiint_V dV\,(\mathbf{E}_i(\mathbf{r})\cdot\mathbf{J}_j(\mathbf{r}) - \mathbf{H}_i(\mathbf{r})\cdot\mathbf{M}_j(\mathbf{r})), \tag{1}$$

where $\mathbf{E}_i, \mathbf{H}_i$ are the fields generated by radiator i (transmitting element) and $\mathbf{J}_j, \mathbf{M}_j$ are the sources that excite radiator j (receiving element), for all element pairs (i, j). For an exact evaluation of the reaction, the field quantities in eq. (1) have to be examined under consideration of scattering effects due to adjacent radiators and other significant scatterers like, e.g., an array-supporting structure. Once the reaction for each pair has been calculated, important quantities, such as the active reflection coefficient [2], may be derived accurately. As the complexity of the problem (number of elements, bandwidth, structure detail) is increased, the numerical effort to evaluate eq. (1) becomes large. Approximations that yield an accuracy which is adequate within the typical range of measurement uncertainties are therefore of great interest. For array antennas with a single type of radiator, methods that are based on a truncated eigencurrent expansion [3, 4] are generally suited, provided that a sufficiently large number of eigencurrents is considered. However, this may be difficult to achieve for complex, broadband antenna elements. Alternatively, an approximation of eq. (1) can be achieved by assuming a reaction of finite order, e.g., by considering equivalent currents obtained by a near-field sampling of an isolated antenna element excited at its port [5]. The result can be interpreted as a first-order approximation of the reaction term, since current modifications of higher order due to scattering are neglected. The quality of such an approximation will hence depend on the scattering characteristics of the considered antenna element. It is therefore of interest for which array configurations the method leads to an acceptable error.

In this contribution, the accuracy of a first-order reaction model will be investigated for two arrays with similar characteristics (far-field, self-coupling), but different types of antenna elements. The first array consists of 49 reflector-backed bowtie elements. The second array consists of 49 cavity-backed stacked patch antennas. Both elements provide a fractional bandwidth of $B_{\mathrm{rel}} \approx 20\%$ with a center frequency of $f = 10$ GHz. The validity of a finite-order approximation is discussed for the two arrays under consideration of typical uncertainties in scattering parameter measurements.

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