EMBEDDED ELEMENT PATERNS IN RECEIVING ARRAY ANALYSIS

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The traditional approach to antenna design is the array factor (AF) method. This method separates the effects of the array topology from the element radiation pattern; the overall radiation pattern is then the product of the array factor and element pattern. This is still the default method taught in most courses on antenna engineering, and it is encountered ubiquitously in antenna textbooks. However, this approach neglects mutual coupling, and the limitations of AF method have long been recognised for high performance applications. For the high-sensitivity receiving arrays being designed for contemporary radio telescopes, this is highly relevant.

The key to fully characterising the electromagnetic performance of an array is the set of embedded element patterns (EEPs). The theory underlying this has been developed in the literature, but until recently, a comprehensive synthesis of this was not available. A recent book provides the first textbook describing this approach in detail [1]. An embedded element pattern is the radiation pattern of an element of the array, with all the other elements terminated in a convenient impedance. Open-circuit termination is particularly useful in the theoretical development [1], but short-circuit termination is easier to apply in a typical MoM code. Transformations from one termination to another may be applied using the array mutual coupling matrix.

A result for a uniform linear array is shown in Figure 1.The array consists of 6 thin dipoles, of length 0.5 λ, radius 0.001 λ and spacing 0.4 λ. The figure shows the EEPS for element three (i.e. one of the two central elements). All of the results are computed from a thin-wire MoM formulation based on the Pocklington integral equation [2], and implemented by the author. The MoM code yields the short-circuited (SC) loaded EEPs; the figure shows the results for the transformation to open-circuited and 50 Ω loading, as well as results computed using an extension of the MoM code to permit loading to be applied directly at ports. There are five plots; two pairs lie on top of each other, demonstrating excellent agreement. E_{SC} is the short circuit loaded EEP, computed directly from the MoM code; E_{OC} is the open-circuit loaded EEP, computed from the SC EEPs; and E_{Yg} is the EEP with a finite load (50 Ω here), computed from the OC EEPs. The other two patterns ($E_{OC,load}$ and $E_{Yg,load}$) are the EEPS computed from the MoM simulation with 50 Ω loads at each port added, with an appropriate transformation for the OC case.

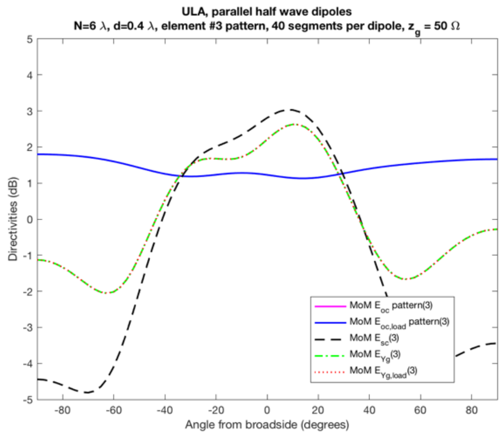

Figure 1: Comparison of EEPs for a 6 element array.

Given the EEPs, the array overlap matrix can be computed – this is a matrix representing the overlap of the far-field elemental patterns, integrated over angle. Importantly, this includes the phase difference due to relative positioning in the array. At the same time as the EEPs are computed for each element, the array mutual coupling matrix can be computed, one column at a time, from the MoM simulation. With this, it is then possible to fully characterise the radiation and reception properties of the array – on both transmit and receive.

This paper will discuss this, as well as a useful approximation, the Linear, Resonant, Minimum Scattering Approximation, which provides an intermediate step between the AF approach and a full EM simulation.

[1] K. F. Warnick, R. Maaskant, M. Ivashina, D. B. Davidson, and B. Jeffs, *Phased Arrays for Radio Astronomy, Remote Sensing, and Satellite Communications*. Cambridge, UK: Cambridge University Press, 2018.

[2] D.B. Davidson, *Computational Electromagnetics for RF and Microwave Engineering*. Cambridge, UK: Cambridge University Press, 2nd ed., 2011.