Beamforming with radiation modes of finite ground planes excited by heterogeneous arrays

K. R. Schab* and J. T. Bernhard
Electromagnetics Laboratory, University of Illinois at Urbana-Champaign, Urbana, IL USA

Antennas mounted in mobile devices are often electrically small and their performance is highly dependent on the finite ground plane or conducting chassis to which they are mounted. In such systems, many intuitions have been developed regarding the relative roles of the antenna element and finite ground plane in radiation and impedance matching. Specifically, the ground structure is commonly responsible for the radiation properties of the system, not the driven antenna element. Attempts to leverage this behavior is traditionally heuristically-driven, though recent research into source-based and modal analyses of antennas has offered more quantitative insight into sources of radiation in these types of systems. One such modal method involves identifying the potential radiation mechanisms on an object by solving an eigenvalue problem associated with the real part of its discretized electric field integral equation impedance matrix. The resulting eigenmodes are known as radiation modes and offer a convenient method of isolating radiating and non-radiating components of arbitrary current distributions.

In this presentation we propose a technique for beamforming using heterogeneous antennas mounted to a finite ground plane. The total size of the system is neither electrically small nor electrically large, reflecting the range of sizes typically encountered in mobile devices (mobile phones, tablets, laptops, etc...). The design technique focuses not on traditional beamforming methods, but rather the phased excitations of ground plane radiation mechanisms identified through radiation mode analysis. The relative invariance of radiation modes with respect to small geometry perturbations is leveraged to use radiation mode analysis of the ground plane to inform the design of multiple driven antenna elements in a non-iterative manner. Simulated examples of the design procedure are presented to demonstrate the process, its potential applications, as well as its limitations. Comparison of this technique to similar strategies using characteristic modes is also briefly discussed, with mention of how hybrid radiation / characteristic mode methods could utilize advantages offered by both methodologies.