Direction of Arrival Estimation of Electromagnetic Signals with an Electrically Small Antenna Array

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Direction of arrival (DOA) estimation of incoming electromagnetic signals can play a critical role in covert surveillance and sensing applications. Traditionally, DOA antenna arrays measured several wavelengths across. This size was required to attain reliable phase information. For our application at 300 MHz, an array would need to be approximately 5 meters across. However, by combining directional antennas and an algorithm which relies on amplitude information rather than phase information, a much smaller array becomes feasible.

For this design we chose two loop antennas aligned orthogonally, with a dipole in the center. All three elements are electrically small, about $\lambda/10$ in their maximum dimension. Baluns are used to convert the unbalanced coaxial lines to feed the balanced antennas. A folded-sleeve balun design was chosen, since it could be made smaller than a traditional sleeve balun (Icheln, Krogerus, and Vainikainen, Trans. on Inst. and Meas., 53, 498-505, April 2004). For this prototype array, the three elements measure a vertically polarized incoming wave.

Using this array, high-resolution direction finding is demonstrated using a frequency-domain algorithm that relies on antennas with diverse directional amplitude responses. Alone, each antenna element possesses an omnidirectional radiation pattern. When the antennas are spaced closely in the array, the individual element radiation patterns are no longer omnidirectional. Instead, the effects of mutual coupling are evident in all three element patterns. By considering parasitic effects in an array of electrically small antennas, additional directional features may be obtained and possibly exploited. A calibration procedure captures the parasitic effects of the closely spaced antennas, with the nulls of the ideal patterns being greatly muted when elements are closely spaced. After calibration at one degree intervals, the array achieves accuracy with resolution of three degrees, with no front to back ambiguities. Measured results at 300 MHz will be presented for an azimuthal DOA system with the entire array measuring less than 0.016 m^3.