COUPLING BETWEEN LOOP ANTENNAS

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An array of N thin, identical circular rings that are coaxial provides an analytically tractable model to study electromagnetic coupling effects in phased array antennas. The circular symmetry of the pertinent integrodifferential equation (Pocklington's equation for the loop) and the boundary conditions do not break the orthogonality of the azimuthal Fourier modes $\exp(in\phi)$. Therefore, physically realizable three-dimensional antenna elements can be characterized by a single complex number for each independent Fourier index n, without recourse to a 'single mode' approximation. Both plane wave (receive mode) and localized voltage sources (transmit mode) are considered.

Equivalent circuits are constructed from an electrostatic and magnetostatic analysis to model the low frequency coupling between a pair ($N = 2$) of rings and compared to the low frequency limit of the full electrodynamic equations-of-motion. Such lumped-circuit modeling of field problems requires the identification of self and mutual capacitance and inductance. Partial validation of the low frequency analysis applied to a single ring is obtained by comparison with appropriate limits of exact solutions to potential problems in toroidal coordinates.

At the other extreme, a large array ($N \gg 1$) offers another glimpse into the edge-effects in mutual coupling that have captivated antenna engineers for decades. Accurate calculations lead here to the usual observations of traveling wave behavior in the terminal currents and admittances for finite arrays. One goal is to better explain the physics of these effects, perhaps by exploiting a semi-infinite array approximation. The individual coupling terms involve Fourier coefficients of the thin-wire kernel, which are evaluated via a combination of numerics (FFT) and asymptotics.

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