Radiation modes and fundamental limitations on MIMO antennas

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MIMO (multiple input multiple output) antenna systems are ubiquitous in modern communication systems. Although the performance of a MIMO system is ultimately limited by the capacity (in bits per second) of the communication channel (Paulraj *et al.* 2003) it is more practical to consider the spectral efficiency (in bits per second per Hertz) to quantify optimality. To determine fundamental limitations on the transmitter or receiver antennas in a MIMO system it is necessary idealized the other antennas and the propagation channel. Here, we idealize the propagation channel together with the receiving antennas by letting the receiver perfectly receive radiated spherical modes (Gustafsson and Nordebo 2007). The transmitting antenna is modeled by its current distribution using a MoM (method-of-moments) approximation where each basis function corresponds to an element of the transmitter. This leads to a MIMO system of infinite dimension and therefore an unlimited capacity if the signal-to-noise ratio is scaled with the number elements (Paulraj *et al.* 2003).

Antenna current optimization can be used to determined physical bounds on the capacity for MIMO antennas of arbitrary shape (Ehrenborg and Gustafsson 2018a). The bounds are formulated as a semidefinite programming problem in the correlation matrix of the current density and show how capacity is limited by the size, shape, Q-factor, efficiency, and signal-to-noise ratio. The formulation in (Ehrenborg and Gustafsson 2018a) is computationally demanding for electrically large structures due to the quadratic growth of the number of unknowns in the correlation matrix. A Model order reduction based on modal expansion can be used to reduce the computational cost.

In this presentation, the simplified problems of maximal capacity for arbitrarily shaped objects limited by either the efficiency or Q-factor are considered. We show that these problems can be solved efficiently using mode expansions together with the water-filling algorithm (Paulraj *et al.* 2003). Radiation and stored energy modes are used for efficiency and Q-factor, respectively. In addition to simplifying the numerical solution, mode expansion provides physical understanding from the mode distributions as well as the number of used modes (Ehrenborg and Gustafsson 2018b). Numerical examples are used to illustrate the results for different shapes and electrical sizes ranging from electrically small to large.