Optimal Antenna Characteristics for MIMO Systems

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While a vast body of work exists on analyzing the performance of specific antenna configurations in a propagation channel for multiple-input multiple-output (MIMO) and antenna diversity systems, there has been little material published on the synthesis of optimal antennas for such systems. Designers therefore typically base their designs on the rule-of-thumb concept that the element radiation patterns should be nearly orthogonal, as such a criterion leads to good performance in multi-antenna systems where the multipath is equally likely to arrive from (or depart into) all angles. However, for environments where the propagation differs from this simple model, pattern orthogonality will not generally lead to optimal performance, motivating the development of more advanced design strategies.

Recently, some work has appeared on this topic, where optimal antenna characteristics can be determined for MIMO systems operating in a specific propagation environment. While these methods are intriguing, they necessarily consider the transmit and receive antenna characteristics together (i.e. the designs are interdependent), and the resulting antenna properties are optimal for the specific propagation channel considered. An effective and practical approach for antenna synthesis should rely only on average propagation behavior at one end of the link.

This paper proposes a method for determining the optimal antenna array radiation characteristics based on stochastic characteristics of the propagation environment at either the transmit or receive end of the link along with an aperture within which the antenna must reside. The approach is based on ensuring that the radiation patterns are eigenfunctions of the spatial correlation operator, a principle which is a generalization of the pattern orthogonality commonly assumed. It can be applied to virtually any antenna aperture configuration and offers the advantage of providing the optimal antenna current distribution in addition to the radiation patterns. A practical method of limiting the impact of array supergain is also included in the formulation. The paper includes comparisons of the diversity gain of the optimal antenna with that for practical designs in realistic environments. The framework is also used in conjunction with genetic algorithm optimization to demonstrate synthesis of practical designs which perform well relative to the optimal performance bound.