Condition for Minimum Scattering Antennas

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The concept of a minimum-scattering antenna was introduced by Dicke more than 60 years ago, and Khan and Kurss redefined it. The theory of minimum-scattering antennas was considerably extended later. The minimum-scattering antenna is one which does not scatter electromagnetic fields when its feeding ports are terminated in a suitable set of reactances. Modeling an antenna as a minimum-scattering antenna simplifies antenna analysis. P. G. Rogers demonstrated that lossless antennas whose scattering behavior is dominated by a single characteristic mode can become minimum-scattering antennas (P. G. Rogers, IEEE Trans. Antennas Propag., vol. 34, no. 10, pp. 1223–1228, Oct. 1986). To the best of our knowledge, there is no literature that derives a condition where lossy antennas become minimum-scattering antennas. In this study, we investigate whether lossy antennas can become minimum-scattering antennas and determine a condition where antennas become minimum-scattering antennas.

In order to find a condition for minimum-scattering antennas, we express a generalized scattering matrix of an antenna in terms of transmitting patterns of characteristic modes. In this study, we assume that the antenna is composed of a dielectric or a conductor, the number of feeding ports is one, and the antenna is excited at an infinitesimal gap on the conducting wire. The formula for the scattering pattern is as follows:

$$\mathbf{S} = \mathbf{I} + \frac{1}{1+\Gamma}\mathbf{T}\mathbf{R} - 2\sum_{p=1}^{\infty}\frac{1}{1+j\lambda_p}\mathbf{T}^p\mathbf{R}^p$$

where $\mathbf{I}$ is a unit matrix, Γ is a reflection coefficient, $\mathbf{T}$ and $\mathbf{R}$ are the modal transmitting and receiving patterns of the antenna, respectively, λ_p is the eigenvalue of pth characteristic current, and $\mathbf{T}^p$ is the spherical mode coefficients generated by pth characteristic current. We assume that the input impedance and current distribution of the antenna are dominated by a single characteristic mode, i.e., all eigenvalues except one are infinitely large. If a reference plane is at a feeding gap, the generalized scattering matrix of the antenna becomes the generalized scattering matrix of a canonical minimum-scattering antenna. If a reference plane is not at a feeding gap, the antenna becomes a minimum-scattering antenna.