Characteristic Mode Analysis of a TM_{10} Electrically Small Spherical Antenna

Jacob J. Adams* and Jennifer T. Bernhard
Electromagnetics Laboratory, University of Illinois at Urbana-Champaign,
Urbana, IL, 61801, http://antennas.ece.uiuc.edu
E-mail: jbernhar@illinois.edu, jjadams@illinois.edu

Previous work has demonstrated an electrically small antenna with low quality factor (Q) and high bandwidth relative to the Chu limit. The antenna primarily excites the TM_{10} spherical mode resulting in a Q near the Chu limit. When properly tuned, the antenna exhibits a resonance and antiresonance within the electrically small region. Within this region, the resonant resistance is always small (less than 5Ω) and cannot be changed through simple geometry changes. However, the antiresonant resistance is strongly dependent on the geometry of the antenna. Consequently, the antenna can be matched at its antiresonant point through appropriate geometric changes without raising the Q of the antenna.

In our previous work, we have also demonstrated that the antiresonant resistance can be decreased by increasing the capacitance between the antenna feed trace and ground and vice-versa. Our presentation will reveal some detail about our physical understanding of this phenomenon. Specifically, we will analyze the antenna using the theory of characteristic modes, originally developed by Garbacz and Turpin (and subsequently, Harrington and Mautz). The theory of characteristic modes essentially allows us to expand the currents on a conducting surface in terms of an orthogonal set of eigenmodes which all contribute independently to the impedance of the antenna. In the case of an electrically small antenna, the number of significant eigenmodes is small, making the analysis of individual mode contributions to input impedance possible.

From the characteristic modes of the antenna, we develop a circuit model that exhibits the double resonance characteristics of the TM_{10} antenna. Using the circuit model, the origin of the antenna's resonance and antiresonance will be explained along with the tuning mechanism used to resonate the small antenna at 50Ω.