Metamaterial-Inspired Efficient Electrically Small Z and Stub antennas

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The introduction of electrically small metamaterial shells surrounding electrically small radiators has been shown to lead to electrically small antenna systems with high overall efficiencies (R. W. Ziolkowski and A. Erentok, "Metamaterial-based efficient electrically small antennas," *IEEE Trans. Antennas Propagat.*, vol. 54, pp. 2113-2130, July 2006). By including active metamaterials into those shells, electrically small antenna systems that have both high overall efficiency and broad instantaneous bandwidth have also been proposed (R. W. Ziolkowski and A. Erentok, "At and beyond the Chu limit: passive and active broad bandwidth metamaterial-based efficient electrically small antennas," *IET Microwaves, Antennas & Propagation*, vol. 1, no.1, pp. 116-128, February 2007). It has been shown that the essence of this class of antennas is the presence of a resonant parasitic, whose electromagnetic properties are tailored to those of the driven element, in the very near field of that driven element.

Following these metamaterial shell ideas, various metamaterial-inspired 3-D and 2-D structures are proposed to achieve the predicted performance enhancements with much easier implementations. Several such antennas structures have been designed and fabricated; the measured results have confirmed the design predictions. The Z antenna, which is composed of a coax-fed monopole and a highly resonant parasitic element placed in very near field of the monopole, is a simplified version of the metamaterial-inspired 2D electric EZ antenna. The Z antenna has been designed, fabricated, and tested. For a Z antenna with $ka\sim0.4$, a being the radius of the smallest enclosing sphere, the measurement results successfully confirm the ANSOFT HFSS predictions. These results will be discussed and presented. Based on the fundamental understanding of the radiation mechanism of the Z antenna, the stub antenna, a simpler version of the Z antenna, was designed and simulated using HFSS. In terms of the bandwidth and, hence, the quality factor of the antenna, the stub antenna behavior is significantly better than the Z antenna and begins to approach the Chu limit. To understand just how close their Q factors can come to the Chu limit, several stub antenna configurations have been studied. These stub antenna systems have $ka\sim0.046$ and a resonance frequency near 300MHz. The Q values of these various stub antenna configurations will be presented and discussed. As anticipated from the shell designs, the introduction of an active internal matching element into both the Z and stub antennas significantly increases their effective bandwidths. For the purpose of comparison, in both simulation and testing, versions of the bare electrically small driven element matched to the source with an external matching network have also been designed. Performance comparisons between these non-traditional and traditional systems will be presented.