Impedance Matching of Electrically Small Self-Resonant Spherical Wire Antennas with Non-Foster Elements

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Electrically small self-resonant antennas are of strong research interest and many magnetic and electric dipole antennas approaching the Chu lower bound have been reported. However, such electrically small antennas exhibit anyway a narrow bandwidth. Recently, non-Foster active matching technique has been receiving attention from electromagnetics community again since it has a potential to widen the impedance bandwidth of electrically small antennas dramatically. In this paper, we investigate the application of non-Foster elements to electrically small, self-resonant spherical wire antennas. Both magnetic and electric dipole antennas are considered and their impedance matching characteristics are compared. A spherical split ring (SSR) monopole is chosen for a magnetic antenna [O. S. Kim, *IEEE Trans. Antennas Propagat.*, 58, 2210-2217, 2010] and the well-known folded spherical helix (FSH) monopole is chosen for an electric antenna. For fair comparison, the SSR design is modified to have the same dimension and resonant frequency as the FSH design in [S. Best, *IEEE Trans. Antennas Propagat.*, 52, 953-960, 2004] before loading any elements (*ka*=0.38).

First, different positions of a series loading lumped element (inductor) inside both antennas are tested. It is found that parasitic arms in the SSR antenna and folding arms in the FSH antenna are better positions than the excitation port in terms of widening impedance bandwidth. It is because the loading element in series with the excitation only can change the imaginary part of the input impedance, while that in the parasitic or folding arms also contributes to change in the real part.

Second, it is found that the SSR antenna reacts more sensitively to the loading element than the FSH antenna, resulting in a wider bandwidth (26.4% vs. 10.2%, at -10dB) with the same range of inductor values. This phenomenon is probably caused by the fact that the wires in the SSR design are more coupled to each other, thus the impact of the lumped component on the current distribution along the excitation monopole is higher. However, such a wideband impedance matching of the SSR antenna is hard to obtain using actual circuit design composed of negative capacitors and inductors, especially in the lower frequency range. It is because the antenna experiences even higher Q at lower frequencies and even a very small difference between the required and actually implemented values of the reactance leads to mismatch. Nevertheless, we show that at least 18% impedance bandwidth can be achieved for both the SSR and FSH antennas using the circuit values, but with smaller reactance variation for the SSR antenna. It is also worth noting that the bandwidth enhancement ratio is two times larger for the SSR antenna than for the FSH antenna.