Wireless Power Transfer in the Radiating Near-field Region

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Many works on near-field wireless power transfer (WPT) have been carried out in the coupled-mode resonance region. In this region, very high power transfer efficiency (PTE) above 80% can be attained. However, such a region is very short when measured in terms of wavelength and it is rather difficult to design antennas that extend the distance over which such coupled mode phenomenon can be maintained. Furthermore, optimal impedance matching is distance-dependent and challenging to implement in practice.

Beyond the coupled-mode resonance region, the PTE decays rapidly as a function of distance in the radiating near-field region. Nevertheless, a theoretical PTE bound derived by Lee and Nam for this near-field region showed that a 40% PTE value can be achieved at a distance of 0.26λ (J. Lee and S. Nam, *IEEE Trans. Antennas Propagat.*, 58, 3442-3449, 2010). It is attained when two electrically small dipole antennas of perfect radiation efficiency are placed in the co-linear configuration with an optimal load value.

Under this background, this paper reviews previous and on-going works for the WPT in the radiating near-field region. The objective is to see the feasibility of the region if it can be used for efficient power transfer. The first line of the work is to demonstrate such a theoretical PTE bound in practice using two electrically small but highly efficient folded cylindrical helix dipoles. The measured results showed a PTE of 40% at a distance of 0.25λ in the co-linear configuration, which is very close to the derived theoretical PTE bound. Next, near-field WPT under multiple transmitters is investigated as a means of increasing the range or PTE, in comparison to the case of utilizing single transmitting and receiving antennas. It is found that a stable PTE region can be created for sufficiently close spacing among multiple transmitters in theory and practice. Lastly, after characterizing the near-field WPT in free space with perfect orientation thus, material effects on the near-field small antennas coupling are studied to address practical deployment issue. To quantify the interactions of the near fields with materials, an analytic upper PTE bound is derived between a transmitting antenna surrounded by a finite-thickness lossy dielectric shell and a receiving antenna located outside the shell in free-space. The derived PTE bounds are verified using numerical simulation via FEKO and show good agreement for both TM mode and TE mode radiators.

All together, it is found that the radiating near-field region also can be properly used for efficient WPT. There can be several potential research topics for the practical implementation of near-field power transfer along this line.