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Analysis of Metamaterial Permeability on the Performance of Loosely Coupled Coils

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Abstract : Electrical energy can be wirelessly transmitted through resonant coupled coils that operate in the near-field region. Once in this region, the field has evanescent character, the efficiency of Resonant Wireless Power Transfer (RWPT) systems decreases proportionally with the inverse cube of distance between the transmitter and receiver coils. The commercially available RWPT systems are restricted to short and mid-range applications in which the distance between coils is lesser or equal to the coil size. An alternative to overcome this limitation is applying metamaterial structures to enhance the coupling between coils, thus reducing the field decay along the distance between them. Metamaterials can be conceived as composite materials with periodic or non-periodic structure whose unconventional electromagnetic behaviour is due to its unit cell disposition and chemical composition. This new kind of material has been used in frequency selective surfaces, invisibility cloaks, leaky-wave antennas, among other applications. However, for RWPT it is mainly applied as superlenses which are lenses that can overcome the optical limitation and are made of left-handed media, that is, a medium with negative magnetic permeability and electric permittivity. As RWPT systems usually operate at wavelengths of hundreds of meters, the metamaterial unit cell size is much smaller than the wavelength. In this case, electric and magnetic field are decoupled, therefore the double negative condition for superlenses are not required and the negative magnetic permeability is enough to produce an artificial magnetic medium. In this work, the influence of the magnetic permeability of a metamaterial slab inserted between two loosely coupled coils is studied in order to find the condition that leads to the maximum transmission efficiency. The metamaterial used is formed by a subwavelength unit cell that consist of a capacitor-loaded split ring with an inner spiral that is designed and optimized using the software Computer Simulation Technology. The unit cell permeability is experimentally characterized by the ratio of the transmission parameters between coils measured with and without the presence of the metamaterial slab. Early measurements results show that the transmission coefficient at the resonant frequency after the inclusion of the metamaterial is about three times higher than with just the two coils, which confirms the enhancement that this structure brings to RWPT systems.

Keywords : electromagnetic lens, loosely coupled coils, magnetic permeability, metamaterials, resonant wireless power transfer, subwavelength unit cells
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