Increasing efficiency in the powering of implantable biomedical devices using negative permeability metamaterials

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Implantable devices are used for diagnosis and monitoring in a number of biomedical applications. Such devices have to be powered efficiently to ensure reliable operation for a considerable period of time. Near field inductive coupling is the most widely used method to power implantable devices. In such systems, there is an external coil mounted outside the body and an internal coil mounted on the implantable device. However, this power transfer link has serious limitations of range and is inefficient beyond short distances. The monotonically decreasing coupling between the two coils is the main contributing factor to this decrease in efficiency. In this abstract, we propose to use negative permeability materials (a unique class of metamaterials) to enhance coupling in such power transfer systems and thereby extend the range and reliability of operation.

Metamaterials are artificial materials that have been engineered to possess properties that are not seen in naturally occurring materials. Electromagnetic metamaterials may possess negative values of permittivity, permeability or both. A material having negative permittivity and permeability can act as a perfect lens because it not only corrects for phase changes in propagating waves but also enhances near field evanescent waves lens (J.B.Pendry, Physical Review Letters, 85, 3966-3969, 2000). Since power transfer in bio-telemetry systems occurs on account of near field inductive coupling, this suggests that metamaterials having negative permeability can be used to enhance mutual coupling in such systems. This work describes the design of a metamaterial slab to achieve coupling enhancement and efficiency increases at low frequencies. The slab consists of stacked layers of double sided spiral resonators that are miniaturized deep into the sub wavelength limit ($\sim\lambda/600$). This ensures that the effective medium approximation is applicable and effective medium parameters can be assigned to the metamaterial slab. It will be shown that the metamaterial has negative effective permeability.

The metamaterial is then used in a prototype wireless power transfer system. Efficiency values will be reported in the presence and the absence of the metamaterial and an increase in efficiency will be demonstrated. The implications of the results and the effect of the metamaterial slab on the coil self impedance will also be discussed. Possible strategies for mitigating the effect of the metamaterial on the self impedance of the coils will also be explored.