Optimal configurations of multi-transmitter wireless power transfer systems for biomedical implants

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As the technology of modern medicine continues to move forward, an increasing emphasis will be placed on smart electrical biomedical implants. With various advances already made over the past years, these technologies are still restricted by the size and weight of the battery used, as well as its required replacement at the end of its life. An emerging alternative is to consider wireless power transfer (WPT) to operate or recharge biomedical implants in place (in vivo), thereby eliminating the aforementioned issues. While the characteristics and optimization of single-transmitter WPT systems in free space have been well-established, the same problem in a medium of biological tissue, and when considering multiple transmitters, is not yet understood to the same degree.

The purpose of this study is to find optimal configurations of multi-transmitter WPT systems providing power to a receiver implanted in biological tissue at the maximal power transfer efficiency. This extends the recent study of optimal free-space multi-transmitter WPT systems in [H.D. Lang, A. Ludwig and C.D. Sarris, IEEE Trans. Antennas and Propagat., Sept. 2014]. The results will also give an estimate of the maximum achievable power transfer efficiency to implants embedded in lossy dispersive biological tissue. Further, besides the electrical transfer performance of the system, also the interactions with its biological surrounding (such as heating of the tissue due to absorbtion of the electromagnetic energy) are taken into consideration.

WPT in general is a highly multifaceted problem involving many factors, such as the frequency of the system; the number, locations and geometries of the coils; and the media surrounding the coils. This computational study will focus on the characteristics of multi-transmitter devices and their arrangement around a single receiver device embedded in human tissue. For any number of transmitter devices, the optimum values for the magnitude and phase of each current source as well as reactive loading elements are obtained from closed-form expressions, leading to optimal performance of that setup under consideration. Then, maximum efficiency values for a range of geometric arrangements are compared, to find the optimal configuration for a certain use case.

The results of this study will be of use for both ongoing research in wireless power transfer systems as well as biomedical engineering. Ultimately, the aim is to bring us one step closer to designing a practical, wirelessly rechargeable biomedical implant.