Metamaterial-inspired Radio-frequency Coil Design for Ultra-high Field MRI

Elizaveta Motovilova
Singapore University of Technology and Design

Abstract—This report provides a brief summary of the main outcomes of the research project supported in part by the 2017 IEEE MTT-S Graduate Fellowship for Medical Applications. The research objective of the study is to improve the radio-frequency (RF) coil system used for transmission and/or reception of the magnetic resonance imaging (MRI) signal by using metamaterial-inspired coil designs. Specifically, this report will summarize the progress made regarding the originally proposed project and the new ideas resulted from it.

I. PROJECT INTRODUCTION

One of the challenging problems of ultra-high field (UHF) magnetic resonance imaging (MRI) is creating highly efficient radio-frequency (RF) transmit/receive coils. My research work is focusing on the developing of new strategies to overcome the limitations of the commonly used RF systems and help to enable the potential benefits of the UHF MRI such as increased special and/or temporal resolution. The proposed approach is to use metamaterials (MM) and metamaterial-inspired coil designs to manipulate and improve the RF field distribution. The MM concept can be applied both in the development of novel coil design and as an addition to currently existing ones.

II. PROJECT OUTCOME

The first part of this project was to create a novel coil design based on the extended transmission line (TL) theory. A double-loop coil was created that introduced additional distributed lumped elements as shown in Fig.1(a) and (b). The proposed modified transmission line was then folded to form a loop resulting in Fig.1(c). An array of eight elements was formed as shown in subfigure (d) and the resulting RF field distribution is shown in subfigure (e) and (f) for the case of a typical coil array (TEM coil) and the proposed one, respectively.

A. Double-loop RF coil

The results of this project were presented at the ISMRM2017 [1], the leading conference in the field of MRI. The proposed double-loop coil array was further tested at the 7T scanner. However, one challenging issue was immediately noticed during the measurements at the scanner. It is the coil sensitivity to the presence of the load and its position. The increased sensitivity arises from the fact that the distributed capacitance introduced by the gaps becomes very sensitive to the loading conditions. Unfortunately, after a series of experiments and discussions with the experts, it was concluded that in its current stage the proposed coil it not practical for the use at the MRI scanner as it requires a wide range tuning depending on the loading settings. Nevertheless, it was a good learning experience and it equipped me with a better understanding of the limitations and challenges of metamaterial application for MRI.

After this, a new project was started that employs the concept of a space-filling curve for the miniaturization of metamasurface field enhancer for UHF MRI.
It has been a privilege to have my research work recognized by the IEEE Microwave Theory and Techniques Society (MTT-S). The reception of the award has not only motivated me tremendously for solving the challenging problems of MRI, but it has also improved my research work. Moreover, this recognition allowed me to attend the IMS-2017, where I got exposed to the latest developments in the microwave research and has a chance to network with the experts in the field. In the future I would like to join the industry and to solve real-life problems using the skill-set that I have developed during my PhD.

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REFERENCES


