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Dissertation Announcement

Implementation of Superconducting Receiver Coils in Magnetic Resonance Imaging Technique

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Clinical and research magnetic resonance imaging (MRI) demands high resolution and fast imaging speeds, but the intrinsically weak signal-to-noise ratio (SNR) is the main limitation to achieving these goals. Noise in the system, in general, is created by conductive losses in the coil and in the body. There are two regimes of such conductive losses in an MRI system. In the first situation, the loss is body dominated, so that the SNR is body loss dependent and in the second instance, loss occurs when the SNR is primarily coil loss dependent. When the coil loss is the governing source of noise, it has long been recognized that cooling the probe reduces this noise contribution and therefore can significantly increase the SNR of the measurement. Indeed, several studies have shown that for selected applications, where the MRI system noise is in the coil loss regime such as low-field MRI, high-field microscopy, and small-volume MRI, cryogenic receiver coils perform significantly better than comparable room temperature copper coils. The design of cryogenic coil arrays has received relatively little systematic study despite the recent rapid development in parallel imaging processing and array techniques.

In this dissertation, the SNR gain from the use of cryogenic coils, cooled metal and HTS coils, has been investigated both analytically and numerically. A numerical tool has been developed for optimized cryogenic coil design according to maximized SNR gain. A simplified analytical model has been proposed to provide the general trends of SNR gain changes with important design considerations, resulting in the identified regime where the implementation of cryogenic coils leads to appreciable SNR improvement. The results of the models are tested by microwave measurements of Q factors, based on an innovative approach proposed in this work. Also an HTS coil array is designed and fabricated for MRI tests.

Another part of this dissertation addresses a critical challenge in cryogenic design—decoupling between elements in coil array. In order to preserve the relatively high quality-factor in cryogenic arrays, the decoupling system should have low loss. A capacitive-only decoupling network seems to fulfill such requirements. However, there is limited literature on this subject. An innovative model is proposed to predict the coupling frequency split based on which Nx1 array with symmetric configuration can be decoupled using a capacitor network. Matched experimental results verify that this model serves as a guideline to capacitive decoupling design.

The results in this dissertation provide insights and criterion to MRI cryogenic coil array design.

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