

AN IN-DEPTH LOOK AT THE ELECTROMAGNETICS OF MRI RF PROBES

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Human magnetic resonance imaging (MRI) is now reaching magnetic field strengths as high as 7, 8, and 9.4 tesla. Ultra high field (7 tesla) operation brings the potential for increases in signal-to-noise ratio. However along with such advantages, there are significant and technical difficulties associated with such operation. From a radiofrequency (RF) perspective, higher field strengths correspond to increased operational frequencies; an 8 Tesla coil, for example, operates at approximately 340 MHz for proton imaging. At these frequencies, the wavelengths of the electromagnetic waves produced by currents on radiofrequency (RF) coils can become significantly less than the dimensions of the human head/body. As such, designing suitable RF coils and/or RF approaches that render useful clinical and research images, as in the case when the RF fields are homogenous within the imaged subject, is technologically as well as physically difficult.

Current ultra high field volume coils share a common design criterion, which is to produce modes that are transverse electromagnetic (TEM) to the coils axis. This notion, however, is only applicable when the resonator is empty or when the load has minimal effect on the coil performance, such as the case with low field imaging. Clearly ultra high field MRI operation does not fall under these two conditions; and the associated volume coils produce hybrid modes that may differ significantly from the intended and desired TEM modes. Therefore, a combination of experimental approaches with full wave modeling is indeed required in order to analyze the behavior of loaded RF coils most especially during ultra high field operation.

In this work we explore what happens electromagnetically during ultra high field operation. Our goal is to study the extent of the deviation of the hybrid modes from the TEM modes in UHF MRI. Using experiments and numerical modeling, we will address 4 critical questions associated with these hybrid modes: 1) what kind of global (across the object to be imaged) and local polarization (at a single voxel) they possess, 2) how their corresponding coil current distributions deviate from those associated with the TEM modes, 3) how far their field distributions (excite and receive fields) differ from those associated with the TEM modes, and finally 4) how all of these issues would impact imaging.

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