Excitation Probes for Ultra-High Field Magnetic Resonance Imaging

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Ultra-high DC field (magnetic flux density $> 3\,\mathrm{T}$) wide-bore magnetic resonance imaging (MRI) can potentially increase SNR, allowing for improved spatial resolution, better parallel imaging performance, and improve contrast in human patient imaging. As the static magnetic field and Larmor frequency increases, the wavelength inside the target volume decreases, creating multiple EM wave modes. The quasi-static approach for creating uniform spatial coverage is no longer valid and complex modeling of the excitation is necessary to determine which modes are excited. Current approaches for homogenization of $|B_1^+|$ include tailoring the currents on the excitation, dielectric inserts, or patient-specific pulse schemes. Dielectric inserts can add significant weight or loss to the system, while patient-specific pulse schemes can add significant overhead since the pulse sequences need to be produced for the patient prior to each scan.

This work presents the use of microstrip patch probes in combination with lightweight metallic structures for 7 and $10.5\,\mathrm{T}$ wide-bore MRI. The excitation is a combination of a coaxially fed circular patch with two feeds in quadrature and a set of traveling-wave probes distributed around the imaging volume. This setup allows for relative phasing, or B_1 shimming, between the circular patch and the traveling-wave probes. To improve the field distribution, approximations to an electrically hard surface is used to modify the boundary conditions of the imaging volume. Electrically hard surfaces are used in waveguide horns to improve the illumination of the aperture (e.g. E. Lier and P.S. Kildal, "Soft and Hard Horn Antennas"). Additionally, an artificial dielectric (e.g. W.E. Kock, "Metallic Delay Lenses"), which approximates a high-permittivity material over a narrow bandwidth, is used to improve the transition between the excitation and the imaging volume. Properly utilizing the excitation and boundary structures together can improve the homogeneity inside of the imaging volume. Full-wave simulations using realistic human body models, Duke from Virtual Population (IT'IS, Switzerland), are crucial to ensure proper functionality of the excitation system. Complex tissues inside of the patient become a substantial portion of a wavelength and must be modeled for an accurate representation of the excitation system.