A radio frequency (rf) penetration model and method correcting for rf inhomogeneity in magnetic resonance imaging

Thomas Kwok-Fah Foo

Radio-frequency (RF) inhomogeneity encountered in magnetic resonance (MR) imaging poses a significant impediment to obtaining images of the highest diagnostic quality. This inhomogeneity arises from the conductivity effect, which attenuates the RF field with increasing depth, and the permittivity effect. The latter is the dominant effect at 1.5 Tesla (64 MHz), and contributes to standing waves within the body.

A theoretical model has been developed which describes these effects for an infinitely long right circularly cylindrical object inside a concentric RF coil and RF shield. This model assumes that the RF field propagates as a travelling wave in the z direction, along the long axis of the cylinder. The resulting solutions adequately predict the field distribution for RF coils which have both a finite wavelength and an infinite wavelength in z. This corresponds to high-pass and low-pass birdcage resonators, respectively, that are in general used in MR imaging. Standing wave models are easily obtained from the superposition of solutions of two travelling waves in opposite directions.

The results of this model indicate that the axial propagation constant k_{z} is a strong function of the dielectric present in the coil-to-shield space. The field distribution in the axial plane can be represented by the Bessel function $J_1(k_{\rho}r),$ where k_{ρ}^{2} = $k^2-k_{z}^{2}$. By varying the dielectric material occupying the coil-to-shield space, an optimum value of k_{z} can be obtained for a particular coil and shield configuration which minimizes the amplitude variations in the axial plane.

Experimental verification of the theoretical model has been obtained. These measurements were performed on a non-resonant, travelling wave test coil with a saline phantom as a load simulating the body. The measured field profiles in the axial plane agree with the predicted values, establishing the validity of the theoretical model. As expected, optimal RF homogeneity was obtained for a value of the relative dielectric constant in the coil-to-shield space between 20 and 40. Although the primary purpose of this test coil was to verify the theoretical predictions, it provided some insight to future RF coil development.