MR Technology Beyond 4T

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Compared to the present clinical field strengths, MR at 4T and above promises to improve anatomic imaging quality by factors, and to bring metabolic and functional imaging to the forefront of research and diagnostic modalities. While human bore sized magnets as high as 9.4T are now installed, realization of the potential benefit of these magnets will require more of the MR system than a simple field, frequency or power scaling from technologies used at lower fields. New constraints on the high field MR studies, both physical and physiological, will require new technical developments to be considered for the highest field systems.

The radiofrequency (RF) subsystem exemplifies many new problems posed and solutions sought for these highest field strengths. At magnetic field strengths of 4T and higher, the Larmor wavelengths become increasingly long compared to coil circuit lengths and anatomic dimensions. Lumped element bird cage and loop array circuits become increasingly radiativeat higher frequencies, and their currents become proportionately non uniform. Radiation loses alone would limit the use for human head and body imaging as practiced at fields below 4T. Additionally, the propagation of RF fields in the human anatomy becomes very lossy and nonuniform. In a head for example, the B1 gradient across a head is 23%, peaking in the middle of the head. At 7T this gradient is 42%, and at 9.4T RF field contours exceeding 60% are predicted.[1] SNR and image uniformity are proportional to these severe B1 field inhomogeneities. Excitation power requirements increase in proportion frequency and B1 field contour. How will these problems be solved?

One approach is to tailor coils to specific regions of interest. For example, a TEM volume coil couples very efficiently to the brain stem, where as a surface coil couples more strongly to the cortex. Another promising approach is to build a coil with controllable current elements that can be interactively biased in phase and amplitude. Such a coil can be used to interactively optimize signal feedback froman anatomic region of interest to meet specified criteria such as maximum signal to noise and/or uniformity. A multichannel TEM coil works well for this purpose. This design with mutually decoupled elements lends itself to parallel imaging applications for significant increases in temporal resolution. The ultimate high filed MR system incorporating an automatic, negative feedback driven multichannel transceiver is already under construction. Feasibility tests at 7T predict the TEM Parallel Transmit / Receive "TEMPTR" coil driven by a multichannel transceiver to be a solution for imaging the human head, body and limbs well beyond 4T, possibly to 9.4T. [2,3,4]

1.) Vaughan, J.T., Garwood, M., Collins, C.M., Liu W., DelaBarre, L., Adriany, G., Anderson, P., Merkle, H., Goebel, R., Smith, M.B., Ugurbil, K., "7T vs. 4T: RF Power, Homogeneity, & Signal-to-Noise Comparison in Head Images." Magn. Reson. Med., 2001. **46**: p. 24-30.

2.) Vaughan, J.T.: "RF Coil for Imaging System" US Patent # 6,633,161 (2003)

3.) Vaughan, J.T. Adriany G,. Ugurbil K. "Shim, Gradient and Parallel Imaging Coil", US Patent Appl. #60/378,111
4.) Vaughan, J.T., Adriany G., Strup J., Andersen P., Ugurbil K., "Parallel Transceiver for Nuclear Magnetic Resonance System," US Patent Application