Multidisciplinary Approaches to MR Engineering

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The field of MR Engineering has benefited by having at least three principle "drivers": fundamental ideas, emerging technologies and emerging applications. Many of the ideas that are being brought to the clinic today derive from the groundbreaking work of the basic MR scientists that started our field. The MR manufacturers rapidly adopt or even drive new technologies. Perhaps most importantly, MR engineering benefits from the fact that the fundamental strength of MRI (the wide array of available contrast mechanisms) attracts researchers from many disciplines who drive the development of new technical solutions to enhance applications. This talk will discuss this multidisciplinary approach to the engineering of the MRI system, beginning with examples that have driven MRI and focusing on how emerging technologies and applications are changing the scanner and its capabilities.

Examples of the tight connection between science and engineering in MRI are readily apparent. One example is the push to higher static fields, starting with the original 1.5 T "high-field" magnet (1). MR manufacturers have driven the development of higher field magnets, which in turn has led to new technologies such as transmit arrays and coil design for high-field imaging. Even the configuration of the magnet is driven by application considerations. The desire for rapid whole-body scanning, driven partially by new contrast agents, is leading engineers to consider both short-bore magnets with moving tables and long-bore magnets with gradient array coils (2,3). Other examples abound. Dynamic imaging, proposed at the very beginning of MRI (4), has driven the development of gradient coils and gradient power supplies. More recently, parallel imaging has become the principle vehicle for improvements in imaging speed. While the possibility of parallel imaging had been suggested well before coil arrays were available (5-7), it remained for the engineering of multiple receiver systems (8) to enable parallel imaging to be demonstrated and developed (9-12). Today, array systems with as many as 64 to 128 channels are being used to obtain images in a single echo or FID (13,14). Development continues today in areas such as cryogenic coils, implanted coils and coil arrays and sensors with optical interconnects. High-field MRI, with its related problems in susceptibility effects and dielectric effects, is also driving the development of transmit coil arrays for Transmit SENSE (15,16). Technical challenges include rapid assessment of RF power absorption, isolation of coil elements (17,18) and the challenges associated with developing tailored RF pulses in complex media at high-fields (19,20). Today, the complexity of the modern MR system is leading researchers to develop models for the entire system, including the static and time-varying fields and the MR physics (21,22), as well as the acoustic and mechanical performance and spectrometer electrical characteristics. This type of modeling is critical for the development of the next generation MRI systems, which will likely include moving tables, short bores, real-time motion compensation and interactive control, and ultra-quiet gradients.

These few examples can only begin to illustrate the MR engineering produced by thousands of engineers, physicists, physicians, chemists and others from all disciplines that have shaped and are shaping the modern MRI scanner. The commoditization of electronics technologies such as high-speed digitizers, real-time DSP units, low-cost miniature receivers and transmitters, and optical interconnects (23), together with new materials such as high temperature and high current density superconductors, will continue to enable evolution in the MRI system, driven by emerging applications in basic science and medicine.

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