High Performance Ecoils and Interfaces for 3.0 Tesla Prostate Imaging and Spectroscopy

G. J. Misic[1], D. C. Feo[2], J. O. Barentsz[3], T. W. Scheenen[3], D. W. Klomp[3], J. Futterer[3], S. W. Heijmink[3], D. R. Callen[1], W. J. Monski[2]

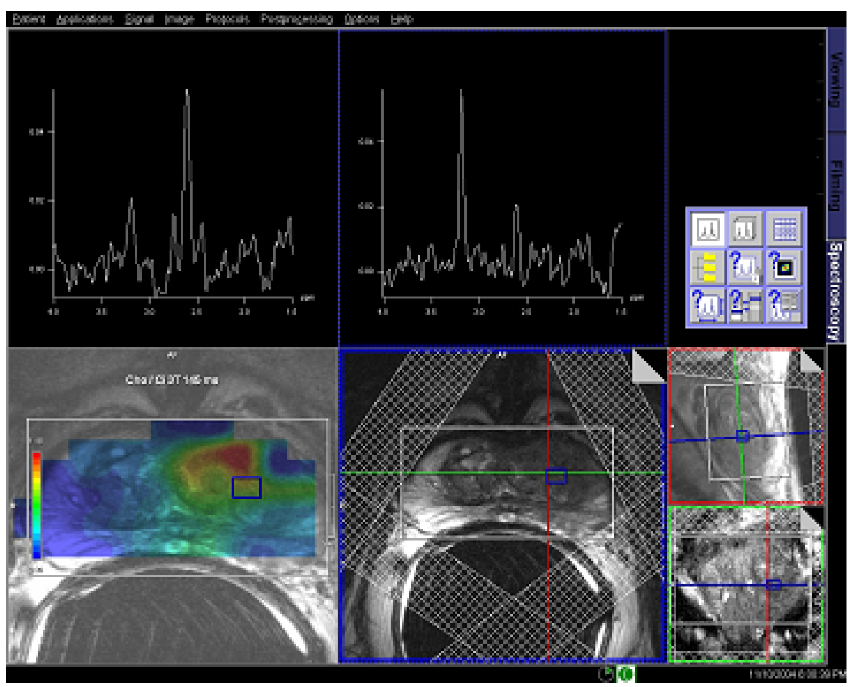
[1]Corporate Innovations, Medrad, Inc., Indianola, PA, United States, [2]MR SBU, Medrad, Inc., Indianola, PA, United States, [3]Department of Radiology, University of Nijmegen, Nijmegen, Netherlands

INTRODUCTION: Our recent work was aimed at greatly improving the performance of our hardware for 3.0 Tesla prostate imaging without giving up any of the benefits of the initial design incorporating a disposable endorectal coil [Ecoil]. We developed a new Ecoil design that featured a balanced decoupling scheme, placing large series impedances in each end of the coil loop to improve the uniformity and effectiveness of the transmit field decoupling. A design that provided excellent decoupling in the event that the Ecoil was present in the bore, but not connected to the interface was devised, and successfully implemented. The Ecoils developed were compatible with all three major OEM whole-body 3.0 Tesla scanners [Siemens, GE, and Philips] when the appropriate interface device was used. The interface design includes preamplifier decoupling and cable trapping, making it useable in combination with other array coils covering the pelvic region to obtain a larger field of view, and better spatial localization. Lastly, the functionality of Interface Device was expanded to support a reusable Ecoil, so that special-purpose Ecoils with additional features could be developed.

HIGH PERFORMANCE DISPOSABLE ECOIL DESIGN AT 3.0: The Ecoil for 3.0 Tesla imaging, despite its small size, requires decoupling that disconnects the coil conductor at both ends to ensure complete and uniform decoupling; this is due to the very short wavelength of 127 MHz RF [2 ½ meters], and the high dielectric constant of tissue and water. To accomplish effective decoupling, and still retain the Ecoil as a disposable device, we duplicated the concept of a tuned output cable decoupling system using a tuned length of transmission line on both sides of the coil loop; this provides a high impedance at both ends of the coil loop during the transmit phase of the NMR sequence by parallel resonating the drive capacitor with the inductance of the tuned, shorted coax stub. Another consideration was to provide safety decoupling of the Ecoil even when it was not connected to the Interface Device. Making the transmission line on the Ecoil one-quarter wavelength long plus a length to parallel-resonate the drive capacitor accomplished this. When the Ecoil is not plugged in to the interface, the open condition of the 50Ω, one-quarter wavelength cable is reflected back as a short circuit, thus placing the tuned length in shunt with the feedpoint capacitor on each end of the coil. The coil is a single loop made from a highly flexible conductor; it is attached to an inner balloon in a position that causes it to be held in close proximity to the wall adjacent to the prostate gland by the inflated inner balloon. Because the loaded Q of the coil is very low [10 to 20], it was found to be unnecessary to tune the coil on a per-coil and per-patient basis. The difference in the Larmour frequency of various 3.0 Tesla MRI systems [123.20 to 127.75 MHz] is reasonably accommodated by a single Ecoil design that is resonated at 125.5 MHz.

INTERFACE DESIGN: The Interface Device was changed to accept a balanced input from two 50Ω coaxial cables, and to place an appropriate phase shift in front of each input to allow the signals to add together constructively; this also allows shunt PIN diodes to optimize the decoupling during the transmit phase by placing a short circuit one-half electrical wavelength away from the tuned length of each cable, or approximately ¼ wavelength from the Input Port for the Ecoil. This was accomplished by using two PI networks at the two inputs, one having a +90° phase shift, and the other having a –90° shift; this resulted in a total electrical length of 0° plus the tuned length on one side, and 180° plus the tuned length on the other side. The two outputs of the two phase shift networks were combined constructively to drive the preamplifier. The interface contains a low noise figure GASFET preamplifier with low input impedance, but designed to work with a 50Ω RF signal source. A shunt PIN diode directly across the input of the preamplifier provides added protection from the large transmit RF fields for the preamplifier. During receive, the low impedance of the preamplifier is reflected as a high impedance to each end of the Ecoil loop, thus providing a degree of preamplifier decoupling; during transmission, the PIN diodes are biased on, decoupling the Ecoil from both ends. A cable trap was placed on the coaxial cable output of the preamplifier to block any potential cable currents; the cable trap was designed to not couple to a uniform RF field to prevent coupling to the transmit B1` field. With modern 3.0 Tesla MRI systems having phased array capability and many receivers, provision is made for two surface coils to be used simultaneously; this allows the Ecoil to be used in combination with a Torso Array Coil to provide a larger field of view of the anatomy surrounding the prostate, while providing excellent SNR in the prostate. Because of this, an interface to combine the Ecoil and Torso Array was not needed.

RESULTS: The Ecoil design provided improved decoupling which resulted in increased performance in imaging, and especially in spectroscopy studies that look at the Creatine, Choline, and Citrate peaks. The technique that we are employing to produce the 1H spectra uses several 180° RF pulses to produce the high resolution spectra, the uniformity of the transmit field, and the resulting 180° pulse calibration, is of crucial importance, especially if adiabatic 180° RF pulses are not used. The improved uniformity of the transmit RF field, and the improved calibration of 180° RF pulses produced substantial gains in the clarity and utility of Creatine-Choline-Citrate spectroscopic data. The image quality, especially with Turbo Spin Echo or Fast spin Echo techniques that use multiple 180° pulses, was similarly improved, as was the resulting image uniformity. A sample of the imaging and spectra on a Siemens TRIO 3.0 Tesla system are shown at the right.



FUTURE DIRECIONS: A specialized reusable Ecoil with provisions to fill the inner balloon with a liquid to solve the susceptibility issues is currently being developed. It is accommodated by a scheme within the Interface Device to support reusable Ecoils. The reusable coil design can use perfluorocarbon liquid instead of air to fill the inner balloon; this will substantially reduce the susceptibility artifact issues, especially for Creatine-Choline-Citrate spectroscopy.