The Technology and Techniques of 4T Body Imaging

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Synopsis: To make whole body imaging possible at 4T, new understanding, technology, and techniques have been developed. New understanding was required to update initial impressions that practical 4T body imaging was not feasible. RF technology including a body coil, front end, and specialty receiver technology was developed to make 4T body imaging possible. New techniques such as RF shimming were implemented to correct for artifacts not observed at lower field strengths. The result of bringing together new technology, techniques and understanding is a demonstration of the feasibility of 4T whole body MRI with examples from brain, breast, abdomen and heart.

Objective: To investigate the feasibility of whole body imaging at 4T using a newly developed body coil and front end together with applications dedicated phased array and parallel array receivers.

Background: Notably, 4T whole body imaging was performed nearly 15 years ago.[1,2] As with most “first” results, the images acquired were not the “best” results. Skepticism about imaging at 4T followed. RF power requirements were thought to be too high, and RF penetration too low for successful body imaging at 170 MHz. Recent success with body imaging has been demonstrated by the major MR system manufacturers at 3T,[3] though the limits of conventional coil technologies and RF power requirements are being challenged at this field. Is clinical quality body imaging yet possible at 4T and higher? By developing and applying new RF technology and techniques, 4T body imaging may now prove to be feasible.

Methods and Materials: An active body coil system was developed for efficient head and body imaging at field strengths of 4T and higher. This complete RF front-end system employs an actively detuned TEM body coil for NMR signal excitation together with local receiver coils of the phased array or parallel array type.[4] Included in the system are the homogeneous transmit coil (a), the multi-channel receiver coil (b), the coil power supply and control unit (c), the optically triggered, nonmagnetic PIN diode driver unit (d), the non-magnetic, multi-channel preamplifier (e), and all of the necessary fiber optic control lines (f), power supply lines (g) and RF signal cables (h). Not shown are the high power, non-magnetic transmit/receive (TR) switches that complete the RF front end. The actively detuned body coil was used as a transmitter, together with applications specific receiver coils for better imaging of the regions of interest in the body.

Results: Four regions of the body were targeted for demonstrating the feasibility of whole body imaging at 4T, namely the head, abdomen, breast, and heart. See Figure 2. A body coil (Figure 1) was used for the transmitter in all cases. The multi-slice gradient echo head images were acquired with a four loop, strip-line, parallel array receiver and combined by a simple sum-of-magnitudes. The abdomen images were acquired with a four channel phased array receiver using a breath hold, T1 weighted, recalled echo sequence with the parameters: TE = 3.9 ms, TR = 200 ms, flip = 90, slice = 5 mm, FOV = 36x27 cm, matrix = 256x192. Again, no intensity correction was applied as would be typical in clinical phased array images. The high resolution T1 weighted spin echo breast images were acquired with a two loop, quadrature crossed pair phased array by the parameters: TE = 21 ms, TR = 400 ms, slice = 3 mm, FOV 20 cm, matrix = 512x512. Finally, the pair of breath held, gradient echo, cardiac images was acquired with EKG gating from a 160 lb. male. A four loop phased array was used for the receiver. Attention is called to the RF artifact causing signal drop out in the right atrium, in the upper image. This artifact appeared consistently in four of four subjects imaged. The cause of this artifact is prominently featured as a steep RF current density gradient in Maxwell models of the human chest at 170 MHz. This artifact was consistently removed by adjusting the magnitude and phase of the body coil’s RF field by an RF field shimming technique.[5] The lower cardiac image from the same subject has been RF shimmmed.

Conclusions: High quality MR Imaging of the whole human body at 4T is feasible. These initial images will improve with further refinements to technique and technology. This collection of images may demonstrate that RF power requirements and RF field penetration are not barriers to a future of clinical body imaging at 4T.

References:

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