RF System for Ultra-High Field Upper Extremity Imaging

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INTRODUCTION: Imaging extremities in MR is an invaluable, non-invasive method widely used in orthopedic, hand surgery, post-transplant evaluation, variety of pathologic hand conditions [1]. In order to address soft-tissue related challenges, UHF-MR imaging is the precise imaging tool which provides high signal/contrast-to-noise ratio(S/CNR), higher anatomic resolution, and reduced scan time [2]. Due to the small electrical size(filling-factor) of the arm/hand, we use a TEM resonator in conjunction with eight channels receive(Rx)-only-insert array rather than the multi-channel transmit or transceiver approach at 7T.

METHODS: A shielded design of an actively detuned TEM resonator (Fig. 1.a) has two ports driven by quadrature hybrid instead a T/R switch. It contains eight inductively decoupled surface loops(each 18x8 cm^2 in size, fig.1b)[3]. A detailed method mentioned in Ibrahim et al [4] was followed to simulate the TEM coil(fig.1c,d) and human hand as a single system using FDTD (figure 1c) in order to estimate RF power absorption for RF safety. All the MR experiments were conducted at 7T Siemens Magnetom scanner by recruiting volunteer under university approved IRB.

RESULTS: For TEMcoil: S11:-21dB, S12:-16dB(<3%), Rxcoil: S11:-15dB, S12:-14dB(<3%). The B_1^+mean/SD: 743/126(coverage area: 120sq.cm). The SNR:44, and CNR:33 for in-vivo coronal images (almost double compared to 3T throughout the volume measured and verified). At 7T, experimental B_1^+maps(Fig.2leftcolumn) show a good agreement with the simulated B_1^+field distribution(Fig.2.centercolumn) and average SAR/10g of tissue is 2.02W, and peak SAR/10g of tissue is 8.98W. Fig.3 T1VIBE shows exquisite anatomical detail identifying various nerve branches, cartilage delineation, brachial branches, nerve fascicles and vessel-wall imaging in forearm(and elbow); and palmer arch(PA), and proper digita palmer(PPD) arteries in hand. T2WDESS represents cartilage and ulnar nerve with high intensity signal delineation, synovial fluid(bright signal) in between very fine cartilage. SWI demonstrates forearm micro-vasculature; ToF depicts PA and PDP arteries; DTI shows FA (median:0.83, radian: 0.48) and Color-coded maps; vessel segmentation of brachial branches and venous vasculature.

CONCLUSION: The actively detuned TEM coil now makes independent transmit-receive coil operation possible at 7T for extremities which surpasses the work of current 7T applications and it goes beyond head and body (torso) applications. Our ongoing work involves optimizing the coil design, musculoskeletal pulse sequence development, and in addition nerve and smaller vessel imaging for neuropathy and transplant patient populations.

REFERENCES:

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[3] The NMR phased array, Roemer P.B., MRM Nov 2005, 192-225.
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FIGURE LEGENDS:

Figure 1: a) TEM Coil b) 8-Ch Rx Array c) FDTD TEM model, d) S11 matching for both ports,Figure2: Left Exp. $B1^+$ map, Center: Sim. $B1^+$ maps and SAR

Figure 2: Forearm T1VIBE: a) Elbow (median nerve, cartilage); b) brachial artery and nerve branches in Forearm; c) ulnar and radial nerve fascicles and vessels wall imaging; Forearm T2DESS d1(elbow) cartilage and ulnar nerve; e(close to wrist) ulnar , median and radial nerve d2) fine image of synovial fluid in between cartilage; forearm SWI (f) ulnar artery and micro-venous bed; Hand TOF: (g,h): Non-contrast enhanced MRA image of digital proper palmer arteries and super palmer arch; Hand T1 VIBE: i) Cartilage , joints, and palmer arch; Hand T2DESS: j) joints and digital arteries ; Forearm DTI: (k,l): FA map median(k) and radial (l) nerve; (m,n): Color coded map of median (m) and radial (n) nerve; Forearm vessel segmentation: o) brachial branches and venous vascualture; p) paint grow segmented slices using MIPAV (NIH, MD) without skeletonization / dialtion to avoid any identification error

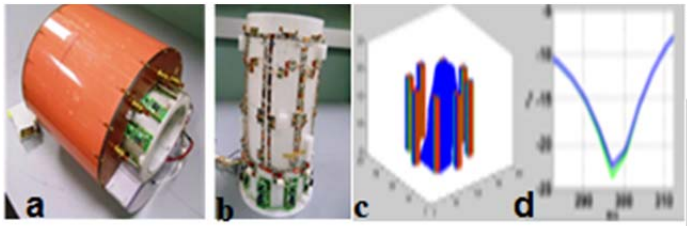

Figure1: a) TEM Coil b) 8-Ch Rx array c) FDTD TEM model, d) S11 matching for both ports

Table 1: 7T Musculoskeletal imaging protocol

Sequences	FOV(mm)	TR/TE	Slices
T2 DESS (294x 448)	105x 160	18/5.2	238
T1 VIBE(304x512)	95 x 160	12/4.5	288
T2 SWI (336x512)	105 x 160	23/15	128
DTI (D:32, b=0,1300)	700 x 620	7000/83	65
TOF(236x640)	85 x 208	12/4.5	-
B_1^+ field map	100 x 100	1500/1.8	112

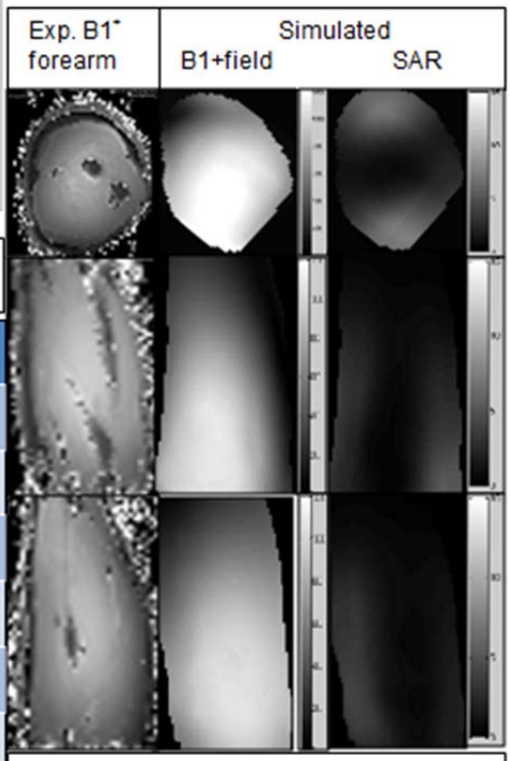

Figure2: Left: Exp. $B1^+$ map, Center: Sim. $B1^+$maps and SAR

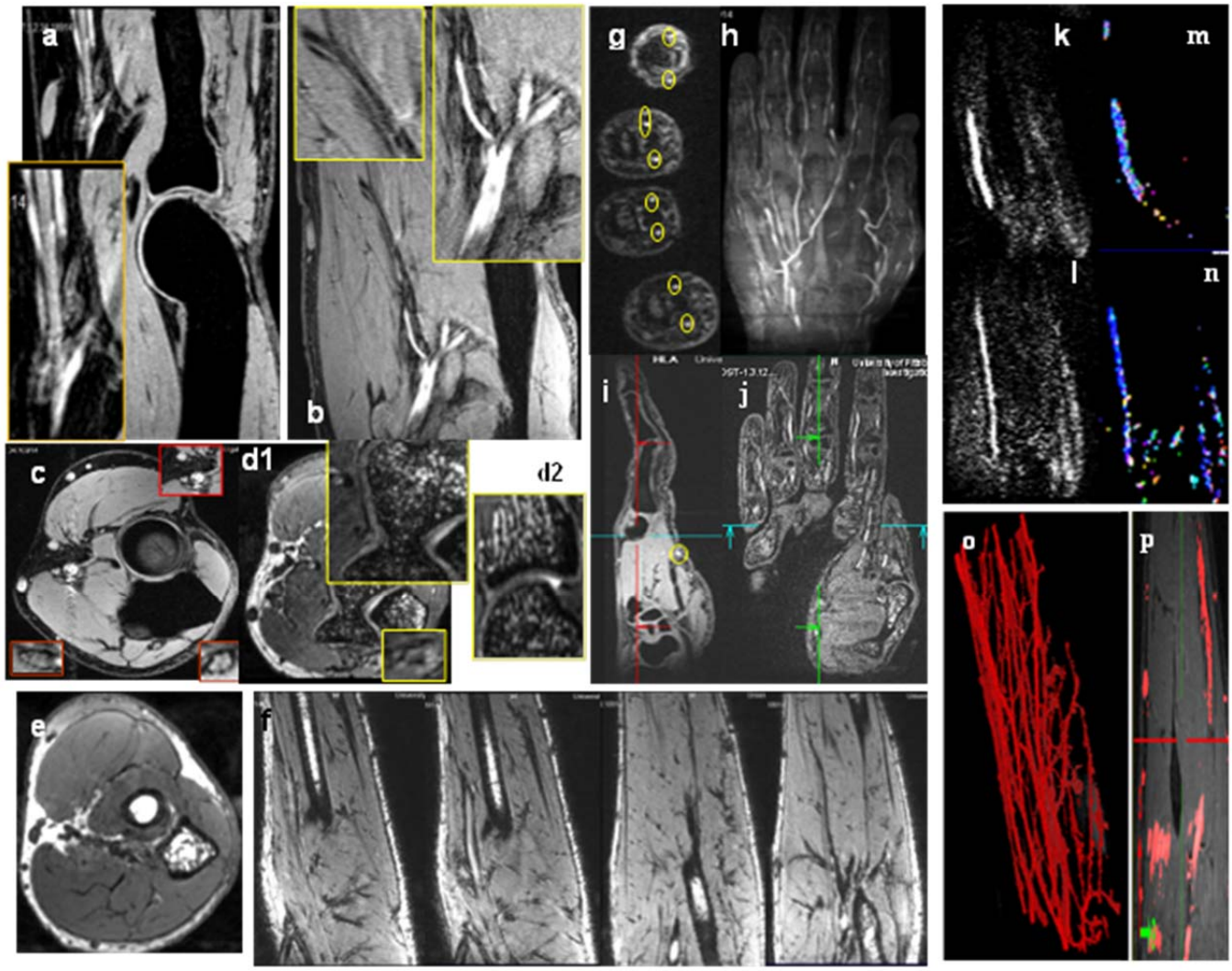

Figure 3: *Forearm T1VIBE.* **a)** Elbow(median nerve, cartilage); **b)** brachial artery and nerve branches in Forearm; **c)** ulnar and radial nerve fascicles and vessel wall imaging; *Forearm T2DESS:* **d1**(elbow)) cartilage and ulnar nerve; **e**(close to wrist)) ulnar, median and radian nerve d2) fine image of synovial fluid in between cartilage; *Forearm SWI* **(f)** ulnar artery and micro-venous bed; *Hand TOF:* **(g,h):** Non-contrast enhanced MRA image of digital proper palmer arteries, and super palmer arch; *Hand T1 VIBE:* **i)** Cartilage , joints and palmer arch; *Hand T2DESS:* **j)** joints and digital arteries; Forearm DTI: **(k, l)**: FA map median(k) and radian(l) nerve; **(m, n)**: Color coded map of median(m) and radian(n) nerve ; *Forearm vessel segmentation:* **o)** brachial branches and venous vasculature; **p)** paint growsegmented slice using MIPAV (NIH, MD) without skeletonization / dilation to avoid any identification errors.