A New UHF Transceiver Antenna Design: Modified Folded Dipole

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Introduction: The linear dipole antenna is analogous to an open bifurcated transmission line, which can effectively radiate rf energy into the far field upon forming a sinusoidal current distribution on its leg [1]. The simple linear structure at resonance inherently allows standing wave current distribution, which generates the transverse magnetic field that is orthogonal to its axis. The radiative antenna design [2] exhibits little B1+ twisting behavior which may have potential benefits for B1 mapping and pulse design [3]. It includes a low loss high dielectric material between the antenna and the object, which mediates fields adaptively towards the imaging object, creating a far field condition. The dielectric material also serves to capture local electric fields between the antenna and the conductive object. Based on electrodynamics suggesting favorable performance for elecgtric dipoles at high fieldIn [4] several new antenna configurations have been introduced. A combination of linear dipoles and loops can offer SNR improvement up to 23% , compared to the loop only [5]. However, the linear dipole exhibits high sensitivity to loading due to the close proximity to the conductive object, which hampers applications in subject dependent body imaging. To aim for practical transceiver body array implementation at 7T, a new antenna design, calling "modified folded dipole (mf-dipole)" is presented. The evaluation of the proposed antenna exhibits less loading sensitivity, and favorable B1 patterns, proposing a solution for challenging 7T body imaging.

Fig.1 Photograph of the mf-dipole

Methods: The mf-dipole was machined (fig.1) on a single cladding FR4 PCB, sized of 32cm long, 1.8cm leg spacing, and matched and tuned to 50 ohms with the body size conductive phantom (permittivity 60, conductivity 0.7 [S/m]). Another mf-dipole 35cm length was prepared only for the antenna gap impedance measurement. The antenna was matched and tuned on top of the phantom in vertical position to minimize electric coupling between the antenna and the phantom. The matching network consists of the balanced L-section and the 50 ohm lattice balun, implemented at the center gap to obtain symmetric currents on its bifurcated legs. The lumped components placed symmetrically along the legs are four identical capacitors that serve to capture local electric fields and four phase-compensating inductors to sustain the half wave standing wave currents. To determin the antenna sensitivity toloading changes the resonant frequency shift was quantified by s11 measurements as the function of air gap between the antenna and the phantom (H0:1.6cm, H1:2.8cm, H2:4cm). Those are compared to two reference coils, the 12cm diameter loop and the linear dipole 37cm. The antenna gap impedance of two elements (dipole 37cm, mf-dipole 35cm) also was measured to see their resistance/reactance changes by the air gap. The axial flip angle (FA) image of the mf-dipole was obtained using the pre-saturation based B1 map [6], and compared to the reference coils at the same Tx reference. The 3 plane SNR images of the mf-dipole and the loop were obtained by acquiring 2D GRE signal and separate noise images at the same setup.

Results: The linear dipole exhibits the strong resonance shifts (30/36 MHz) upwards at H1/ H2 (fig.2b) from the reference at H0 as the effective antenna length is shortened, due to the capacitive reactance (fig.3 b1-b2-b3). In contrast, the loop shows relatively less shifts (5/8MHz) downwards at H1/ H2, attributable to inductive screening (fig.2a). The mf-dipole reduces the resonance shifts further (3.5/5.5MHz in fig.2c) against the air gap changes. Note that the input reactance change of the mf-dipole at H0,1,2 is roughly constant (in fig.3 c1-c2,c3), which explains that the antenna resonance sustains against the air gap changes, however the matching is affected as seen by the resistance variations. The axial FA distribution of the mf-dipole exhibits the almost identical to the linear dipole, and both are comparable to the loop at the same Tx reference, noting that the FA profile of the loop was taken at the maximum B1+ sensitivity (as shown the arrow). In figure 5 on the sampled locations (rectangles) the mf-dipole shows approximately 20 to 28% higher SNR compared to the loop at the same distance from the surface. In note of the geometrical difference of two elements (loop 12cm, mf-dipole 32cm) the mf-dipole shows the wider sagital FOV, and monotonic field patterns in all planes, whereas the single loop shows wider axial FOV with more dynamic patterns.

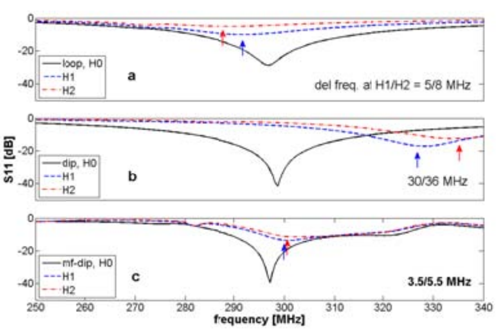

Fig.2 S11 at H0:1.6cm, H1:2.8cm, H2:4cm, (a) loop (b) dip (c) mf-dip

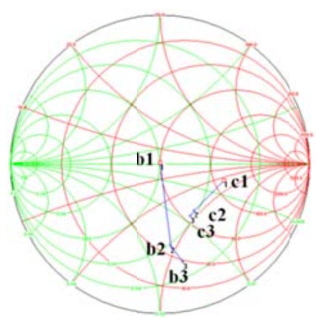

Fig.3 Ant. gap impedance at H0, H1, H2, (b1-2-3) dip (c1-2-3) mf-dip 35cm

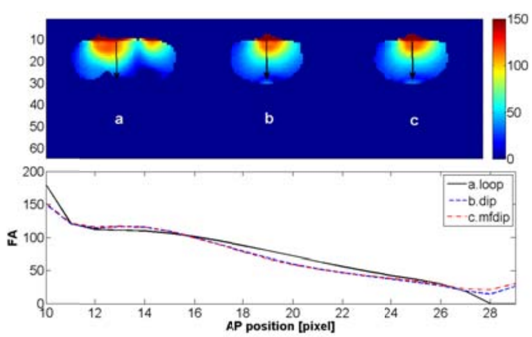

Fig.4 Axial FA image (a) loop (b) dip (c) mf-dip

Discussions: The reactance of the linear dipole antenna is strongly perturbed by the proximity of the conducting object through the parasitic capacitance between them, challenging reliable tune and match with varying imaging subjects. The distributed lumped components of the mf-dipole serve to sustain the antenna reactance in the presence of loading variations without the aid of a mediating material, which may be favorable to the body array construction at UHF. Noting that the excitation efficiency between the loop and the dipole/mf-dipole is comparable at their own maximum sensitivity lines, the higher SNR with the mf-dipole may be attributed to the degree of B1+ and – sensitivity coherence. In other words, the sampled SNR location of the loop is not at the maximum B1+ nor B1- regions due to the field twisting behavior [7]. The generous sagital FOV of the mf-dipole might be beneficial to body imaging, such as thoracic lumbar spine imaging with benign B1 field twisting behavior. In regards to SAR concern the temperature increment by the mf-dipole was measured to be comparable to the loop (not shown in this article). The proposed antenna design should find the benefits in UHF body imaging.

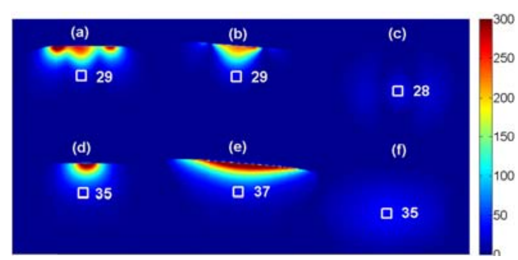

Fig.5 3plane SNR image (a,b,c) loop (d,e,f) mf-dip, (a,d)axial (b,e)sagital (c,f)coronal

Ref. [1] Ant. Theo. & Des., 2nd Ed., Stutzman [2] MRM2011, 66(5):1488-97. [3] ISMRM 20(2012), p307 [4] MRM2012, 68(1):286-304 [5] ISMRM 20(2012) p541 [6]ISMRM 16(2008) p1247 [7]] ISMRM 20(2012) p2996