A 7 T Spine Array Combining Dipole Transmitters and Loop Receivers

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Target Audience

MR physicists, engineers.

Purpose

In absence of RF body transmit coils, 7 T spine arrays need to integrate both transmit and receive functions via either transceivers or separate transmitters and receivers. In the past few years, several groups have proposed various designs [1-6] utilizing loop-based transmit structures. However, given the relatively large field-of-view (FOV) in comparison to the wavelength, those coils for thoracic and/or lumbar spinal imaging [1-3,6] usually require rather sophisticated designs involving several transmit coils with carefully devised cabling. Alternative designs exploiting the traveling wave phenomenon [7,8] may have inferior sensitivity and undesirable RF power deposition outside the region of interest. Recently, electric dipole antennas have been proposed as an alternative to achieve higher transmit efficiency [9]. However, the length of dipoles as well as inter-element coupling prevent achieving the high density that is available with loop arrays, and desirable for parallel reception. Thus, to exploit the advantages of both designs, a combination of dipole transmitters and loop receivers was explored. The performance of the new array was compared to a previous loop-based design [3].

Methods

The transmit array was constructed by converting a transceiver dipole array [9] into a detunable transmit-only array (Fig. 1a), with $S_{11} < -30$dB and $S_{21} = -12$dB. The receive array (Fig. 1b), was based on an overlapping loop design [3] with $S_{11} = -35$dB and $S_{21} = -24$dB for each coil. The receive array was placed on top of the transmit array with center lines from each array aligned, thereby not utilizing the B_1 field twisting effects as done previously with loop transmitters [3] (Fig. 1c). Transmit efficiency for loop and dipole transmitters was compared using Bloch-Siegert B_1^+ mapping [10] using FOV 200 x 400 mm, resolution 3.125 x 3.125 mm^2, slice thickness 5 mm, slice spacing 5 mm, TR = 800 ms, and TEs of 13.3 and 14.6 ms. To compare RF heating effects between both designs, MR thermometry based on proton resonance frequency shift was performed using a 10-minute heating test, with local SAR derived from temperature change assuming no significant heat diffusion.

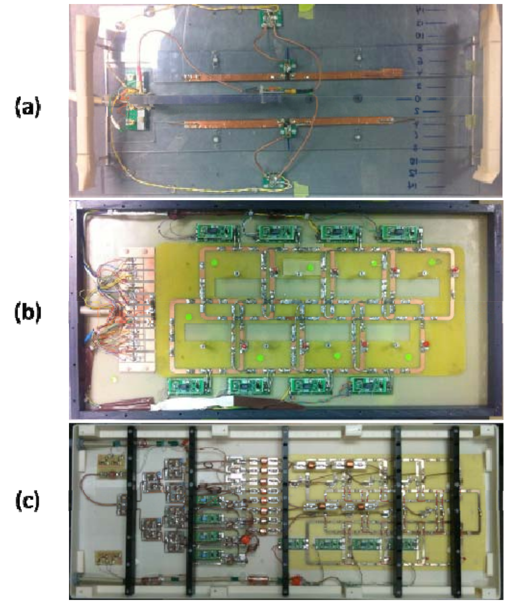

Fig. 1: Photos of finished (a) dipole transmit array, (b) receive array, and (c) a replica of previously proposed loop-based T/R array.

Results and Discussion

Axial B_1^+ efficiency maps (Fig. 2) indicate a much higher transmit efficiency at the center of the array for the dipole design versus the loop design. The dipole array also reached somewhat deeper and wider into the phantom, while associated peak SAR was slightly higher (0.41 W/kg versus 0.37 W/kg, Fig. 3). The improved transmit efficiency of the dipole design was however maintained after normalizing transmit efficiency to peak SAR (Fig. 4). Preliminary human application indicates that the novel design permits high resolution spinal cord imaging *in vivo* at 7 T with clear depiction of the cord (Fig. 5).

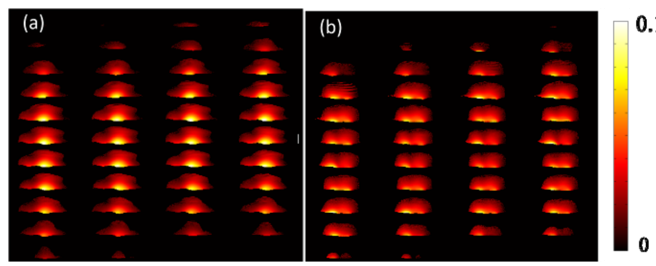

Fig. 2: Axial B_1^+ efficiency map (μT/V) covering the entire coil range for (a) dipole-based and (b) loop-based spine arrays.

Conclusion

A transmit array based on electric dipoles was built for 7 T spine imaging, and combined with a loop-based receive array, in order to simultaneously achieve high transmit efficiency and high receive sensitivity. The proposed dipole array is much simpler and more efficient than a loop-based transmitter, and allows easy integration with existing receive array technology. Parallel imaging performance can be further improved by a receiver array with higher density.

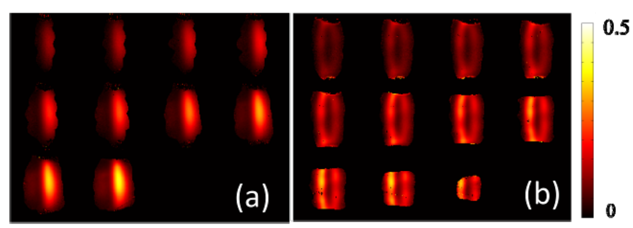

Fig. 3: Coronal unit SAR maps (i.e. local SAR (W/kg) generated by a 1 W input power) calculated through MR thermometry for (a) dipole-based and (b) loop-based spine arrays

References

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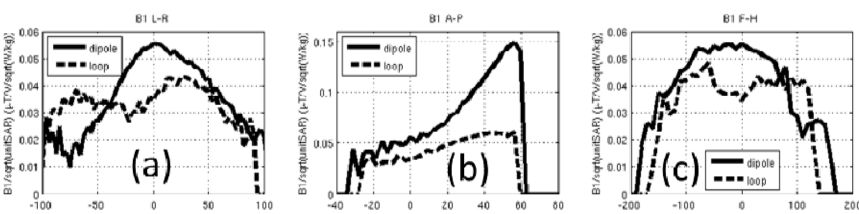

Fig. 4: Normalized B_1^+ efficiency profiles through the center of the spinal region-of-interests (at the center of the phantom and about 5 cm from posterior boundary) normalized by the square-root of maximum unit SAR: (a) from left to right, (b) from anterior to posterior, and (c) from foot-to-head directions.

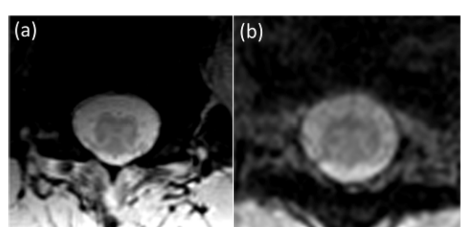

Fig. 5: In vivo images: (a) 3D FLASH 0.6x0.6x2 mm^3 and (b) 3D GRE 0.75mm isotropic