Investigation of the Transition from Travelling Wave to Near Field Excitation Using Crossed Dipole Antennas

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Introduction:

At 7.0 Tesla and higher field strength MR systems travelling waves sustained by the RF shield of the magnet bore have been used for MR imaging [1]. Excitation is typically provided by a patch antenna or crossed dipoles located some distance from the object. Travelling wave excitation is inefficient compared to conventional volume resonators [2], [3]. Near field application of a patch antenna has been explored for head imaging at 9.4 Tesla, where a patch antenna was placed at a distance of 25 cm from the subject [4]. In this study we compared the excitation profile and efficiency of a Crossed Dipole Antenna as a function of distance from the Imaging object.

Figure 1.
Crossed Dipoles Setup

Methods:

Figure1 shows the experimental setup. The dipoles were fabricated from FR4 circuit board with 6 mm wide traces. To achieve maximum efficiency at 7.0 Tesla a simple dipole in free space needs to be around 50 cm long [5], which is not practical. The dipoles were shortened to 23.5 cm long with a tuning inductor placed in each of the dipole wires. The dipoles were matched to the load using a capacitor and a λ/4 lattice balun (Fig 2). The coils were connected to the scanner using in house constructed T/R coil interface boxes. An in house built head shaped phantom (Agarose Gel, 1% w/v of NaCl) was used for imaging. All data were acquired on a Siemens 7.0 Tesla whole body scanner (Siemens Medical Solutions, Erlangen, Germany) with an 8 channel parallel transmit system. With the phantom fixed on the patient table, with the same landmark B1 maps were generated with the crossed dipoles located at 90cm, 70cm,50cm,30cm,15cm,7.5,3.5 and at 0 cm from the top end of the phantom. Actual flip angle maps were obtained using an AFI sequence [6] with TR1/TR2 = 33.33/166.67 ms, 3mm isotropic resolution with 80x40x80 matrix.

Figure 2.
Matching Circuit

Results:

The coupling between the crossed dipole pair was –20 dB. The crossed dipole elements are sensitive to proximity to the sample, exhibiting strong frequency shifts. With fixed coil to phantom relationship we were able to tune and match each dipole element to better than -20 dB. The flip angle maps are shown in Figures 3A and 3B. The transmit efficiency of the Crossed dipole antennas increased with decreasing distance to the phantom. From 90 cm to 30 cm the setup demonstrated a classic travelling wave excitation [3] pattern with a peak excitation relatively low in the head and with excitation in the neck. At 15 cm we see the B1 pattern changed from a classic travelling wave excitation to a more of a near field excitation with the excitation primarily confined to the top of the head.

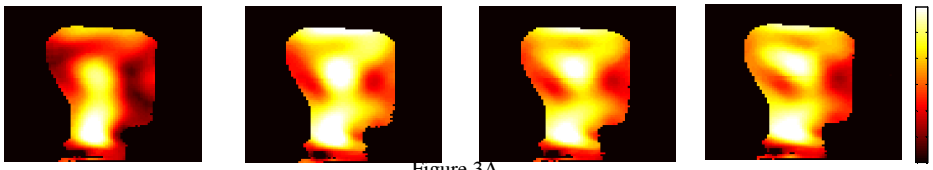

Figure 3A
Flip Angle Maps Crossed Dipoles located at 90, 70, 50 & 30 cm (L-R). Please Note the difference in scaling between 3A and 3B.

Discussion:

We observed that as the distance between the phantom and the Antenna was reduced the transmit efficiency increased. We observed the excitation getting confined to the top of the head region when the distance between the phantom and the crossed dipole pair was around 15 cm. Quarter wavelength for 7.0 Tesla in air is about 25 cm. At this point we believe that we transition from the realm of travelling wave to near field excitation. As we move closer to the phantom, near field effect starts to dominate as indicated by flip angle maps for distances of 3.75 and 0 cm. By choosing the appropriate distance between the crossed dipoles and the head we may achieve a favorable distribution.

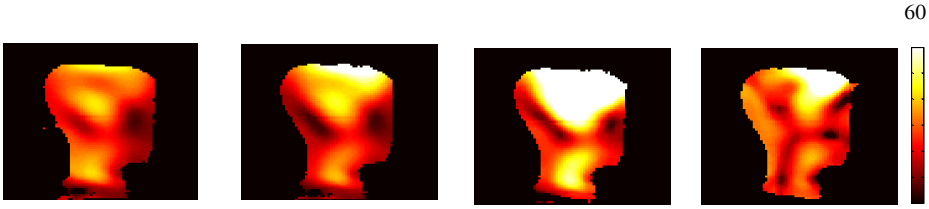

Figure 3b
Flip Angle Maps Crossed Dipoles located at 15, 7.5, 3.75 & 0 cm (L-R). Please Note the difference in scaling between 3A and 3B.

Distance from phantom to crossed dipole(cm)	Tx. Ref.Voltage(V)
90	200
70	200
50	200
30	200
15	200
7.5	150
3.75	75
0	50

Table 1
Transmit Reference Voltages

References:

[1] Brunner, et al., Nature 2009, 457:994-999
[2] Zhang Bei, et al. mrm67:1183-1192 (2012)
[3] Wiggins GC, et al ISMRM 2009. P393
[4] Hoffmann, et al. ISMRM 2011. P164.
[5] Wiggins GC et-al., ISMRM 2012. P541.
[6] Yarnykh, MRM57:192-200(2007)