A Focused MRI with Coupled Phased Array at 7T

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SYNOPSIS Inhomogeneous RF excitation in 7T MRI is due to not only “dielectric resonance” but also coil placement. An analysis and FDTD simulation demonstrate that by manipulating the amplitudes/phases of port-voltages in a volume strip array during transmit, the brightened region can be shifted to a specified location, which may suggest a focused MRI.

INTRODUCTION 7T MRI suffers from central brightening RF excitation due to “dielectric resonance” (1,2). A recent study demonstrates that the central brightening is not only due to “dielectric resonance” but also coil placement (3), which indicates that by manipulating the distributions of amplitudes/phases of the voltages on transmit ports in an array of coupled coil elements, the location of the brightened region (BR) can be shifted to a specified region. This may become an alternative strategy for high field MRI, in which the local homogeneity replaces the global homogeneity.

METHODS Recently a 16-ch transmit/receive coupled volume-strip-array (VSA) demonstrated its feasibility on parallel imaging, see Ref. (4) which suggests that the relation between port-voltage vector **V** and mode-voltage vector $\mathbf{V_m}$ is

$$\mathbf{V}=\mathbf{F}*\mathbf{V_m}, \qquad [1],$$

where **F** is DFT matrix when the impedance matrix is circulant. This relation allows us to analyze how the modes are mixed as results of varying voltage amplitudes/phases during transmit, and what is the coupling among strips for certain modes during receive. Thus, a VSA is an ideal coil for shifting BR by varying amplitudes/phases of multiple ports.

During transmit, different arrangements of the amplitudes/phases of voltages on 16 ports will lead to different mode mixing, which can be calculated using inverse of Eq. [1]. For example, if the amplitudes on 16 ports have Gaussian distribution, as in Fig. 1, and if the phases on the 16 ports have different linear pattern as in Fig. 2 (a), (b), (c), or (d), then the mode distribution will be (e), (f), (g), and (h) correspondingly. The essential point is that different mode mixing leads to different composite field patterns which manifest the BR shifting.

During receive, one cannot specify the amplitude/phase of voltages on each port. However, if the coil is tuned to a specified mode, then the port voltages can be resolved from the Eq. [1]. In Fig. 3, (A) is the typical homogeneous mode which is the degeneracy of mode 1 and 15, (B) is its sinusoidal amplitude distribution of port voltages which is well known.

Figure 1
X-Axis: port
Y-Axis: voltage amplitude

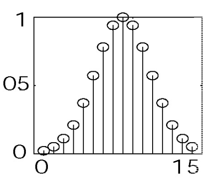


Figure 2
Row 1
X-Axis: port
Y-Axis: voltage phase

Row 2
X-Axis:mode
Y-Axis: mode distribution

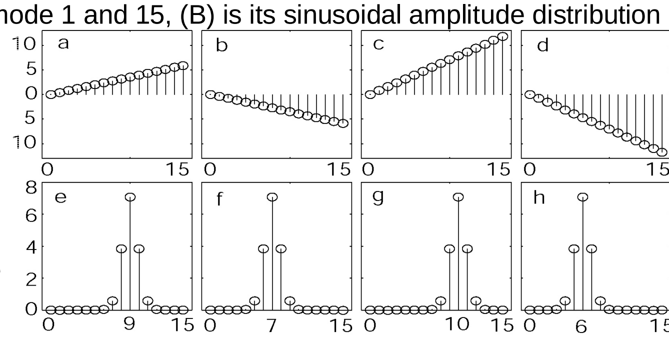
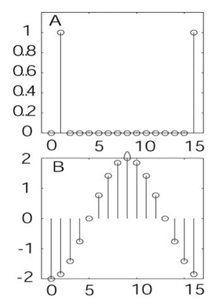


Figure 3
A
X-Axis: mode
Y-Axis: mode distribution
B
X-Axis: port
Y-Axis: relative voltage amplitude



RESULTS XFDTD (REMCOM, State College, PA) was used for verifying above analysis. The coil and sample model is Fig. 4, where diameter and length of shield is 30.4cm and 38cm. Copper strips are all 30cm long, 1.2cm wide, strip-to-shield is 2cm. The diameter and length of sample is 22 and 26cm, its ε_r=65 and σ=0.3mho. VSA is tuned to 300MHz.

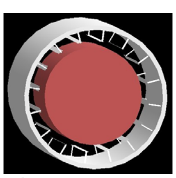


Figure 4

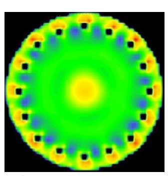


Figure 5

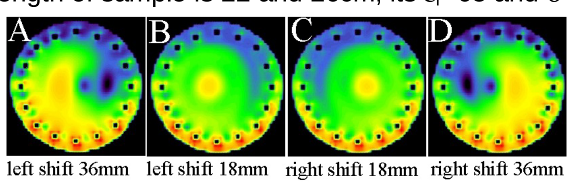


Figure 6

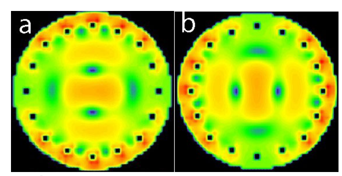


Figure 7

The simulation results verify the theoretical analysis. Fig. 5 is the case where amplitudes of voltages are the same for all ports and phases is sinusoidal distributed during transmit, BR is in the center. In Fig. 6, A, B, C, and D are the results of that all the amplitudes are distributed as in Fig. 1 and phase distributions correspond to Fig. 2 (c), (a), (b), and (d). Their shifts are -36mm, -18cm, 18cm, and 36cm. Note that when BR is shifted too close to the sample boundary, it becomes deformed a bit, as in Fig. 6 A and D. In receive, when all the ports are tuned to the first mode (second lowest resonance frequency), the transverse magnetic fields from port 1 and 5 are shown in Fig. 7 (a) and (b).

CONCLUSIONS We demonstrate that central brightening is due to both “dielectric resonance” and coil placement. By varying the amplitudes/phases of the voltages on the ports of the VSA, BR can be shifted to a specified location.

REFERENCES: (1) Vaughan JT, et al. Magn Reson Med 2001, 46:24. (2) Ibrahim TS, et al. Magn Reson Imaging 2001, 19: 1339. (3) Collins CM, et al. Proc 11th ISMRM, p2391, 2003, Toronto, Canada. (4) Lee RF, et al. Proc 11th ISMRM, p.467, 2003, Toronto, Canada