Mode-Scanning Excitation (MSE) Method for Locally Homogeneous Transmit Profile at 7T

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SYNOPSIS Mode-Scanning Excitation (MSE) method was introduced to achieve a locally homogeneous transmit $\mathbf{B1}^+$ profile in desired locations and patterns at high field (≥7T). It first establishes the base functions by manipulating port voltage distributions in a multiple-port transmit to generate a set of $\mathbf{B1}^+$ maps of all basic modes of volume array in presence of an imaging object; then it applies a singular value decomposition (SVD) to the base function matrix in order to estimate the mode distribution of the desired $\mathbf{B1}^+$ map; and then the port voltage distribution for the desired $\mathbf{B1}^+$ is derived from the FFT of the mode distribution. The MSE was verified in FTDT simulations.

INTRODUCTION During transmit in 7T MRI, due to the dielectric resonance, the global homogeneous excitation may not be easily achieved (1). The locally homogeneous excitation was suggested to circumvent this problem (2). To make local excitation feasible, the controllability of its spatial location and spatial pattern become essential. Here we introduce a method, mode-scanning excitation (MSE), which takes advantage of multiple-port transmit of volume strip array (VSA) (3) to generate a complete set of mode $\mathbf{B1}^+$ maps in presence of the imaging object, and then uses the map sets as base functions to estimate the mode distribution of the desired $\mathbf{B1}^+$ of local excitation with singular value decomposition (SVD). Since MSE acquires base $\mathbf{B1}^+$ functions for each imaging object, it is a powerful tool for *in vivo* heterogeneous objects.

METHODS Unlikereceive, during transmit, one can generate all n basic mode excitations of n-element VSA by controlling the amplitudes and phases of port voltages, regardless of the degree of degeneracy of VSA. Although both decoupled VSA and coupled VSA are capable ofexciting all basic modes, as indicated in Equation $\mathbf{I^m}(k)=(\mathbf{\Psi}+\mathbf{Z^g})^{-1}\mathbf{V^m}(k)=(\mathbf{\Psi}+\mathbf{Z^g})^{-1}\mathbf{FV^g}(p)$, their power requirements are different. Here $\mathbf{I^m}(k)$ and $\mathbf{V^m}(k)$ are the mode-current and mode-voltage vectors, $\mathbf{V^g}(p)$ is the port-voltage vector. The impedance matrix $\mathbf{Z}=\mathbf{F^H\Psi F}$, $\mathbf{F}$ is DFT matrix since $\mathbf{Z}$ is the circulant matrix, and $\mathbf{Z^p}$ is the impedance matrix of power sources.

The MSE method includes the following steps: First, specify a desired excitation location and pattern in the $u\times u$ matrix, and convert this matrix into a $(uu)\times 1$vector $\mathbf{b}$. Second, varydifferent port-voltage vectors n times to generate n $u\times u$ basic mode $\mathbf{B1}^+$ matrices, and convert them into a $(uu)\times n$ matrix $\mathbf{A}$. Third, usea linear combination of the basic mode maps to estimate the desired excitation profile in the minimum least square error, $min\|\mathbf{Ax}-\mathbf{b}\|_2$. So, if $\mathbf{A}$ is decomposed by single value decomposition (SVD), $\mathbf{A}=\mathbf{USV^T}$, then the coefficients of the mode distribution can be calculated by $\mathbf{x}=\mathbf{VS^{-1}U^Tb}$. Fourth, the port voltage distribution $\mathbf{y}$ for generating desired local excitation can be calculated from $\mathbf{y}=\mathrm{FFT}\{\mathbf{x}\}$.

RESULTS The MSE method was verified with the EMF simulation software XFDTD (REMCOM, State College, PA). A 16-ch VSA and cylindrical sample are modeled as in Fig. 1, where the diameter and the length of shield is 30.4cm and 38cm. The copper strips are all 30cm long, 1.2cm wide, and the strip-to-shield is 2cm. The diameter and length of the sample are 22 and 26cm, its $\varepsilon_r=65$ and $\sigma=0.3$mho. VSA is tuned to 300MHz. Each transmit $\mathbf{B1}^+$ field was calculated from two sets of $\mathbf{Bx}$ and $\mathbf{By}$ which are a quarter period apart in time. Note that although the sample is homogeneous here, MSE is fully capable of handling heterogeneous samples.

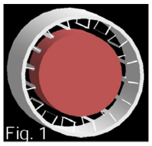

Fig. 1

16 basic mode $\mathbf{B1}^+$ maps of the 16-ch VSA are shown in Fig. 2, which serveas base functions for SVD estimation. The 2D 16th order Butterworth filter with a linear phase is used as the desired excitation regions in Fig. 3a and 3h. For a desired excitation region located in the upper right corner of sample, Fig. 3a, SVD suggests the mode distribution should be as in Fig. 3b and 3c. The composite excitation profile from base functions is in Fig. 3f. FFT of the mode distribution is the voltage port distribution shown in Fig. 3d and 3e. Plugging the port distribution into FDTD model results in the $\mathbf{B1}^+$ map in Fig. 3g. In the same fashion, two region excitations are also achieved, see Fig. 3 h-n.

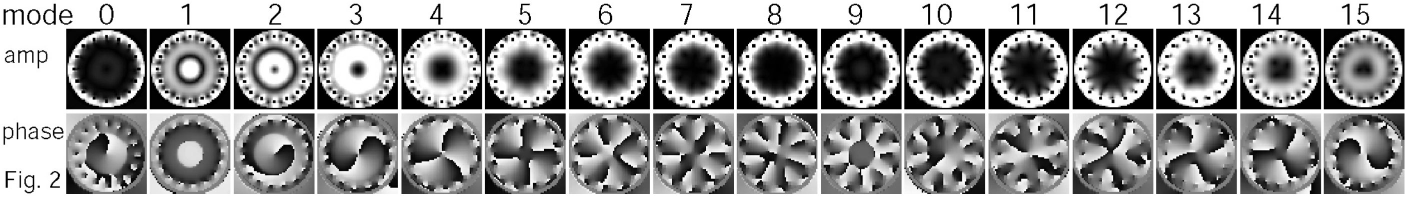

Fig. 2

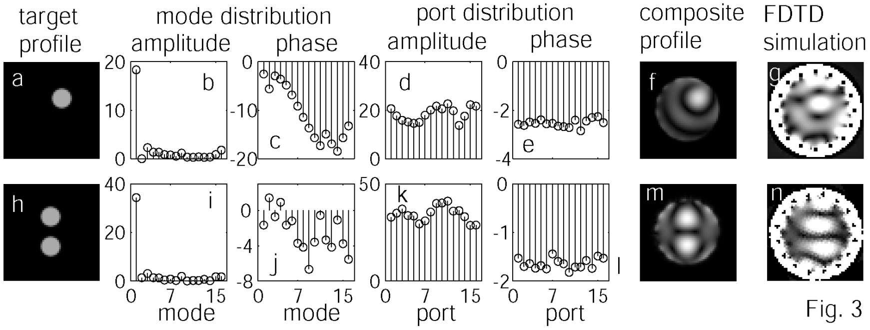

Fig. 3

CONCLUSIONS Amode-scanning excitation method was presented to generate a locally homogeneous excitation in the desired locations and patterns at 7T. Its object-orientated base functions enable it to be used on any in vivo heterogeneous sample.

REFERENCES: (1) Vaughan JT, et al. Magn Reson Med 2001, 46:24. (2) Lee RF et al, Proc. 12 th ISMRM, p. 34, Japan. (3) Lee RF et al, Proc 11th ISMRM, p.467, Canada.