Implementation of Mode-Scanning Excitation Method with a 16-ch Transmit/Receive Volume Strip Array at 7T

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INTRODUCTION At high fields, especially 7T or above, the interaction between coil and sample is so pronounced that not only the sample loading has to be included in tuning (as in lower fields), but also the sample dielectric resonance has to be considered to determine the magnetic field pattern of the coil. The Mode-Scanning Excitation (MSE) method (1) was previously proposed and simulated to obtain the desired transmit field pattern of any arbitrary sample inside a volume strip array (VSA) (2) by inverse design of the voltage amplitudes and phases at transmit ports based on a set of pre-scan measurements. In this study, a 7T 16-ch transmit/receive coil and its 16-way transmit/receive RF interface was built to prove the feasibility of the MSE method. Our experimental results show that desired regional excitation patterns at specified locations can be achieved by MSE in presence of sample dielectric resonance.

METHODS The MSE method can be used to generate either global or regional homogeneous excitation when a sufficient number of distinguishable modes are available. It includes four steps: <1> Specify a desired excitation location and pattern in the $u\times u$ matrix, and convert this matrix into a $(uu)\times 1$vector **b**. <2> vary port-voltage vectors n times to generate n different $u\times u$ basic mode $\mathbf{B1}^+$ matrices, and convert them into a $(uu)\times n$ matrix **A**. <3> use a 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 **A** is decomposed by single value decomposition (SVD),

$$\mathbf{A}=\mathbf{USV}^\mathbf{T}, \quad [1]$$

then the coefficients of the mode distribution can be calculated by

$$\mathbf{x}=\mathbf{VS}^{-1}\mathbf{U}^\mathbf{T}\mathbf{b}. \quad [2]$$

<4> Due to the cyclic symmetry of VSA, the relation between port-voltage distribution and mode-voltage distribution is simply FFT, so the port voltage distribution **y** for generating desired local excitation can be calculated from **y**=FFT{**x**}.

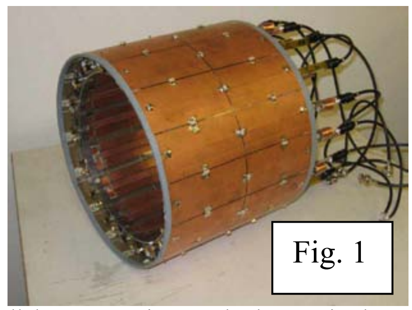

Fig. 1

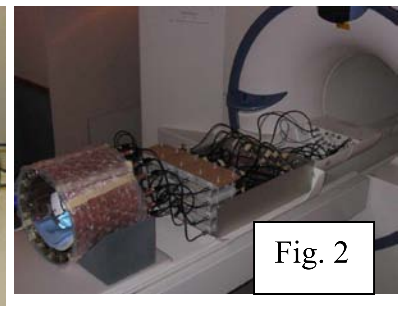

Fig. 2

To implement the MSE method, we built a 16-ch coupled transmit/receive VSA (2), see Fig. 1. The 16 elements are uniformly distributed inside a 12" diameter 9" long cylindrical shield. Each element is made of three 0.5" wide and 7" long parallel copper strips. Each element is shunted to the shield by two Voltronics 12pF range trimmers; and matched through a 5.7pF ATC capacitor. Each unloaded element was individually tuned to 322.0MHz and matched to about 525.0Ω outside the bore. When all elements are coupled together, the homogeneous mode (2nd from left in frequency response) of each element is tuned to 297.2MHz (center frequency of the scanner) and matched to 50±4Ω inside a 7T scanner loaded with a human head, while each element manifests the distinguished phases. The unloaded and loaded Q-factors inside the scanner are 130 and 50.

Each of 16 elements is connected to a TR switch via a cable and balun. The TR switch connects both preamplifier in the receive channel and phase shifter and attenuator in the transmit channel. The 16-ch transmit was realized by using a high power 1-to-16 power splitter. Each of 16 transmit channels can be individually controlled by phase shifters and attenuators. Both coil and RF interface are shown in Fig. 2.

RESULTS We have implemented the MSE method on our 16-ch transmit/receive VSA and 16-way transmit/receive RF interface. First the 16 basic mode field maps were generated by 16 unique acquisitions, shown in Fig. 3. For each acquisition, the transmit voltage amplitude was equal on all ports but the phase was varied according to k^{th} order harmonic phase distributions (k=0, …, 15). Note that unlike the single port coils, VSA can be forced into the desired modes during transmit (not receive). The total transmit voltage required to achieve a 90º flip angle for each mode varied from a minimum of 86V (mode 2) to a projected maximum of 960V (mode 8). Then SVD calculation results in the mode and port distribution of VSA (Fig. 4) for generating the desired regional excitation which is specified in Fig. 5A. Applying the derived transmit voltages, we can shift the regional excitation as shown in Fig. 5B. The excitation profile in Fig. 5B could be improved by increasing the number of the elements and improving the accuracy of phase and amplitude. (The phase accuracy in these experiments was ± 11º.)

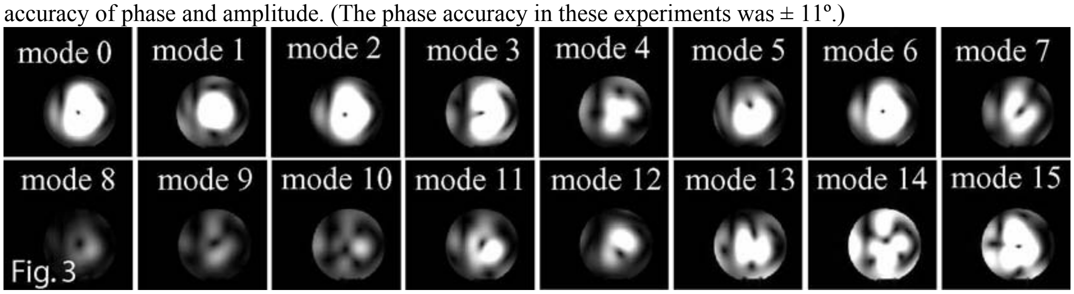

Fig. 3

CONCLUSIONS The feasibility of regional excitation by MSE and VSA in the presence of sample dielectric resonance at 7T was experimentally proven. It provides an analytic and experimental way to circumvent B1 inhomogeneity and high SAR issues for transmit in high fields.

REFERENCES: (1) Lee RF, Proc. 13th ISMRM, p. 823, Miami. (2) Lee RF et al, Proc 13th ISMRM, p.676, Miami.

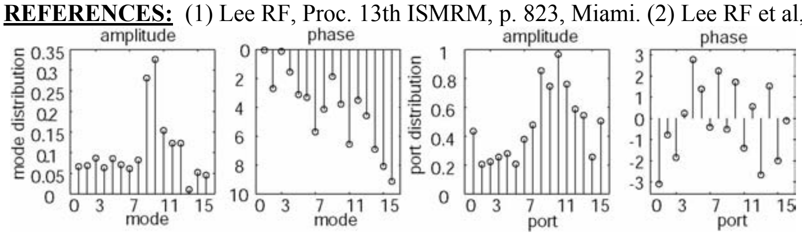

Fig. 4

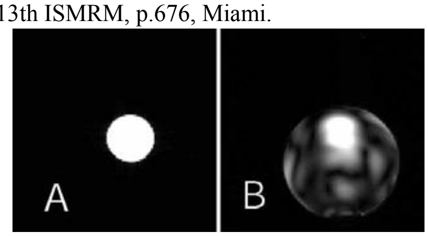

Fig. 5