4T Human Brain Spectroscopic Imaging with Four-Channel Phased Array

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Introduction: Since its introduction by Roemer (1), receive-only phased arrays in combination with body transmit only coils have been proven to be highly effective in extending the sensitivity of a single surface coil to a much larger field of view (FOV). Although used regularly at 3T and lower fields, body volume coils are not commonly available at higher fields and are difficult to construct. To overcome this limitation Vaughan (2) has recently described an actively detuned transmit-only volume TEM head coil in combination with a single receive-only surface coil, at 4T (2). This work describes a head sized TEM volume transmit/four-channel array receive RF system developed for 4T (170 MHz) MRSI of the human brain. The coil can be used either in the volume-transmit/ array-receive mode or in the volume-transmit/volume-receive mode with the phased array actively detuned.

Methods: A 16 element actively detuned 4T (170 MHz) TEM head coil was built as described by Vaughan (2) (Figure 1 A and B). To accommodate receive-only surface coils/arrays, the RF cavity was 38 cm in diameter, 23.8 cm in length with the elements at a diameter of 31.8 cm. The inner bore of the coil was 29.5 cm. The TEM coil was driven in quadrature using a two-port drive. To detune the TEM coil during reception each coaxial element was shunted with a PIN diode biased forward with 100 mA at 3.8 Vdc. When the PIN diodes are reverse biased with –300 Vdc the coil is tuned to the ^{1}H frequency. With the –300V negative bias the magnetic field B_1 generated by the TEM coil, was linear with respect to output voltage of the RF amplifier up to 1 kW.

A four-channel phased array was built, as shown in Figure 1A. Each surface coil measured 8 x 8 cm and had four capacitors equally distributed over the coil. The surface coils in the array were decoupled by overlapping the coils and using low input impedance preamplifiers (1). At higher frequencies (>4T) lumped element quarter wavelength (λ/4) transformers, an essential component of the matching network connecting the preamplifiers to the coils, become difficult to construct due to requirements for low inductor values. To overcome this limitation, we used distributed element microstip transmission line λ/4 transformers (Figure 1C. To provide an overall λ/4 electrical length, the microstrip was loaded with capacitors at the ends. The coil-to-coil isolation was better than 18 dB. The surface coils were detuned during transmission by active PIN diodes placed after the λ/4 transformers (Figure 1C). The impedance of the trap, formed by the λ/4 transformer and the shorted forward-driven PIN diode, measured about 400 Ohms, which provided >30 dB of isolation between the volume and the surface coils.

Results and Discussion: In spite of the substantial increase in the coil volume, the TEM volume coil efficiency decreased by only 1dB in comparison to a smaller TEM head coil (27.2cm id, 20cm length). A circular polarized RF magnetic field B_1 of 1.36kHz (or 32μT) was obtained in a human head using 1kW of RF power, as measured at the output of the RF amplifier. In comparison with the TEM volume coil, the SNR of the phased array improved 4-6-fold in the periphery of the brain. Figure 2 displays spectroscopic imaging data acquired from the occipital lobe using the four-coil phased array. All images and spectroscopic data were acquired on a Varian INOVA 4T whole-body system. Spectroscopic images were acquired using a 3D LASER sequence with a broadband semi-selective excitation pulse. The data were obtained with a slice thickness of 5mm, 32x32 phase encodes over a FOV of 160x160mm for a nominal voxel size of 125ul. Since the volume coil can also be used for reception, high quality anatomical images from the entire brain can also be acquired in the same setting without the need for patient repositioning or changes in hardware configuration.

1A

1B

1C

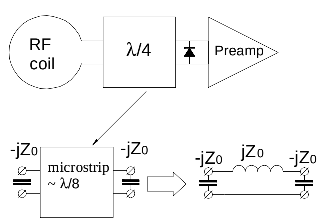
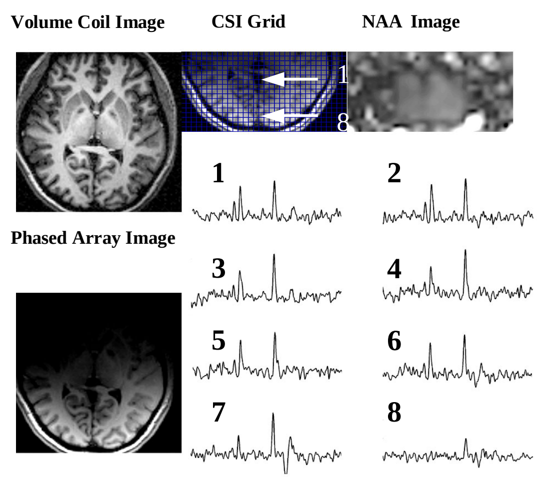


Figure 1. A) Front and B) back views of actively detuned 4T ^{1}H (170 MHz) TEM volume coil with four-channel phased array inside. C) Block-diagram of preamplifier decoupling network.

2



Conclusion: TEM volume transmit/four-channel array receive RF system has been developed for 4T MRSI of the human brain. It can be used either in volume-transmit/array-receive mode or in TEM transmit/receive mode with the array detuned. The microstrip line matching λ/4 transformers were constructed for preamplifier decoupling, which can be easily extended to higher frequencies.

References: 1. Roemer PB, Magn Reson Med 1990;16:192-225. 2. Vaughan JT, Magn Reson Med 2002;47:990-1000.