An Four Port Drive Flat-Element Transmission-Line Coil for Brain Imaging at 3T

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Purpose: We demonstrate a four port drive flat-element transmission line volume resonator for brain imaging at 3T. The design employs fully soldered flat copper elements with discrete capacitors. This flat element design produced a mechanically rugged coil that is considerably simpler to manufacture and tune than the conventional TEM resonator without an adverse affect on coil efficiency or sensitivity.

Introduction: The use of transmission line resonators has been found to provide an increased signal to noise ratio for brain imaging at 3T and higher field strengths(1,2,3). The TEM design is based on inductive coupling of N multiple conductors which form transmission lines over a closely spaced cavity shield. The design has N/2+1 distinct resonant modes the second of which provides a homogenous transverse magnetic field suitable for MR imaging.

The conventional TEM resonator design (1,3) utilizes expensive machined coaxial elements (with up to 16 machined parts per element). While the coaxial geometry provides a high element Q and excellent coil performance, the tuning mechanism of the coaxial elements requires multiple copper-to-copper press fit electrical connections which are subject to mechanical shock and corrosion. These two factors may result in damage from rough handling and may give rise to long term reliability problems.

In this work we describe a high performance shielded transmission line head coil with the coaxial elements replaced with fully soldered flat copper elements with discrete tuning capacitors.

Methods: The mechanical construction of the coil consisted of laminated fiberglass shells on a machined polyethylene form. The shielded cavity was closed (end-capped) at one end to reduce radiative losses and was 35 cm in diameter and 18 cm long. The cavity wall had multiple longitudinal slots with overlapping segments to minimize eddy currents encountered during EPI imaging. Sixteen 1" copper tape elements were equally spaced around the coil 2.5 cm inside the cavity wall. Element tuning was accomplished with discrete variable tuning capacitors (Johanson Manufacturing Corp, NJ) in series with distributed fixed capacitors (Dielectric Laboratories, NY). Four elements spaced equally around the coil were capacitively matched to 50 ohms. Two pairs of elements located 180 degrees from each other were combined with a 180 degree phase shift. These two signals were then driven in quadrature.

Electrical properties of the coil were measured using a HP8712C network analyzer. Phantom and brain images were obtained with a 3T Signa GE / ANMR system. The transmit power needed for a 90 degree excitation was compared to a commercial transmit-receive unshielded birdcage and a nearly identically sized conventional slotted shield coaxial-element TEM coil. Signal to noise ratio (SNR) was measured by comparing image intensity with background noise.

Results and Discussion: The ratio of unloaded to unloaded Q of the coil was found to be greater than 6:1. Tuning the second mode of the coil to 128 MHz required a resonant frequency of approximately 146.5 MHz for each isolated element. The coil tuning was unaffected by 3 foot drop onto a hard wooden floor.

The transmit power required for a 90 degree pulse was 3.5 dB better than the unshielded birdcage coil and was 1 dB better than conventional TEM design. Signal to noise ratio was improved 60% in comparison to the birdcage coil and was approximately 15% better than the conventional TEM resonator.

Conclusion: This study demonstrates the feasibility of a high performance flat element shielded transmission line coil with a 60% increase in sensitivity in comparison with a standard unshielded birdcage head coil. The use of flat copper elements with discrete capacitors did not result in loss of sensitivity compared to a conventional coaxial element TEM design. Moreover, the fiberglass coil construction with soldered electrical connections showed good mechanical stability and structural strength with a considerable reduction in the number of precision machined components.

Figure 1. FSE TR=5000, TE=20 (A), FSE TR=5000, TE=180 (B) Spin Echo TR=500, TE=15 (C), 3D IR prepped SPGR TR=27 TE =12.6 TI=300

References: