A Prototype Head Coil for 11.7T using the Inductive Birdcage Geometry

J. Murphy-Boesch[1], S. Dodd[1], P. van Gelderen[1], A. Koretsky[1], and J. H. Duyn[1]
[1]LFMI/NINDS, National Institutes of Health, Bethesda, MD, United States

Introduction

The circumference of a shielded head coil tuned for 500 MHz is considerably larger than a wavelength, so a backward-wave transmission structure is needed to support a circularly polarized (CP) wave. The inductive resonator [1] can be configured as such a structure [2], and a head coil resonator has been tested up 300 MHz for 7T [3]. When placed within a close-fitting shield, it can be analyzed in terms of three transmission lines that describe the differential and common mode currents of the coil. A distributed impedance model can then be used to develop an omega-beta diagram for the backward-wave structure [3]. The end-rings and cross-members of the coil can then be designed and tested separately in order to optimize for the highest frequency of operation. Here, a prototype 24-mesh coil was designed and constructed for use as a general purpose transmit/receive volume coil at 500 MHz (11.7T).

Methods

A 24 mesh inductive birdcage, similar to one described for 7T [3], was constructed on 11 inch (280 mm) G-10 cylinder, and the shield for this coil was mounted on the inside of a larger G-10 cylinder having outer and inner diameters of 321 and 314 mm, respectively. A slotted shield with 2 mm gaps was assembled from four 254 mm long, flexible (10 mil) PCB's printed with a 1 oz (35 μm) Cu mesh. An 18 cm long, 24 leg inductive resonator was constructed on the inner cylinder using two gapped end-rings fabricated from flexible PCB tapes with 12 mm wide conductors, as indicated in Fig. 1, with a final spacing between the end-rings and the shield of 16.5 mm. 19 cm long legs or "cross-members" were then mounted vertically across the gaps in the end-rings to form the coil. Cross-members with four sets of capacitor breaks on each side were fabricated with double-clad Cu on 3.2 mm thick Teflon dielectric (Polyflon, Norwalk, CT). A single end-ring populated with 3.3 pF capacitors was resonant within the shield at 594 MHz. From this, ω_1 was estimated [3], and for initial prototyping all breaks were populated with 5.1 pF chip capacitors (Voltronics Corp., NJ).

Results

Resonant modes of the coil were measured with an Agilent 5071C network analyzer using the two-loop method. As indicated in the tracing of Fig. 2, the coil exhibits 12 birdcage modes with the homogeneous birdcage mode appearing at 538 MHz. Two longitudinal modes, LG-ctr and LG-co, appear at 579 MHz and 644 MHz, respectively. A four-element distributed impedance model [3], using $\omega_1/2\pi$=567 MHz, $\omega_2/2\pi$=358 MHz and C_1/C_2 = 1.06, was used to fit the modes, as indicated in Table 1. High-frequency modes are well separated, and the B1 field of a single linear mode of the unloaded coil was mapped, as indicated in Fig. 3. The coil was loaded with a hollow phantom filled with 80 mm saline. The phantom was constructed with two concentric, acrylic cylinders yielding fluid dimensions of 19 cm o.d., 12.6 cm i.d., and 19 cm in length. The unloaded and loaded Q's for this prototype were 80 and 20, respectively, and the unloaded Q is expected to improve as the coil is tuned downward. The slotted/meshed shield was found to yield the same unloaded Q as a solid shield, and the end-cap of this shield was found to reduce E-field effects at the subject end of the coil.

Table 1. Measured frequencies (MHz) and fit using the DI model.

Mode #	1	2	3	4	5	6	7	8	9	10	11	12
Measured	537.5	492.9	447.7	423.9	404.7	392.1	382.5	376.7	372.5	369.8	368.7	368.0
Fit	540.1	489.8	448.7	421.3	403.7	392.1	384.2	378.7	374.7	371.8	369.5	367.8

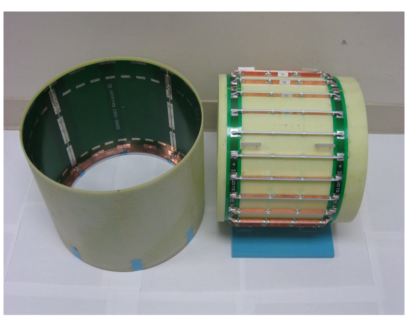

Fig. 1. Inductive birdcage and its shield.

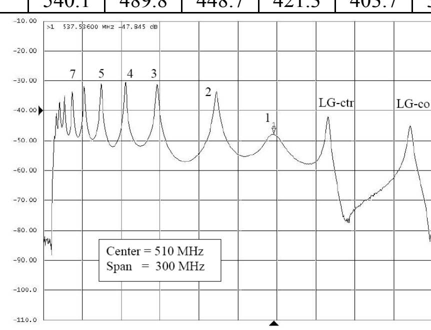

Fig. 2. Modes of the 24-mesh resonator.

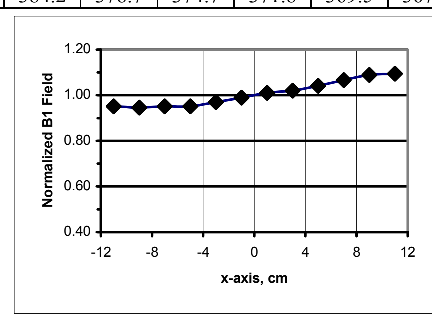

Fig. 3. B1 plot of the linear y-polarization.

Conclusions

An inductive birdcage suitable for use with a human head could be tuned for a frequency in excess of 500 MHz (11.7T). Transmission line analysis and a distributed impedance model were used to develop the prototype, and initial data suggests that the coil will perform well as a CP transmit/receive volume coil. Because of the low Q at 500 MHz, four-port drive will be required to maintain field uniformity, and 8-port drive with phase/amplitude control may provide improved B1 uniformity over limited regions of the brain. A detunable version of the coil is quite feasible, which could serve as a transmit coil for use with phased-array receive elements.

References: 1. H. Wen, A.S. Chesnick, R.S. Balaban, US Patent 5,483,163 (Jan 9, 1996). **2.** J. Murphy-Boesch, Y-J Yang, S. Wang, 14th Annual Meeting ISMRM (2006), p. 215. **3.** J. Murphy-Boesch, 18th Annual Meeting ISMRM (2010), p. 3817.