A Double-tuned $^{1}H/^{31}P$ 3T Homogeneous CP Head Coil with Improved Usability

Jatin Kulkarni[1], John P. Staab[1], Qing Yang[2], Michael B. Smith[2], and F. David Doty[1]

[1]Doty Scientific, Columbia, SC, USA [2] Pennsylvania State Univ., Hershey, PA, USA

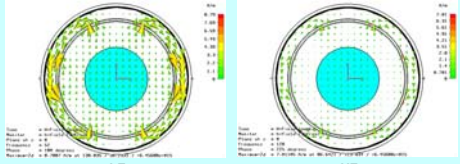
Synopsis

- A novel double-tuned (DT) RF head coil generating uniform circular polarization (CP) at both frequencies.
- Behaves as a balanced low pass (LP) birdcage at the low frequency (LF) and a high pass (HP) birdcage at the high frequency (HF).
- Reduced HF sample losses and LF coil losses.
- Better B_1 homogeneity for both frequencies compared to previously reported DT CP designs.
- Improved tuning range and easier matching capability.
- Appears advantageous for head coils at least up to 3T.

RF Circuit Model

- Rungs are represented by a short transmission line at each end (TRL) with balanced couplings (L_C) between adjacent rungs.
- Losses are mostly represented by appropriate attenuation coefficients in the TRLs.
- The parallel resonant tanks comprised of high-Q inductors (L1) and tuning capacitors (C_E) appear inductive at LF and capacitive at HF. Their isolated free resonance is a little below the HF.
- Capacitors (C1) which are mainly responsible for the lower frequency, are nearly shorts at the higher frequency.
- Stray modes were successfully moved away by connecting fixed capacitors (C_P) between adjacent sections.
- Four-point-drive networks are utilized at both frequencies for improved coil symmetry.

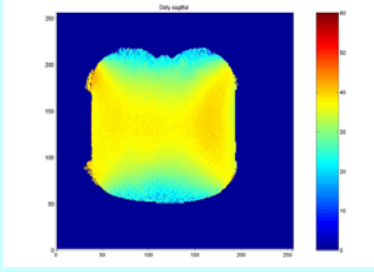
Simulated H field vector plots



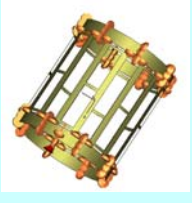
LF HF

- RF magnetic fields within and beyond the sample have profiles very similar to the familiar CP birdcage.
- Absolute peak H magnitude at the center was 0.77 µT @ HF and 1.08 µT @ LF with 0.5 W power excitation. Sample diameter = 150 mm, length = 170 mm, 100 mM saline.

Experimental B_1 Map (oil phantom) at HF



The Coil

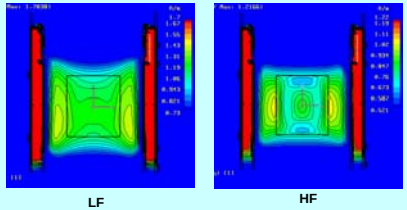


- RF coil topology reminiscent of the 8-section Crozier birdcage.
- Two rungs in each section, shorted centrally to move interfering stray modes.
- Coil diameter : 28.7 cm
- Shield diameter: 34.5 cm
- Rung length: 26.5 cm

The Software, CST MWS 5.0

- Uses Finite Integration Technique (FIT), based on a discretized solution of the integral formulation of Maxwell's equations.
- A structured Cartesian mesh is created for half of the field equations (**E** and **B**), and a second Cartesian mesh, offset by half the element size in each direction from the first mesh, is created for the other half of the field equations (**H** and **D**). This greatly reduces the discretization errors.
- Powerful geometry construction tools, impressive versatility, easy to use, and remarkable agreement with experiments.
- A significant drawback is the long simulation run-time. This will be reduced by the sub-gridding capability which is currently prone to instability.

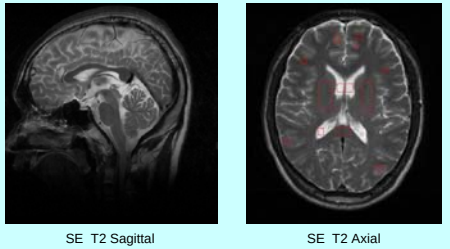
Simulated Absolute H-field plots



LF HF

- The absolute H-field plots in the xz plane show very high homogeneity at the ^{31}P mode, and the ^{1}H mode has the familiar central brightening expected for a saline load of this size at 125 MHz.

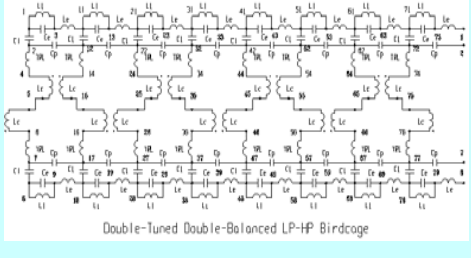
MRI Results



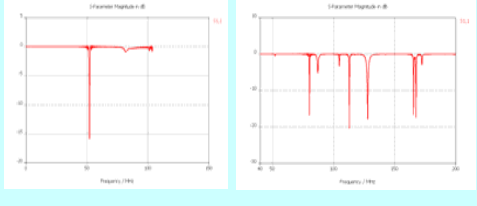
SE T2 Sagittal SE T2 Axial

- Human brain *Turbo Rare* image acquired at the HF. Images taken at Hershey Medical Center, Penn State Univ.

RF Circuit Model



Simulated S11 at LF (52 MHz) and HF (128 MHz)



LF HF

Experimental Results

SIM	C_E pF	C_1 pF	C_P pF	L_1 nH
	55.5	66.4	18	29

EXPT	C_E pF	C_1 pF	C_P pF	L_1 nH
	55.5	66.4	18	29

	M_2 MHz	**M_1 MHz (Expt)**	**M_1 MHz (Sim)**	M_0 MHz	Q_L @ m_1	Isolation	Mean B_1 µT
HF(Loaded)	117.5	125.5	123.3	136	101	28 dB	**0.548**
LF(Loaded)	-	50.8	47.5	68	102	18 dB	**0.861**

- The coil was loaded with a 1 gallon jug containing 100 mM saline water.
- The mean B_1 magnitude corresponds to 0.5 W rms excitation power.

Conclusions

- A novel, robust design for a DT Head Coil which can generate uniform CP has been introduced.
- The DT Head coil generates a homogenous B_1 field at both frequencies with minimum SAR.
- S/N at HF is over 90% that of an optimized single-tuned coil for the same conditions. (The S/N for ^{1}H exceeded that of a reference single-tuned ^{1}H CP head coil.) Calculated LF S/N is ~80% that of an optimized single-tuned coil.

Acknowledgements: This work supported by NIH R44 EB000445-03.