Comparison of the Coax Element and Stripline Element TEM Head Coils at Ultra-High Field

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Introduction: Two popular RF volume coils currently used in ultra high field (UHF) MRI head imaging applications are the coax element [1] transverse electromagnetic (TEM) resonator and the stripline element [2] TEM resonator. In this work, we perform a systematic comparison between the two coils at ultra high field (7 T), using the finite difference time domain method [3]. The simulated coils are accurate numerical models of existing head coils experimentally tested at ultra high field. We compare the distributions, uniformities, powers, and strengths associated with the excite and the receive fields, quantities all relevant to MRI operation.

Methods: Discreteized FDTD grids of both a coax and stripline 16 element TEM head coil were developed. The coil grids and simulation equations were carefully constructed using a variety of modified FDTD algorithms to accurately model the electrical characteristics of the actual coils. The coils were loaded with an anatomically detailed head model and tuned such that mode 1 (as shown in the top set of Figure 1) of the coils resonated at the appropriate frequency for proton imaging at 7 T. The coax TEM coil was tuned by altering the lengths of the inner strut conductors that comprise the coax elements, while the stripline coil was tuned by adjusting the value of the lumped capacitors (whose values were 94 % accurate compared to the actual experimental values) that comprise each element. After both coils were tuned, they were operated with 4-port quadrature excitation. Next, the distributions of both the transverse components of the magnetic fields as well as the electric fields throughout relevant portions of the simulation domain were calculated. To compare the fields, three axial slices representing evenly spaced samples of the human brain (labeled *Ax1*, *Ax2*, and *Ax3*), one central coronal slice (labeled *Cor*), and one central sagittal slice (labeled *Sag*) was extracted from the top of the human head model. The distribution of the B_1^+ and B_1^- fields, as well as the actual MR signal (assuming fully relaxed and uniform proton density conditions) were calculated in these slices, along with the corresponding field homogeneities and signal strengths.

Results and Discussion: Fig. 1 shows the frequency spectrums and the distributions of the B_1^+ and B_1^- fields for 1 W absorbed power in the human head loaded in both coils. It also shows the distributions of the MR signals (using the coil for excitation/reception) corresponding to a variety of absorbed powers in the human head. Table 1 provides the average values and standard deviations of these fields. It is observed that the stripline element TEM coil generally provides marginally higher average $B_1^{+/-}$ fields and MR signal per fixed absorbed power throughout the slices, while the coax element TEM coil generally provides substantially better field homogeneity. The slight differences in the averages of the $B_1^{+/-}$ fields, however, may not be observed experimentally since the numerical results show that the coax element coil radiates on the order of 1/5 of its input power, compared to 1/4 for the stripline element coil. It is noted however that the presented findings are for the specified coil geometries and configurations.

Average Field Values

	Slice	B_1^-	B_1^+	MR Signal for Specific Powers						
				0.1 W	*1 W*	*2 W*	*4 W*	*8 W*	*16 W*	*32 W*
Coax Elem. Coil	***Ax1***	0.79	0.79	0.16	0.47	0.60	0.70	0.64	0.50	0.47
	Ax3	0.73	0.73	0.13	0.40	0.53	0.66	0.69	0.47	0.34
	Ax5	0.80	0.80	0.16	0.48	0.63	0.76	0.77	0.42	0.37
	Cor	0.74	0.67	0.12	0.37	0.50	0.64	0.72	0.61	0.25
	Sag	0.86	0.86	0.19	0.56	0.71	0.81	0.71	0.45	0.47
Stripline Elem. Coil	***Ax1***	0.83	0.80	0.18	0.51	0.65	0.75	0.70	0.43	0.54
	Ax3	0.98	0.95	0.24	0.68	0.86	0.93	0.75	0.38	0.71
	Ax5	0.85	0.83	0.18	0.53	0.69	0.82	0.79	0.39	0.47
	Cor	0.72	0.72	0.14	0.43	0.55	0.66	0.63	0.35	0.48
	Sag	0.95	0.87	0.22	0.64	0.80	0.89	0.71	0.44	0.70

Field Uniformities (Measured by Normalized Standard Deviation)

	Slice	B_1^-	B_1^+	MR Signal for Specific Powers						
				0.1 W	*1 W*	*2 W*	*4 W*	*8 W*	*16 W*	*32 W*
Coax Elem. Coil	***Ax1***	0.30	0.30	0.53	0.49	0.44	0.34	0.34	0.58	0.63
	Ax3	0.19	0.18	0.27	0.26	0.24	0.21	0.18	0.48	0.68
	Ax5	0.09	0.09	0.14	0.13	0.12	0.10	0.10	0.37	0.57
	Cor	0.27	0.13	0.26	0.26	0.26	0.25	0.26	0.37	0.80
	Sag	0.21	0.21	0.40	0.36	0.31	0.22	0.24	0.54	0.73
Stripline Elem. Coil	***Ax1***	0.32	0.30	0.62	0.54	0.47	0.38	0.29	0.59	0.64
	Ax3	0.23	0.20	0.43	0.37	0.31	0.23	0.24	0.80	0.56
	Ax5	0.12	0.11	0.21	0.19	0.18	0.14	0.11	0.42	0.61
	Cor	0.35	0.32	0.56	0.54	0.51	0.46	0.35	0.46	0.66
	Sag	0.27	0.27	0.46	0.44	0.40	0.33	0.25	0.52	0.54

Table 1: Average values given in microTesla (top) and standard deviations (bottom) of the coils' B_1^+ and B_1^- fields (corresponding to 1 W absorbed power in the human head), as well as the MR signal (for a variety of absorbed powers in the human head), for both the stripline element and coax element TEM coils through the slices shown in Figure 1.

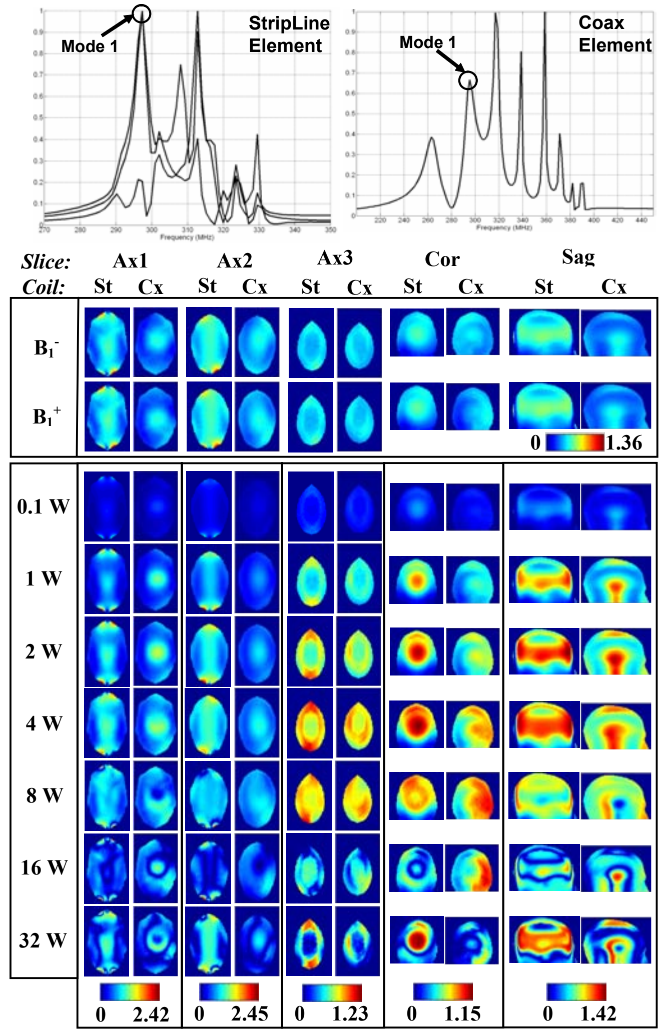

Figure 1: Top: Spectrums of the coax element and stripline element TEM resonators. Middle: B_1^- and B_1^+ field distributions for both the stripline element (labeled *St*) and coax element (labeled *Cx*) TEM coils through a variety of slices taken from the top of the human head, corresponding to 1 W absorbed power in the human head. Bottom: MR field distribution in these slices corresponding to various absorbed powers in the human head. Note that all colorbar labels are given in microTesla.

References:

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