The Quartz TEM Coil: Improved Performance at 3.0 Tesla

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Objectives:

To design a TEM head coil at 3T without compromising sensitivity by the addition of lumped capacitive elements.

Background:

The TEM resonator has been shown to have low inductance and thus functions well at high frequencies [1]. When this technology is applied at around 125 MHz (3T) or less, it functions well but there is a loss in maximum B1 field for a given driving voltage – a common measure of coil sensitivity. This appears to be associated with the addition of extra lumped-element tuning capacitors that are not required at higher frequencies, where all necessary capacitance can be achieved via the distributed capacitance within transmission-line type rungs. Typically, these rungs use a Teflon dielectric material with a dielectric constant near 2. Replacement of the Teflon with precision ground and polished quartz can double the distributed capacitance of these rungs and thus eliminate the need for additional fixed capacitors on the ends of the rungs.

Methods:

One TEM coil [2] prepared for 160 MHz was retuned to a frequency of 125 MHz by the addition of fixed capacitors to the ends of the transmission line elements.   In a second coil the capacitors were removed and the coil was tuned to 125 MHz by the replacement of the Teflon dielectric tube in the rungs with precision ground and polished quartz.   The replacement quartz tubes were 7.338 inches long with internal and external diameters of 0.255 and 0.430 inches, respectively. Quartz has roughly twice the dielectric constant of Teflon with similar voltage breakdown characteristics. After tuning each coil to 125 MHz when loaded with the same human head, the loaded Q-values and the central B_1 field magnitude were measured on a network analyzer. A shielded loop probe of approximately 1.25 inches diameter was used to make the field measurements.

Figure 1: Exploded view of individual elements from the TEM coil showing placement of the Teflon (upper) and quartz (lower) dielectric.

Results:

The capacitance of the transmission-line like rungs were 39pF and 60.7pF for the Teflon and quartz versions of the TEM coils, respectively. The balance of the capacitance for the Teflon TEM coil was added as a fixed capacitance at the end of the rung. The Q-values for both coil versions were similar and greater than 900. The voltage induced in the probe by the B_1 field in the Teflon version of the TEM was measured at an average relative value of -21.4 dB and -24.8 dB below the input voltage for 4 Tesla and 3 Tesla , respectively. The quartz version of the TEM coil had an average relative B_1 field strength of -20.3 dB, about 4.5 dB better than the Teflon coil at 3T, and more consistent with the field strength measured for the 4T Teflon coil. This corresponds to a 68% improvement in sensitivity at 3T. Like the quartz 3T coil, the Teflon 4T coil contained no lumped-element capacitors.

Conclusions:

Lower-frequency TEM resonators can operate with sensitivity similar to that seen at higher frequencies if the tuning capacitance can be located entirely within the transmission-line rungs of the coil. Attachment of fixed capacitance at the ends of the rungs to lower resonant frequency reduces the sensitivity of these resonators. Quartz dielectrics can be used in other forms of TEM resonators such as micro stripline coils in which quartz cylinders can be used as both the increased dielectric and support structure.

	4T Teflon TEM	3T Teflon TEM	3T Quartz TEM
B_1 Field-induced voltage (dB)	-21.4	-24.8	-20.3
Q-value	>900	>900	981
Frequency (MHz)	166.5	124	124

References:

1. Vaughan, JT, Hetherington, HP, Otu, JO et.al., *High frequency volume coils for clinical NMR imaging and spectroscopy.* Magn Reson Med, 1994. 32(2): p. 206-18.
2. Vaughan, J.T., Garwood, M., Collins, C.M., et.al., *7T vs. 4T: RF Power, Homogeneity, & SNR Comparison in Head Images.* Magn. Reson. Med., 46:24 30(2001)