Characterization of Transmission Line Coil Elements

J. Tian[1], C. J. Snyder[1], L. Delabarre[1], C. Akgun[1], J. P. Strupp[1], A. Gopinath[1], and T. Vaughan[1]
[1]University of Minnesota, Minneapolis, MN, United States

Objective: To study frequency dependent current distributions on transmission line elements for coil applications.

Introduction: Transmission lines are being increasingly employed in both volume and surface coil arrays as the primary field generating current elements.(1-6) They are inductively coupled in monolithic resonators, reactively decoupled for parallel imaging applications, and adjusted to conduct current at different frequencies, phase angles, and magnitudes. The objective of this work is to investigate fundamental transmission elements used in present coil circuits, in terms of their current carrying and field generating characteristic. Among the candidate transmission line elements to be characterized over frequency, phase, and magnitude are coaxial elements, stripline or microstrip elements, and waveguides…all generally defined as TEM circuits. Analysis of a coaxial element is reported here as an example of the approach being used to characterize a variety of transmission line structures with hopes of identifying some optimal characteristics for MRI applications.

Methods and Materials: A coaxial element and its field characteristic were modeled as shown in Figure 1 using the Remcom XFDTD package. The co-axial element is not a classical co-axial line since its inner conductor is split into two parts. The element, and coils constructed from it (Figure 1) have a varying current and field characteristic along the length of the coil element due mainly due to the variation of capacitance and conductance along the length of this structure. An anatomically accurate male head from Remcom is used to load the TEM element and coil modeled. The current elements measured 20cm in length, and the shield completing the circuit measured 22cm. 2.5 cm separated the element from the shield. The diameter of the center conductor was 6mm. The diameter of the outer conductor of the coax element measured 12mm. The element structure, equivalent transmission line circuit, and simulated E fields in a loaded coil constructed of these coax elements are illustrated in Figure 1.

Results and Discussions

Circuit analysis showed that the end sections of the coax line have a characteristic impedance of roughly 23 ohms, while the characteristic impedance of the central section is roughly 85 ohms. Wave reflections occur at discontinuities. Therefore there are wave reflections at boundaries between end and central sections and also at the two end terminations where the coax line contacts the cavity wall section of the resonant unit. The current pattern formed by these wave reflections is given in Figure 2. From the figure, we see that maximum current occurs at rung ends when the coax sections are long enough, rather than at element center. This helps to improve B1 field homogeneity and transmission efficiency. B1 field homogeneity deterioration with frequency is not only caused by shorter wavelength and tissue losses, but also by the less ideal current patterns pm coil elements. This more detailed model characterization of current elements used in coil design is applied to other transmission line structures such as micro-strip and strip line elements as well. Varying dielectric between micro-strip rungs and shielding causes more wave reflection and changing the current pattern. More work is needed to optimize the transmission line based coils.

Conclusion: Current patterns and resultant fields generated by transmission line current elements of coils are dependent on frequency, line impedence (phase and magnitude) dimension, and other physical properties that must be characterized for optimal coil application.

References:

1.) Vaughan JT et al. MRM 1994;32:206-218
2.) Baertlein B, et.al Vol. 47: 535-546, 2000.
3.) Lee RF et al. MRM 2004;51:172-183
4.) Ledden PJ et al. Proc. of the 8th meeting of ISMRM(2000) p.1396
5.) Adriany G. et al. MRM 2005;53:434-445
6.) Snyder CJ et al. Proc. of the 14th meeting of ISMRM(2006) p.421

Acknowledgements: NIH-R33 CA94318, NIH-R01 CA94200-01A1, NIH-R01 EB000895-04, NIH-P41 RR08079.

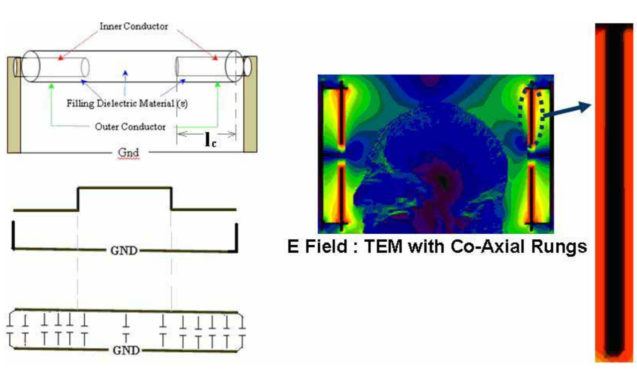

Figure 1. Equivalent Circuit and E-Field distribution of TEM coils

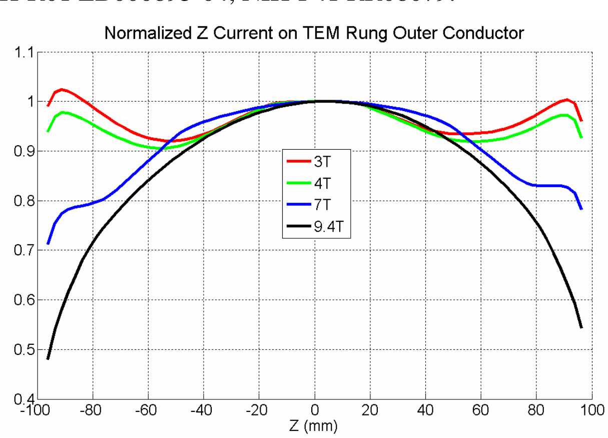

Figure 2. TEM Rung Current: Z Component