Multi Tuned Coupled Microstrip Resonator for High Field Magnetic Resonance Imaging at 9.4T Human System

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Introduction: The combined acquisition images and localized spectra of different nuclei are essential to the practical application of NMR techniques in human and animal research. This can be achieved by the use of multi-tuned RF coils. In this work, a new multi-tuned microstrip resonator is proposed and implemented for 9.4T UIC human magnet. The Dual resonance mode is achieved by inserting the poles in the single tuned coupled microstrip resonance model. The new design is theoretically superior at high frequencies to existing designs as it retains the homogeneity and low radiation losses advantage offered by the coupled microstrip resonator.

Theory: Coupled microstrip resonator design with similarities to a shielded birdcage coil was introduced in [1] to overcome the conventional volume coils problems such as radiation loss and self resonance effects at high frequency. The coupled resonator's inner conductors, which are microstrips, are terminated to the conductive shield through capacitive elements (commonly know as termination capacitance). In a microstrip resonator coil, the shield provides a return path for the currents and makes the coil behave like a longitudinal multi-conductor transmission line (MTL) [2]. Resonance mode separation is accomplished though mutual coupling between the conductors. By varying the termination capacitance the field distribution can be adjusted to achieve the best homogeneity for the required resonance frequency [1]. A single tuned coupled microstrip line resonator can be converted into a double resonant coupled microstrip line resonator by the pole insertion method whereby the termination capacitors are replaced by networks as depicted in Fig. 1 and Fig 2 for parallel resonant circuit configurations. However, a number of different circuit realizations to create these complicated networks are proposed and explored in this work.

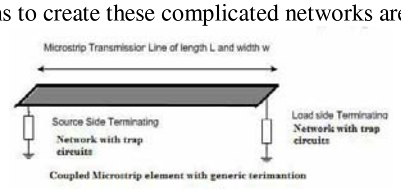


Fig1: Coupled Microstrip element with generic termination.

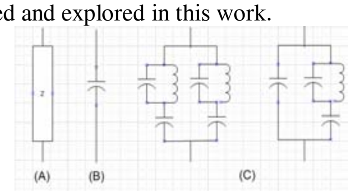
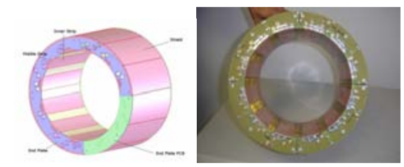


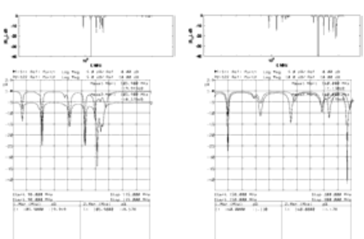
Fig 2: A) Generic termination network, B) capacitor for single tuned and C) different trap circuit configurations for Dual tuned operation.



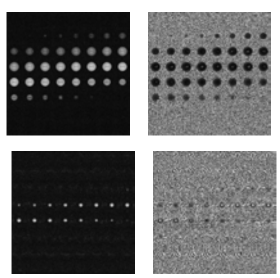
(a) (b)

Fig 3: a) CAD Model of the coil. b) Prototype of the coil.

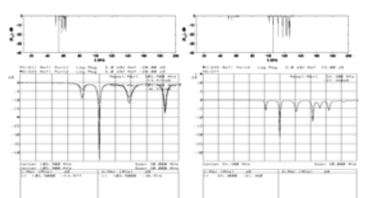
Simulations and Results: Based on the above theory two new dual tuned head coils are simulated and built using the following design parameters. A) The first coil is tuned for phosphorus-31 (165.09 MHz) and sodium (105.9 MHz) in a 9.4T clinical magnet. B) The second coil is tuned to sodium-23(105.9 MHz) and oxygen-19 again in a 9.4T magnet system. Simulations were carried out for different configurations of the termination networks with trap circuits using the MTL model and FEM analysis code [1]. To achieve a good quality factor the traps circuits are implemented not by lumped inductors, but by middle strips between the inner conductors and the shield, acting as distributed inductors. Based on our MTL model [1], the termination network element values were determined prior to constructing the coils. Fig 3 shows the prototype of the coil and figures below depicts the simulated and bench tested results for the coils. The performance testing in the UIC 9.4T human magnet was conducted with standard phantoms and the results are also presented in below figures.



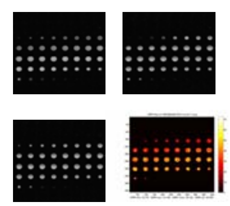
S11 return loss: Simulated a) Na-23 b) Ph-31. Bench tested c) Na-23 d) Ph-31.



a) Axial magnitude for Ph-31 b) axial phase for Ph-31 c) Axial magnitude for Na-23 b) axial phase for Na-23



S11 return loss: Simulated a) O-17 b) Na-23. Bench tested c) O-17 d) Na-23.



Sodium phantom images for Na-O coil. a) Axial magnitude b) coronal c) Sagittal d) SNR image

Conclusion and Future Work: A novel, dual-tuned coupled microstrip resonator for high field magnetic resonance imaging is proposed. The new coil has been successfully developed for sodium-phosphorus and sodium-oxygen imaging in 9.4T MRI systems. Future research will be directed toward the development of coils for other nuclei. In addition, geometric coil refinements will be made to enhance patient comfort.

[Ref]:

[1] Bogdanov G, Ludwig R. "Coupled microstrip line transverse electromagnetic resonator model for high-field magnetic resonance imaging." Magn Reson Med. 47(3), 579-93. Mar:2002.

[2] B.A. Baertlein, O. Ozbay, T. Ibrahim, R. Lee, Y. Yu, A. Kangarlu, and P.M.L. Robitaille. "Theoretical Model for an MRI Radio Frequency Resonator." *IEEE Transactions on Biomedical Engineering*, vol. 47, pp. 535-545, 2000.