Analysis of the Behavior of Planar Spiral Coils for Superconductive NMR Probes

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Introduction

Self-resonant single-sided spiral coils have been used for low frequency irradiation channels in highly sensitive superconductive NMR probes.[1] The simple spiral structure patterned on a sapphire or other ceramic substrate produces lower frequencies than other structure types. The lowest, or fundamental, resonance is most useful for NMR. We can think of the spiral as a type of transmission line resonator. It is necessary that the higher modes are not close to the NMR resonances of other channels in the probe. Electric fields of these resonators are large so they must be located relatively far from the sample or must be shielded by other resonators or a Faraday shield. Understanding the basic structure can lead to a reduced reliance on simulation and thus significantly reduce the length of time required to generate new coils.

Experimental

Simulations conducted with IE3D, also known as Hyperlynx 3D EM, have shown good agreement with the fabricated HTS probe coils that were tested experimentally. A ^{15}N coil is used as an example in the chart and table below.

Results and Discussion

We compare the modes of a spiral to those of a uniform transmission line resonator. The mode frequencies of both resonators show a linear dependence on the mode number. However, neither the slope nor the intercept of the spiral resonator match those of the transmission line resonator. We find this to be typical for the resonators we have designed, and to be confirmed by experiment. An example is shown below in **Figure 1**. The frequency difference between modes of the spiral is approximately 120 MHz, which is about twice the frequency of the fundamental mode.

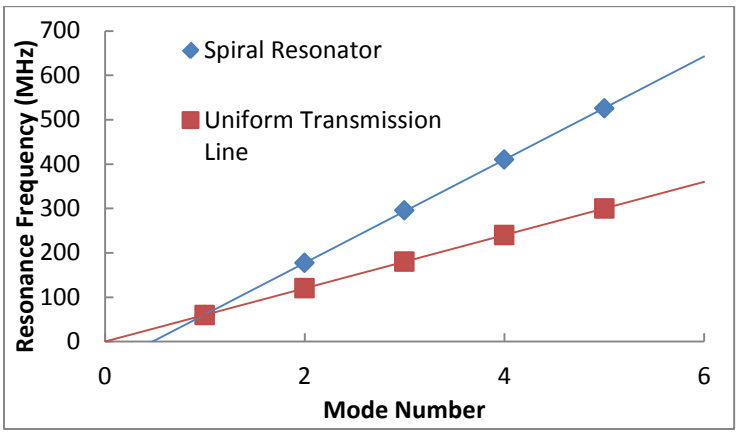

Figure 1: Mode spectrum for a spiral 60 MHz ^{15}N coil and a half wave resonator for comparison.

Mode number	Spiral Resonator	Uniform Transmission Line
1	60 MHz	60 MHz
2	177 MHz	120 MHz
3	296 MHz	180 MHz
4	410 MHz	240 MHz
5	523 MHz	300 MHz

Table 1: Resonance Frequency vs. Mode Number.

If this behavior can be predicted, then an entire mode spectrum can be determined form two identified modes, instead of a set of lengthy simulations.

Acknowledgements

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References

[1] W. W. Brey, *et al.*, J. Magn. Reson., **179**, 290–293 (2006).