Design & Testing of Superconducting Surface Coil Using MoM

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Introduction

The signal-to-noise ratio achieved in MR images is directly related to the performance of RF coil [1]. In this paper, the properties of the HTS spiral coils for 0.2 T and 0.5 T MRI systems, including resonant frequency and Q-factor, are analyzed by Method of Moment (MoM). The simulation results are in good agreement with the measured data. By choosing the suitable width-to-space ratio of the turns of spiral coil, the Q-factor can be improved. In addition, the performance of HTS coil is compared with Copper coil by MoM.

Simulation Method

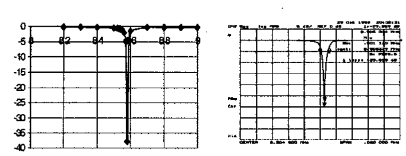
Much research work [2] has been done to analyze the spiral coil with the lumped-element model. However, it has the limitations for circular spiral coil and complex substrate due to lack of accuracy. The MoM has been widely used to analyze stratified structure antenna, because of its high accuracy and efficiency for such structure. But few are to analyze High Temperature Superconductor (HTS) spiral coil. MoM is based on weighted residuals and variational calculus and it converts the integral equation to linear equations. In this paper, the mixed potential integral equation is adopted to analyze spiral configuration of superconducting film. The Green's functions composed of both vector current and scalar charge types are then used.

The HTS spiral coil made of YBCO thin film on 3-inch LAO substrate (thickness of substrate is 0.508mm, $\varepsilon_\gamma = 23$, no ground conductor plane) is analyzed with MoM. The circular coil layout is chosen, because an improvement in Q-factor up to 10% or more is possible in a circular design rather than square design [3].

Numerical and measured results

The relationship of resonant frequency and Q-factor of HTS spiral coil with the design parameters is analyzed here and it gives guidance for a high quality HTS coil.

Here two HTS spiral coils for 0.2T and 0.5T MRI system are designed with MoM. The simulation result of 0.2T system is shown in Fig. 1(a) The resonant frequency is 8.58MHz, Q is 7982. In order to find out the accuracy of the simulation method , the simulation result is compared with the measured one, by using HP network analyzer HP8753E, as shown in Fig.1(b). The error in frequency between simulated and measured result is less than 1%.



a) Simulated Result: f=8.58MHz b) Measured Result: f = 8.505MHz

Fig 1 Frequency Response of the 0.2T HTS coil

The simulated and mesured results of HTS spiral coil For 0.5T MRI system are shown as follows:

Simulated result: $f_0 = 23.08$MHz

Measured result: $f_0 = 22.77$MHz

Moreover, from Table 1, it shows an improvement in the Q–factor when the ratio of width to space of the turns of the coil increases. This is due to the magnetic coupling between windings which can be increased, and in turn, increases the inductance and stored engry.

Table 1 Resonant Frequency and Q-factor at Different W to S Ratios

	D=65 mm ,Turn=12		D=24 mm,Turn=15	
W/S	F (MHz)	Q	F (MHz)	Q
0.83	8.63	5412	23.93	10684
1	8.36	6400	23.08	13676
1.2	8.58	7982	23.97	14246

where W is the width of line, S is the space between turn and D is the outer diameter of spiral coil

For further comparison, one copper coil with the same dimensions of HTS coil is simulated. Results in Fig. 2 shows Q-factor of HTS coil is significantly improved.

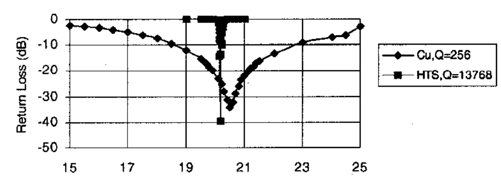


Fig 2 Comparison between HTS coil and Cu coil with MoM

The improvement could be further shown in the MR images. The high spatial resolution image acquired by HTS spiral coil is three times better than the one acquired by copper coil in terms of SNR comparison.

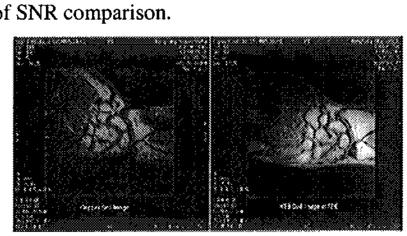


Fig 3 Wrist Images (2 NEX, FOV: 18 x 18) acquired with a 3-inch copper coil (left) and a 3-inch HTS coil (right) at 0.2T

Conclusion

The design of the HTS spiral coil is numerically analyzed by MoM. The simulation results show considerable accuracy on the resonant frequency and the Q-factor of the coil could be improved by choosing appropriate width-to-space ratio of the coil.

Reference

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3.Long J.R, Coperland M.A., Custom Integrated Circuits Conference, 1996., Proc of IEEE 1996 , P185 -188