MRI Magnet Coils Stray Capacitance Effects and the Circuit Analysis Method

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Introduction

The MRI magnet composed of a set of multi-layer solenoidal coils provides the main magnetic field for MRI imaging. Due to the large number of turns in each main coil, its overall parasitic capacitor is possibly at a few nF level. Together with their large inductance, the coils may have a resonance frequency in KHz range, which is within the gradient pulse signal bandwidth. Circuit analysis method considering parasitic capacitance effects has been developed for different types of superconducting magnets to examine the voltage induced at main coil terminals, dielectric loss in main coils and the impact to the input impedance of gradient coils.

Methods

The turn-turn capacitor in main coil can be simulated with FEM. A 2D wire grid model is built in ANSYS and the capacitance between turns per unit length can be extracted with the CMatrix macro[1]. With the method in [2], the overall parasitic capacitance of each coil can be calculated. Meanwhile mutual inductances among main coils can be calculated with the method in [3]. For Z gradient coil driving case, using loop currents as unknowns, a set of linear equations can be established according to the loop voltage drop being zero at any frequency. This is similar with [3, Eqn.1&9], but now with capacitor branches added in the loops.

Results & Conclusions

	Δz(cm)	Δr(cm)	layer	turns	L(H)	c(nF)	Res. freq.(Hz)
Coil1	13.24	0.933	10	109	1.56	8.54	1378
Coil2	4.98	0.933	10	41	0.292	3.21	5198

Tab.1 the overall capacitance of two coils in one design

Table 1 shows two coils in one design have resonance frequency in KHz range. For conventional magnets, the main coils are in the LHe bath enclosed with metal helium vessel, thermal shield and vacuum vessel. It is found that there is no high peak voltage at coils' resonance frequency due to the shielding effects by the surrounding resistive components (Fig.2). Dielectric loss in coils can be taken away by LHe. For conduction-cooled magnet, one should carefully control the gradient coil fringe field and select the right metal for thermal shield, etc. to avoid excessive joule heat beyond the capability of the cryogenic system. For an aggressive design with unshielded gradient coil and magnet with composite material as support structures[4], high voltage can be induced at each main coil terminals at resonance frequencies(Fig.3) and big dielectric loss can be expected (Fig.4). Fig.5 shows in an 8-coil design, the impact to the input impedance of Z g-coil by the main coil parasitic capacitor effects. Remedies can be applied to decrease the coil parasitic capacitance, for example, by dividing big coil into several small coils in z direction.

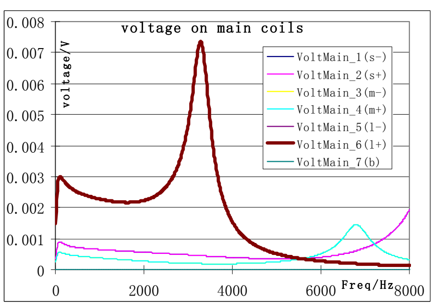

Fig.2 voltage at coil terminals, 7 coil design, shielded G-coil, Al former/TS and SS VV

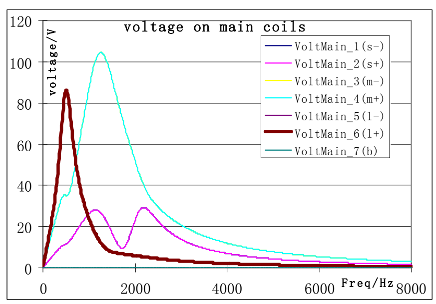

Fig.3 voltage at each coils terminals, same configuration as Fig.2 while remove shielding g-coil , former and TS

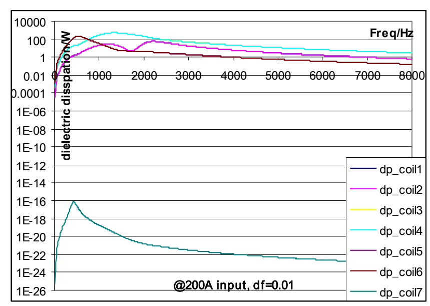

Fig.4 dielectric loss in each coils, dissipation factor=1% , same configuration with as Fig.3

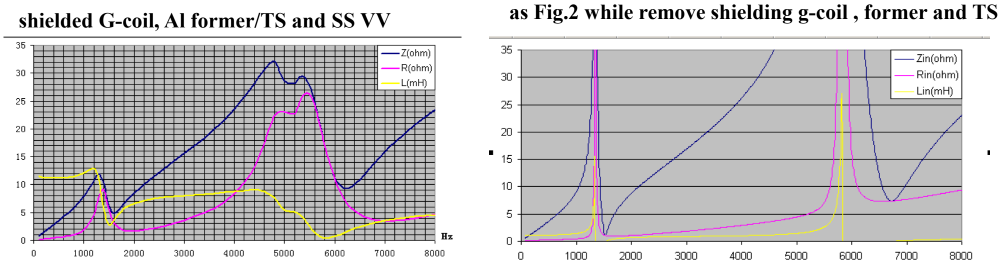

Fig.5 impact to input impedance of z direction gradient coil. (Left) measured data; (right) calculated data, unshielded g-coil, composite coil former and thermal shield, no resistive component is involved in calculation

References

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