# The Effect of Shield Proximity on the Mode Distribution of a Birdcage Resonator

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Introduction: One of the most common types of RF coils used in MR is the shielded birdcage resonator [1]. The birdcage shield is observed to affect the mode distribution significantly and at higher frequencies, may even facilitate the excitation of TEM modes [2,3]. Here we present the results of our study on the effect of the shield to coil spacing on the mode distribution of a shielded birdcage coil.

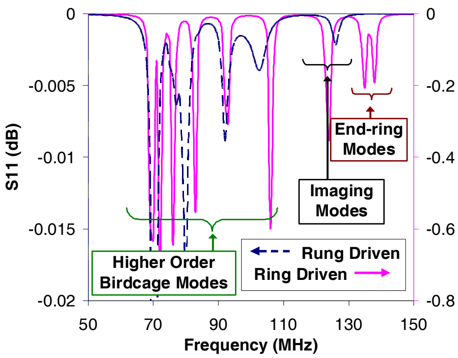


Fig. 1) End-ring modes and the modes of two coupled loops

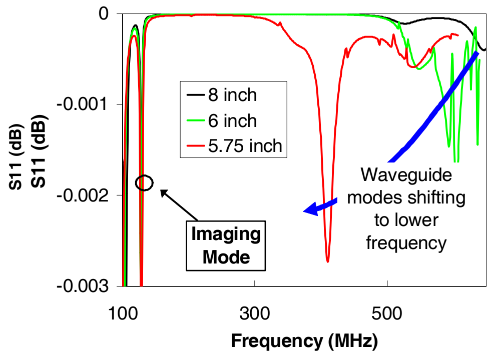


Fig. 2) Modes of the shielded bird-cage coil with the drive point in the rung.

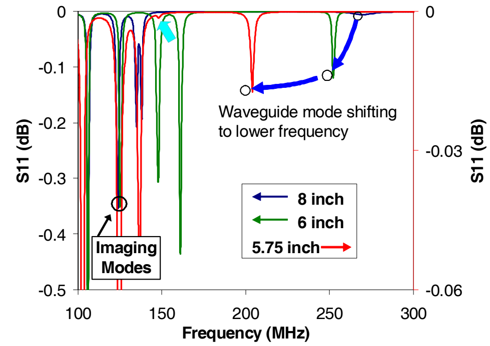


Fig. 3) Modes of the shielded bird-cage coil with the drive point in the end-ring.

Methods: A high pass 16 rung birdcage coil with a radius and height of 5.5″ and 6″ respectively was simulated in Ansoft HFSS®. Simulations were repeated for shield diameters ($R_s$) of 8″, 6″ and 5.75″ respectively. The shield height was 10″ for all case. To solve this problem properly, it is necessary to have a high mesh density in the region between the shield and the coil. In the commonly used Finite Difference Time domain (FDTD) simulator, this gives rise to an extremely large matrix size and as a result requires huge computational resources to solve. HFSS® on the other hand, is based on finite element method (FEM), which is ideally suited for this type of problem because the flexibility in grid size density at different region of the model results in a smaller matrix size, and can be solved in reasonable time.

Results: The simulated S11 plots for a shield radius of 8″ are shown in Fig. 1. The different modes of the bird-cage coil are clearly evident in the plot. In the end-ring driven case the non-degenerate modes can be seen. A high impedance (10kΩ) was source was connected in parallel to one of the capacitors in the end-ring for excitation. In the rung-driven case, due to the finite Q several closely spaced modes appear as a single mode in the plot. In this case, a low impedance (0.01Ω) source is placed in one of the rungs. These source impedances were chosen so that the resonant structure is only minimally perturbed. In Fig. 2, the effect of shield proximity on the mode profile for the rung-driven coil is shown. The modes shift to higher frequency as $R_s$ is decreased and as a result the inductance of the coil elements decreases. The imaging mode frequencies of the models with $R_s$ = 6″ and 5.75″ are tuned down using a larger capacitor values in the ring and the results for this cases are shown in Fig. 2 and 3. Note that rung excitation does not excite the end-ring modes, as the required current distribution (*i.e.* no current in the rungs) can not be achieved.

Coupling in to the end-ring modes can result in a significant field inhomogeneity inside the coil. Hence, it is desirable to move the end-ring modes away from the imaging modes, which can be done by decreasing $R_s$ as shown in Fig. 3. However, if $R_s$ becomes too small, as is the case for $R_s$=5.75,″ then the shield starts to interfere with the normal operation of the coil and the end-ring modes shift closer to the imaging mode again (block arrow showing the location of a end-ring mode). Also, the waveguide modes start to shift to lower frequencies as $R_s$ is decreased. These modes can be a problem for a loaded high frequency coil [3]. So, there is an optimum shield diameter for this case.

A close inspection of Fig. 3 also shows that the end-ring modes do not appear to follow the trend one should expect for two coupled loops. In Fig. 3 the modes of two end-rings coil (rungs removed) are shown. As the shield is brought closer to the coils, the coupling between the coils becomes gradually smaller and eventually become insignificant as shown by the complete disappearance of one of the peaks. However, in the case of the complete birdcage structure, the rings stays strongly coupled as shown in Fig. 4(a) and the coupling appears to be increasing with decreasing shield distance. Also note the S11 values in Fig. 4 is much improved over the rest of the Figs. 1-3, because a source impedance of 100Ω is used here. As evident from the plots, input impedances associated with different modes are different and as a result the source impedance has a strong effect on the excitation of a particular mode in a coil.

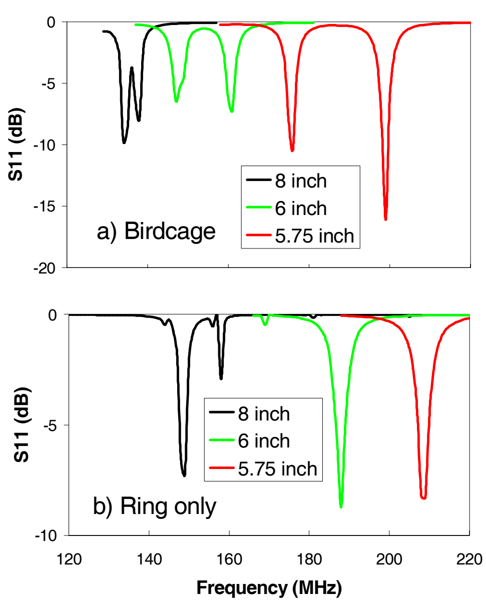


Fig. 4) End-ring modes and the modes of two coupled loops

References:
[1] Hayes CE, *et al.* J Mag Res 63: 622-628 (1985) [2] Vaughan JT, *et al.* MRM 32(2): 206-218 (1994) [3] Reza S., Proc. ISMRM. 14: 1387 (2006)