RF Body Coil symmetry as a function of cable routing

Ed B Boskamp[1], Masahiro Fujimoto[1], and Michael Edwards[1]
[1]*GE Healthcare, Waukesha, WI, United States*

Introduction: The purpose of this investigation is to examine RF body coil symmetry when a cable bundle is routed through the body coil. The cable bundle is typically going to one or more receive coil connectors at the head end of the cradle, baluns (1) are applied to weaken the common mode current on the cable shield. Such cables travel through the body coil when the patient cradle is moved. If there is an asymmetry due to the presence of the cable, then that asymmetry will vary when that cable is moved.

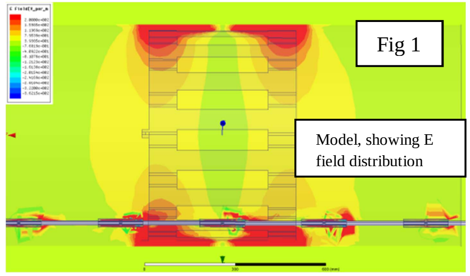

Fig 1

Methods: A whole body RF birdcage coil was modeled in a FEM analyzer (HFSS, Ansys) The body coil is a high pass 16 rung design (fig 1) with 32 100.8 pF capacitors per endring that resonate it at 127.7 MHz. The rung width is 1/32 of the circumference, the endring width is 95 mm. RF coil diameter is 706mm, length is 495 mm. The RF shield diameter is 746mm with a length of 1600 mm. Two 50 ohm ports directly across 2 endring capacitor locations, 90 degrees apart, drive the body coil with 1W per port at a 90 degree phase difference. The conductivity of the coil and the RF shield was changed to give the coil a Q of 400 empty. The cable bundle is simulated by a 2500mm long copper rod with a radius of 7.9 mm. Baluns are 150 mm long, and have an inner radius of 12.7 mm. The front and rear are connected to the cable shield. A 9.4 mm gap in the center of each balun contains 4 capacitors of 19 pF with a parallel resistance of 5.4 Kohm. The baluns are shielded by an outer shield that has a radius of 15 mm but is only connected to one side of the balun. The baluns resonate at 127.5 MHz and have a total impedance of about 1.35 Kohm. The cable position is varied from 38 to 85mm from the inner bore wall in the same plane as one of the drive ports, and from -684 to +684 mm in the z direction. The number of baluns is varied between 4, 5 and 7. In the case of 5 baluns the gap between baluns is 190mm. In the case of 7 baluns they cover the same length of cable with inter-balun gaps of 76 mm. The 4 balun case is similar to the 5 balun case, but with the center balun removed. The number of cables is varied between none, 1, 2 (90 degrees apart). The body coil is either empty or loaded with 2 different sizes of phantoms. E field, B field, surface current density J, capacitor voltages and Body coil S parameter perturbations are studied. In a lab setting, a similar body coil and a similar cable are set up in the same RF shield as above. S parameter measurements are done while the position of the cable is varied. The measurement results are compared with the simulations.

Results: The results shown in fig 2,3,4 are for a single cable with 5 baluns in an empty body coil, shifted in the direction of one of the drive-ports. In fig 2 baluns are 38 or 85 mm from the bore. The reflection coefficient at the minimum is along the vertical axis in dB. The Z position of the central balun is along the horizontal axis. There can be up to a 2.7 dB difference in reflection. This translates into a net forward power difference of 0.4 dB, which needs compensation to make the field circularly polarized. Loading the coil with a phantom equivalent to a 75 kg patient, we still see the same difference but since the reflection coefficients are both below -20 dB it makes the asymmetry negligible. Going from 5 to 7 baluns we see 6 minima instead of 4 in the reflection versus Z curve. The magnitude difference is similar as with 5. Omitting the center balun we see 2 minima in the reflection versus Z curve. The magnitude difference is 6 dB. Having 2 cables in the bore at the same distance but 90 degrees apart over the 2 drive ports, we see the same curves for S11 and S22, so the symmetry returns.

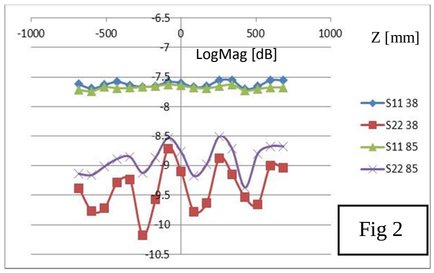

Fig 2

Measurements with a similar body coil and cable show that the impedance normalized to a no cable scenario can go as low as 0.9 when the distance to the bore wall is varied down to 38 mm from the bore (Fig 3). Simulations show an asymmetry of up to 0.87, so there is good agreement. The B field is slightly distorted close to the baluns, but negligible in the patient volume. The E field pattern is distorted close to the baluns that are close to the end rings. There may be local SAR consequences depending on the proximity of the cable to the patient and the net average forward power applied in the pulse sequence. The voltages in the baluns exceed 35V per isocenter µT of B_1^+ for baluns at the endring locations and 38 mm from the bore as shown in Fig 4. The asymmetry with respect to the endring locations in fig 4 is caused by the high E field openings in the balun RF shields being at one end of the balun towards the negative Z axis. The currents in the baluns when they pass over the endring is up to 3 times as high as in the balun at z=0 with baluns 38 mm from the bore wall. Those baluns will see 9 times the temperature rise compared to the center balun.

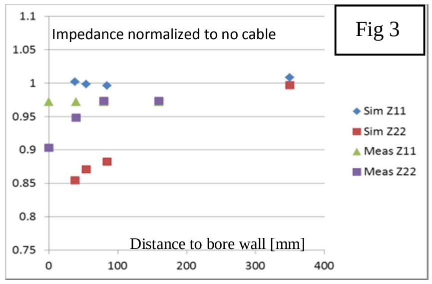

Fig 3

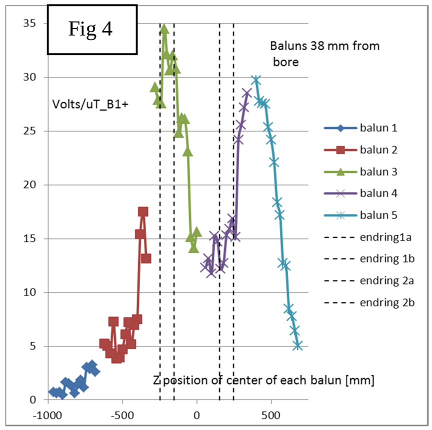

Fig 4

Discussion and conclusions: Birdcage symmetry is perturbed when a cable with baluns runs through the coil. Obviously it is best to run any cable outside the RF shield, but in many cases this is not possible. The asymmetry of the coil maximizes each time a balun crosses the endring plane, where the E fields in the coil are the highest. At that point the voltages and currents in that balun are many times those in baluns away from the endring. The voltages, currents and power dissipation in the balun depend on the distance between the balun and the bore wall, and get bigger with decreasing distance. The asymmetry of the body coil as a function of cable z position can be further minimized by increasing the number of baluns per unit cable length (at least 3 are needed over the length of the body coil), increasing the distance to the bore wall, placing the cable in a symmetry point, like in the middle between the 2 body coil ports, or adding a second identical cable on the opposite side of the coil symmetry plane. Without counter measures the polarization of the coil is slightly elliptical. The eccentricity increases when the cable is closer to the bore, and when shifted in the z direction, where a balun passes the endring plane.

References: (1) B.L. Beck et al. ISMRM Proc 2000, #641