Broadband damping of cable modes

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

Introduction On RF Body coil and receive coil cables unwanted currents are induced due to the E field generated by any RF coil in the bore. The most intense currents happen during the transmit pulse when several 1000 V/m of E field is generated by the body coil. This large E field is very inhomogeneous, and the induced cable current magnitude will depend on the length, the position and the route of the coaxial cable. In many cases the cable currents on receive coil cables residing in the bore is the most intense, but also induced currents on the body coil RF and DC cables. In almost all cases, these currents interfere with the proper tuning and matching of the coils. The induced currents can give rise to large SAR values in the patient if the cable is close to tissue. The standard way of eliminating these currents is to apply baluns (1), which are parallel resonant tank circuits in which the inductance is formed by certain length of the cable's shield. The reactance is low, giving rise to a significant resonant current in the balun, and large local heat generation around the capacitors. In a lab setting we can kill cable modes by clamping ferrites on the cable, they are broadband, and do not require tuning, but cannot be used in a magnetic field. We now propose to add a dissipative non magnetic material, Carbon filled polypropylene to the outside of the coax.

Method In order to be RF coil independent, we built a set of 20 cm long electric dipole antennas, 14 cm apart, and placed in the center of a 4 feet long 75 cm diameter RF shield (fig. 1). Cables connecting the dipoles to the network analyzer are exiting the RF shield in the center through a small hole. The coax shields are electrically connected to the RF shield, hence the cables going to the analyzer are quiet. We measure the S21 between the 2 dipoles and normalize the curve. Now we place a coaxial cable between the 2 dipoles hoping to see a resonance at which the cable is a multiple times a half wavelength. We used 116 cm of 50 ohm Huber Suhner sucoform 250-01 FEP. In placing it between the dipoles we observe a resonance at about 120 MHz (fig 1). This is the frequency at which the cable is half a wavelength long. We will now place different amounts and shapes of 30 mil thick carbon filled polypropylene (PP) on top of the coaxial cable, conductivity 3.6 S/m and permittivity 2.2. We observe S21 for detuning and damping of the cable mode.

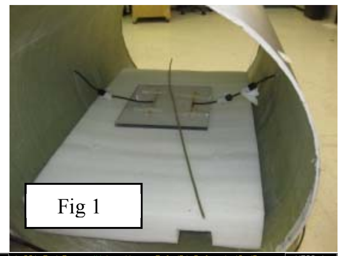

Fig 1

Results In fig 2 we observe the resonance at which our cable mode is a half wavelength long (120 MHz).The highest E fields are at the 2 ends of the cable. Placing a 40 by 135 mm patch of the PP sheet there gave the results shown in fig 3, a damping of -11 dB. These results are confirmed by a FEM simulation in HFSS (Ansys corp.) shown in fig 4, where the blue curve is the S21 showing the cable mode without PP, the red curve is with the PP's long axis aligned with the cable, the green curve has the PP perpendicular to the cable. E field plots before and after placing the PP are shown in figs 5 and 6. Note the difference in scale: 500 in fig 5 and 15 in fig 6. HFSS also calculated the power dissipated in the PP as a percentage of the power going into the Tx dipole. It is 12.3% for the parallel PP and 24.8% for the perpendicular PP. To understand whether this is only an edge effect, we made the cable mode 1.5 wavelengths long by going to 360 MHz. Placing the PP over the voltage maximum 1/3 up the cable, we observed similar damping. Finally, a rectangular loop, 200 by 400 mm with 6 capacitive junctions (4x 10pF, 2x 18pF), resonant at 127 MHz with a 180 degree cable across 1 junction, was measured to have a Q of 250 without the PP patch, and 230 worst case with the PP patch on the cable.

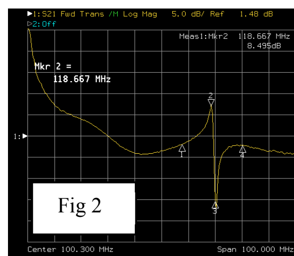

Fig 2

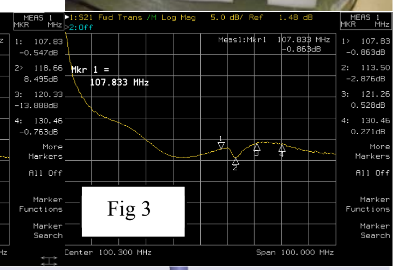

Fig 3

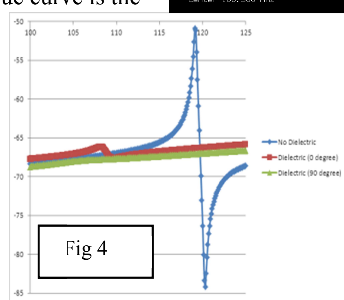

Fig 4

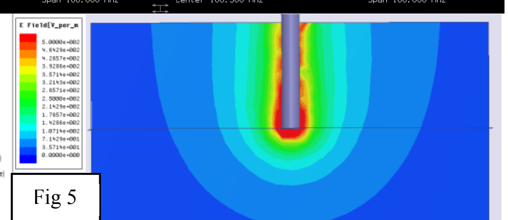

Fig 5

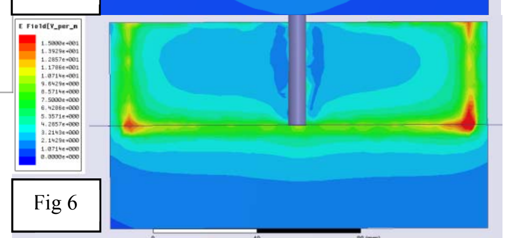

Fig 6

Discussion Instead of weakening the cable modes using tuned circuits like baluns, we have found that adding the right material to high intensity voltage nodes in the cable will damp the cable mode enough. When attached to a coil, there is a minimal impact on the empty coil Q but no impact on the loaded Q. Tuned baluns also dissipate energy depending on their reactance, and our solution is broadband. . In many cases only a small fraction of the power is dissipated in cable modes. HFSS simulation shows that all the E field and surface current is at the perimeter of the patch. The fraction of the energy that is dissipated in the patch will cause a slight temperature rise during high power applications (test in Body coil with same cable at 15 uT, 6% showed 10 C rise on the perimeter of the patch). The temperature rise is limited by increasing the perimeter of the patch.

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