Low Eddy Current RF Shield Design for MR System

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Introduction: Today's powerful gradient coils produce large eddy currents in the RF shield, resulting in significant heating. The magnitude and location of the eddy currents depend on scan duration and gradients used. Stressful EPI and/or Spiral scans can deposit as much as 1000-1500W of power in the shield and do so non-uniformly. This non-uniform heating is deleterious for the performance of thermally sensitive PET detectors in a simultaneous whole body PET/MR system. To address this problem we present here a novel integrated RF coil and shield which not only provides excellent MR IQ but also provide a cooler, more stable thermal environment for the PET detectors.

Method & Result: An integrated whole body RF body coil - RF shield has been designed for our simultaneous SIGNA 3.0T PET/MR system to minimize the eddy current heat generation on the shield. This is of particular interest as in a simultaneous PET/MR system the detectors reside inside the MR bore space and are in close proximity to the shield centered along the magnet axis. To maintain good PET image quality, the temperature requirement of the detector environment has to remain below 30^{o}C over any scan period. Standard practice in any MR system is to cool the shield by some sort of mechanical (air/water) cooling, which may not be feasible everywhere because of spatial restriction as well as due to the danger of water near high voltage components. In other instances multiple slits running parallel to the z-axis have been used on the shield to minimize the eddy current heating which resulted in sub-optimal RF performance. Thus, we designed a shield (Fig 1a) with minimal number of slits which run both axially as well circumferentially at strategic locations to block the eddy current paths and to keep the detector space temperature below 30^{o}C. In some locations, slits are shorted by capacitors to keep the RF current flow intact. The number of capacitors on the shield has also been minimized to improve the reliability of the product. This shield was compared for RF and thermal performance with a standard shield with no slits and capacitors. A 16 rung high pass body coil (Fig 1b) tuned to 127.72 MHz was used in both the shields to quantify the overall performance. Utilizing the standard NEMA SNR tool, the following measurements were taken:

Type of Shield	Empty B1 Efficiency	50kg Phantom B1 Efficiency	NEMA SNR
Slit Shield	40.1	29.7	93.5
Solid Shield	40.4	28.6	89.0

Additionally an EPI sequence (EPI-Y/EPI-Z with a TR of 205/155ms) was chosen to study the thermal performance of the shields. With the slit design, a maximum temperature of ~27^{o}C was recorded in an hour at the central section of the shield where the detectors would reside compared to ~50^{o}C measured with the standard shield. The maximum temperature measured outside the central section on the slit shield was ~52^{o}C which is comparable to ~47^{o}C measured in the standard shield. The slight increase in temperature at the outer location is due to increase in current concentration from various slitting operations. Figure 1c shows the temperature plots measured at various locations on the slit shield. By limiting the thermal excursion in the vicinity of the detector, we create an environment in which the PET detector, which has additional internal thermal compensation mechanisms, can perform effectively.

Conclusion: Thus, we have developed a whole body RF coil with an integrated slit RF shield which not only maintains excellent MR image quality but also improves the PET image quality. This has been achieved by optimizing the slit pattern over the entire shield and without the use of any mechanical cooling. It is purely an EM solution and can be translated to shield problems with space constraint, to reduce cost or to improve reliability of the product.

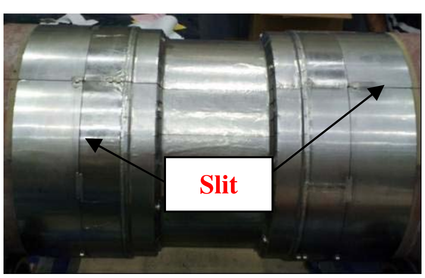

Fig 1a: Slit shield design

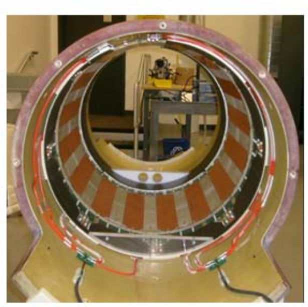

Fig 1b: RF Coil

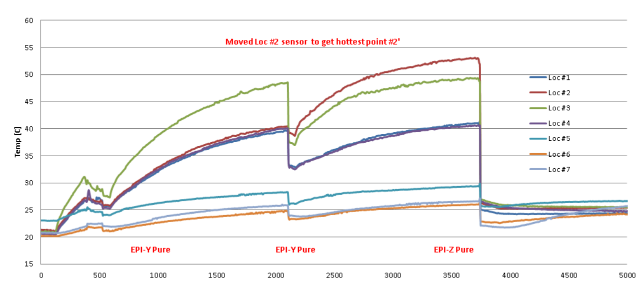

Fig 1c: Temperature plot on the slit shield