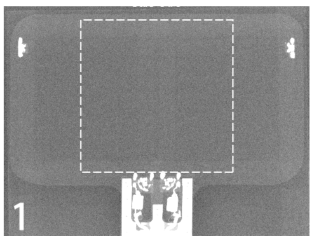
# X-Ray Compatible RF-Coil for MR Imaging

V. Rieke[1,2], A. Ganguly[1], G. C. Scott[2], B. L. Daniel[1], J. M. Pauly[2], R. Fahrig[1], N. J. Pelc[1], K. Butts[1]

[1]Radiology, Stanford University, Stanford, CA, United States, [2]Electrical Engineering, Stanford University, Stanford, CA, United States

**Introduction** Magnetic resonance imaging and x-ray fluoroscopy are powerful tools for guiding interventional procedures. Both imaging modalities can be implemented in a hybrid system combining the advantages of each. However, certain restrictions are imposed from one modality on the other. For the reception of MR signals, an RF-coil has to be placed on or around the patient near the region of interest. X-ray fluoroscopic images on the other hand can become useless for image guidance if x-ray attenuating materials, located between the x-ray source and detector, obscure patient anatomy. Unfortunately, materials used in conventional RF-coils are highly x-ray attenuating. Removing the RF-coil when switching from MR to x-ray image acquisition disrupts the procedure and is impractical for coils positioned underneath the patient. The purpose of this work was to design an x-ray compatible RF-coil with minimal x-ray attenuation such that x-ray fluoroscopic images are not degraded by the presence of the RF-coil in the FOV, while maintaining excellent MR image quality.

**Methods** For the design of an x-ray compatible RF-coil all coil components that potentially lie in the FOV of the x-ray image, i.e. in the path of the x-ray beam, should have minimal x-ray attenuation. To minimize the attenuation by the loop conductor, we used aluminum (Al) as the conductive material which has a significantly lower atomic number (Z=13) than the commonly used copper (Cu, Z=29). The AC conductivity of Al is 80% of the conductivity of Cu. We measured the x-ray attenuation of a 50 $\mu$m thick Al strip and a 36 $\mu$m thick Cu strip by placing both strips directly on the x-ray detector, and compared it to the theoretical value calculated by an algorithm described by Boone [1] for anode voltages ranging between 50 and 110 kVp and different filters at the x-ray source. In a second experiment the strips were placed on 20 cm Lucite which yields a scatter behavior similar to that of the human body. This measurement was taken at 80kVp with a 2 mm Al and 2.5 mm Cu filter.




Using the 50 $\mu$m aluminum foil, we built a four element abdominal phased array (PA) for 0.5 T. Fig. 1 shows two elements of the x-ray compatible PA; the 20 x 20 cm x-ray FOV is indicated by the white square. The capacitors were placed in the loop outside the x-ray FOV, or moved into the detuning circuit. For smaller surface coils, where the loop can lie completely inside the x-ray FOV, the discrete capacitors can be replaced by strip capacitors built by using the aluminum foil itself. This also eliminates the need of soldering joints in the loop conductor which would be visible in the x-ray image. Since the circuitry containing the detuning circuit, baluns, and cable connections can be easily designed to lie outside the x-ray FOV, the use of low x-ray attenuating material is not necessary for this. To evaluate the x-ray transparency of the coil, x-ray images of a porcine spine were taken with the coil in the FOV (80kVp, 2.5 mm Cu). MR image quality of the x-ray compatible PA was compared to a single channel receive-only coil, currently used in hybrid procedures, and to a conventional abdominal PA (SPGR, TR/TE/flip/BW = 40ms/5.5ms/50/31kHz). In addition, the quality factor Q of the x-ray compatible PA was determined. MR Images were acquired on a 0.5T Signa SP MRI scanner (GE Medical Systems, Milwaukee WI) with an integrated x-ray fluoroscopy system [2,3] consisting of a fixed-anode x-ray tube and a high voltage generator (GE OEC, Salt Lake City UT), and a 20 x 20 cm flat-panel detector (GE Medical Systems, Milwaukee WI).

**Results** Fig. 2a shows the x-ray attenuation of the aluminum (left) and copper (right) strip for 50 kVp anode voltage and a 4 mm Al filter. The measured x-ray attenuation is 22% for the copper strip and 1.1% for the aluminum strip. The results compare well to the theoretical attenuation of 24.2% and 1.3%, respectively. For higher anode voltages the attenuation of both strips decreases. Figure 2b shows the x-ray attenuation of the strips placed on top of a 20 cm Lucite layer containing a guide wire phantom. The aluminum strip is not detectable while the copper strip remains visible in the image.

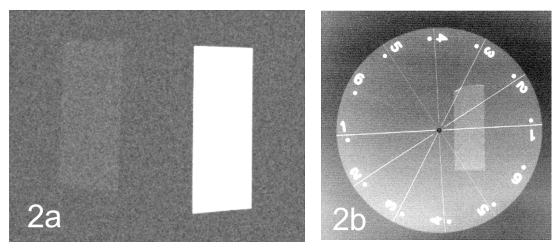
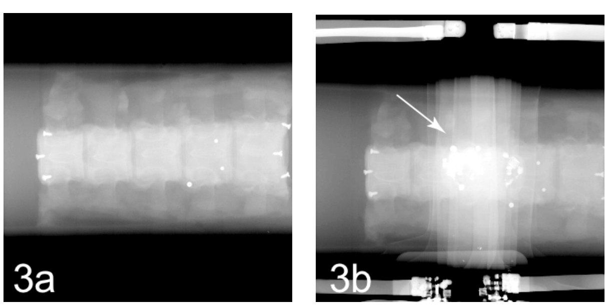
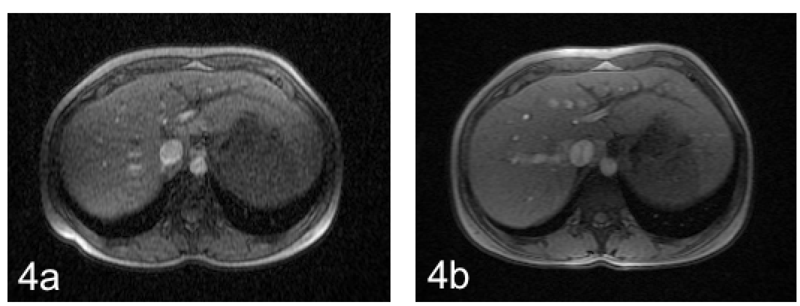



Fig. 3a shows an x-ray image of the porcine spine phantom. The x-ray compatible PA is placed around the phantom but is not detectable in the image. For comparison, the same image was taken with a conventional abdominal phased array in the FOV, seen in Fig. 3b. Copper traces and discrete elements (arrow) of this coil are visibly degrading the fluoroscopic image making this coil unusable in a hybrid system. We measured an unloaded/loaded Q of approximately 270/40 for the individual coils in the x-ray compatible PA. Fig. 4 shows abdominal MR images acquired with a single channel receive-only coil which is commonly used in hybrid procedures and with the x-ray compatible PA. The SNR of the phased array improved by 60% compared to the single channel coil. Compared to the conventional abdominal phased array, the x-ray compatible design achieved the same SNR.




**Discussion** The use of x-ray compatible RF-coils in a hybrid system allows for x-ray fluoroscopic image acquisition with minimal or no impact by the RF-coil without compromising the MR image quality.

**References** [1] Boone J. M., et al, Med Phys 24:1661-70 (1997). [2] Fahrig R., et al, JMRI 13:294-300 (2001). [3] Fahrig R., et al, Acad Radiol 8:1200-7 (2001).

**Acknowledgements** NIH R01 77677, NIH P41 09784, NIH R01 00198