Surface coils with integrated differential amplifiers

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Purpose: We have designed, fabricated and tested surface coils with integrated differential amplifiers. These coils can be used as untuned Hertzian loops, making them ideal for array applications.

Introduction: Most surface coils used in MRI are tuned to the Larmor frequency of interest, matched to 50 Ω, and attached to a preamplifier by a length of transmission line. The tuning of the coil is a consequence of the need to match the transmission line impedance, and helps to avoid significant losses in the transmission line[1]. Tuning the coil leads to high currents during reception that can create significant coupling between adjacent coils in an array. However, it is not necessary for a coil to be tuned in order to receive an NMR signal[2]. This is the principle behind preamplifier decoupling of array coils: the preamplifier creates a high impedance in the coil – effectively detuning it – reducing currents in the coil[3]. By integrating an amplifier directly into the coil we not only eliminate transmission line losses, we also eliminate the need to match the coil impedance to 50 Ω. This allows the coil to be operated without tuning. The high impedance of this coil makes it ideal for use as an element in an array, as coupling between adjacent coils will be minimal.

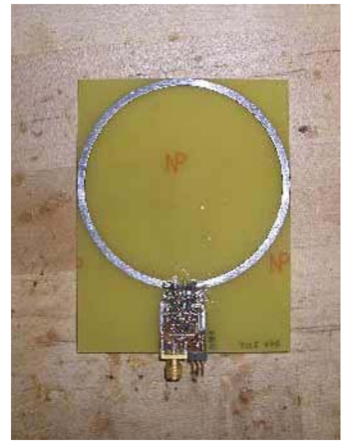

Figure 1 Untuned coil with integrated amplifier.

Methods: Two surface coils, three-inches in diameter, with integrated differential amplifiers were fabricated on printed circuit board (Figure 1). The amplifier, which occupies less than one square inch of space, consists of a low-noise operational amplifier fed by two GaAs high electron mobility transistors (HEMTs). Because the amplifier is differential, there is no need for a balun transformer between the coil and the amplifier. While the initial design included some slightly magnetic components, all components in the amplifier are available in nonmagnetic packaging. The estimated noise figure and gain for the circuit are < 0.5 dB and 25 dB, respectively. The amplifier is powered by a separate bipolar power supply.

Results: The frequency response of each coil and amplifier is nearly flat from 40 MHz to 130 MHz, meaning that the coils could be used at a wide range of field strengths, or to examine different nuclei, with no change of components. Figure 2 shows phantom images using the two coils as an array, using a birdcage coil as the transmitter. Very little coupling between the two coils is evident, although the coils were nearly touching with zero overlap. Figure 3 shows a FLASH image of a wrist taken with one of the coils, using a Helmholtz pair as the transmitter. The sequence used a TR = 500 ms, TE = 9.7 ms, flip angle = 25°, slice thickness = 2 mm, 2 averages, a field of view of 90 x 120 mm, and a matrix size of 192 x 256. The total acquisition time was six minutes.

Conclusion: It is possible to obtain high resolution images with high signal-to-noise ratio using untuned coils with integrated amplifiers. Additionally, when used in an array there is very little coupling between adjacent coils. The flexibility and ease of use of such coils make them highly attractive for a wide variety of applications.

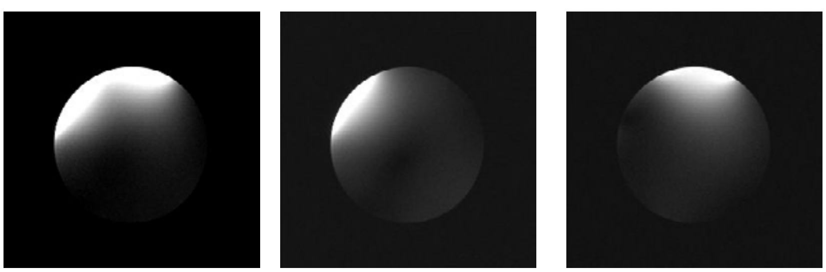

Figure 2 Phantom images taken with two untuned coils used in an array. Left: combined image; middle, right: uncombined images.

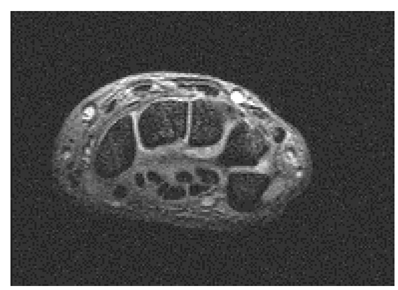

Figure 3 3D FLASH wrist image taken with an untuned receive coil.

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