A flexible highly configurable 16 channel array coil for fetal imaging

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Introduction:

There is growing interest in fetal MRI with an increasing number of centres performing this examination for both clinical and research purposes. There are currently no purpose designed coils for fetal imaging and so most studies use arrays designed for torso or cardiac imaging. These coils do not conform well to the pregnant torso and have limited coverage. Abdominal and cardiac coils with a large number of receiver elements have tended to be both heavy and of rather rigid geometry. In this work we set out to design a receiver coil system specifically for fetal imaging taking into account the challenges set by the location of the fetus within the uterus and the need to ensure that pregnant women can be positioned comfortably for imaging (typically in a lateral tilt). The head of the fetus (often the focus of imaging) can be anywhere within the uterus. The shape of the uterus changes significantly as pregnancy develops and can be markedly different from mother to mother. The fetus frequently moves during an imaging session. Thus the coil should support a large field of view to ensure coverage regardless of changes in fetal position, allow for imaging at depth, particularly when the fetal head is engaged, and accommodate the wide variety of maternal shapes with flexibility in scanning position. We have embarked on development of a 16 channel flexible array for fetal imaging at 1.5T based on these criteria.

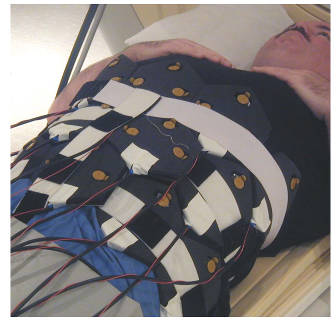

Fig 1 Conformal Harness

Coil design:

An anthropomorphic foam model of a 33 week pregnant woman was built based on published data and measurements taken on 6 pregnant mothers. The need to image from pubic symphysis (to see the engaged head) to head of fundus with full LR coverage led to the choice of a 16 loop design with loops sized and shaped to achieve useful SNR at depth on the larger patient and close packing on the smaller. An elasticated velcro harness was designed with three lateral straps and one passing between the legs that could be first fitted and adjusted to the mother. The loops could then be distributed evenly to provide optimal coverage and held in close contact, crucially at the pubic symphysis. Individual loops (Q unloaded: 120 Q loaded: 20) were designed and tested to match the SNR performance of a commercially available loop of equivalent size (Philips Healthcare Systems). A Spiral coil architecture aided in presenting 50 Ω across an open junction allowing reliance on preamp decoupling isolation [1]. Low output impedance preamps (Pulseteq Ltd, Guildford, UK) located at the end of ¾ wavelength cables presented 400 Ω to open junctions of the loops effectively isolating each loop from its neighbours (Fig 5). All preamps could thus be located remote from the loops [2] allowing for an optimally compact design. Preamp driver circuitry and current distribution, ID circuitry and preamp protection in the form of cable baluns on inputs and outputs were also remotely located (Fig 4). Each loop was decoupled during transmit using pin diodes at two capacitor junctions driven by currents provided by the MR system with a back up system of a set of back to back diodes across a third junction. 1.5mm neoprene was used as the coil substrate with closed cell foam and fabric covers to produce a semi flexible loop.

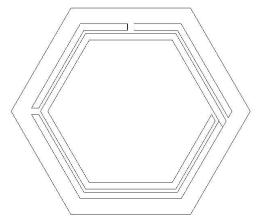

Fig 2 Loop Architecture

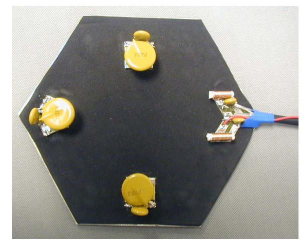

Fig 3 Loop Components

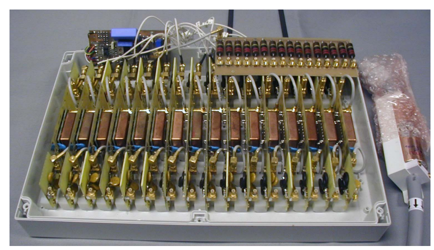

Fig 4 Interface

Results:

Design ergonomics and coverage have received the initial approval of the clinical team based on model and volunteer presentations. The design allows the loops to be arranged and adjusted on the patient ensuring full coverage of the uterus without compromising the most tolerable positioning.
Figure 5 shows a coronal section of a phantom with a sum of squares reconstruction of all coils and below a single element from the same acquisition, confirming effective coil isolation.
Figure 6 shows a zoomed central section of a typical FFE image: TR/TE 200/6 0.7x0.7mm pixel size 16cm FOV shown. The coil is initially being tested as an abdominal coil on a healthy adult male.

Discussion:

We have developed a patient friendly 16 channel fetal coil for use at 1.5T. Initial results suggest that this flexible use of multiple coils with a freely configurable harness can allow effective coil positioning on pregnant women and allow them to assume a comfortable examination position. Test results on the coil elements confirm that coil performance is as expected. The next stage will be to image fetuses, which awaits further safety testing.

References:

1. Roemer et al.'The NMR phased array'. Magn Reson Med. 1990 Nov;16(2):192-225.
2. Boskamp et al. 'Array SNR and Coupling Versus the Input Impedance of the Preamplifiers' Proc, ISMRM, 15th Ann Mtg, 2007, p1048.

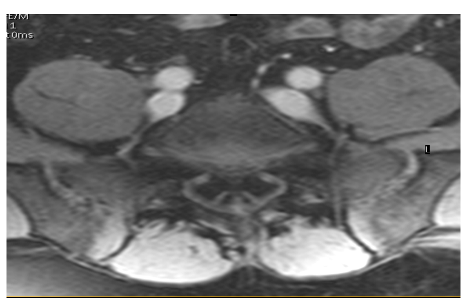

Fig 6 Abdominal Image

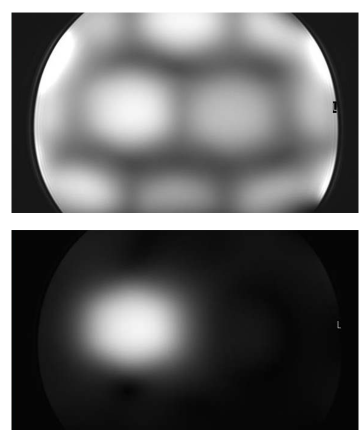

Fig 5 Isolation