An 8-Channel Integrated Balun Phased Array (IBPA) for Small Anatomical Features

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Introduction:

Conventional loop coils are widely used for constructing phased arrays in MR imaging. The size of individual coils in modern arrays is relatively large, which in turn, limits the maximum achievable channel count and acceleration. To reach a very large number of elements and realize the advantages of highly-accelerated imaging, the size of each loop coil in the array needs to shrink. Likewise, for accelerated imaging of small anatomy, (e.g. the fingers), the size of the coil elements in an array has to be small enough so that each element has a unique sensitivity profile. Regardless of the motivation for reducing coil element size, with a small loop size the placement of the feed circuitry becomes a limiting factor in the design. A conventional planar approach is not possible, because the components and traces would interact and cover adjacent elements.

A novel approach to building phased array coils from small elements is presented in this abstract. The approach uses small feeder circuit boards oriented perpendicular to the coil elements to minimize interactions between the feeder boards and the coils. The feeder boards are made smaller than conventional feeder circuits by incorporating a novel Integrated Balun Coil (IBC) design that reduces the number of components needed to create balanced coils in an array. The benefits of an IBC array were investigated using an eight-channel array with small elements for high-resolution imaging of small objects.

Materials and Methods:

A phased array of eight receive channels was constructed with integrated balun coils. These coils combine a balun with each loop coil for common mode suppression. Each integrated balun coil is constructed using 2.196mm diameter semi-rigid coaxial cable on one half of the loop and 2.196mm in diameter copper tube on the other half. The center conductor of the semi-rigid coax is connected to the tuning capacitor which is comprised of a fixed and a variable capacitor placed in parallel. The shield of the semi-rigid coax is connected to the copper tube near the feeder circuit (i.e opposite from the tuning capacitors). A schematic is shown in Figure 1.

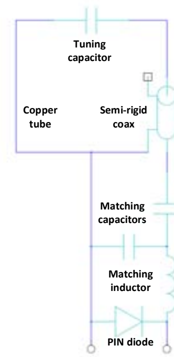


Figure 1: *IBC schematic.*

The eight-channel array is 10.7cm long, 5cm wide, and mounted on a 17.8cm x 15.7cm x 4.2cm Lexan coil former. Each coil was tuned to 127.74MHz. Coils were overlapped for minimum mutual inductance by hand and fixed in place with hot glue. A 3-layer stack up was used to accommodate the solid loop design. The whole array was tuned and matched to a human hand. S-Parameters were measured with a Rhode & Schwarz ZNC Vector Network Analyzer. Measurements for the diagonal elements of the S-Parameter matrix (S11) were performed by connecting each individual channel to the analyzer while the other elements were preamp decoupled. Transmission measurements (S21) were performed by connecting the desired channels to both network analyzer ports. Channel numbering starts with the element on the right bottom of Figure 2 followed by number two in the coil row above. Number 3 is the coil bottom row to the left of channel 1 and so forth. The S-Parameter matrix is depicted in Table 1.

Imaging measurements were performed on a Philips 3T Achieva™ (Philips Healthcare, Best, Netherlands). For safety a cable balun was added between the array and the MR system interface. For phantom imaging a turbo spin echo sequence was used with a 90° flip angle, a TR:305msec, a TE:15msec, an FOV of 50mmx50mm, a slice thickness of 3mm, and coil sensitivity balancing (CLEAR) was enabled. Axial images of the fingers were acquired using a turbo spin echo sequence with a 90° flip angle, a TR:305msec, a TE:15msec, a FOV of 60mm x 60mm, a slice thickness of 3mm, and CLEAR enabled. Coronal hand images were acquired with the same sequence and the following parameters: TR:2161msec, TE:27msec, FOV:70mm x 70mm, and slice thickness of 1.5mm.

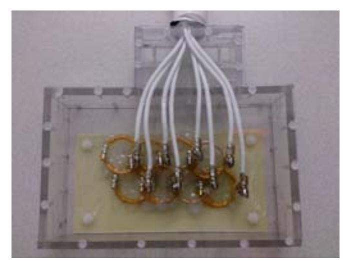


Figure 2: *8-channel array using integrated balun coils.*

Results and Outlook:

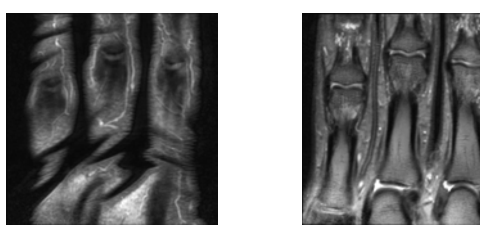
A matching of better than -18.9dB to a human hand was achieved for all channels. Coupling was observed between channels, with the worst coupling between channels 3 and 5, and channels 3 and 6. Coupling between the next-nearest neighbors was in general worse than the coupling to adjacent coil elements. The coupling is thought to be due to sub-optimal coil overlap arising from the layered hot glue construction, and the use of 50Ω ports on the network analyzer (i.e. not having the advantage of low impedance preamp decoupling).

A voxel resolution of 0.4mm x 0.4mm x 3mm was achieved with standard scanner settings during imaging. Figure 3 shows one axial slice of a banana and fingers of the right hand. In Figure 4, coronal images of three fingers of the right hand are depicted. Fine details like blood vessel and bone structures can be seen.

Improvements to the design are currently being developed to make this technology more manufacturable. This novel technology enables the design of ultra-high dense arrays which will allow new applications in parallel imaging and ultra-short acquisition. Moreover, this technology will be ideal for dedicated pediatric phased arrays to achieve high temporal and spatial resolution, potentially without the need to sedate a child because of the short acquisition time.

a) b)

Figure 3: *Axial images of a) banana phantom b) human fingers.*



a) b)

Figure 4: *Coronal in-vivo images of hand a) close to hand palms and b) at finger center.*

CH	1	2	3	4	5	6	7	8
1	-22.0	-15.0	-10.3	-7.7	-9.1	-11.8	-23.8	-23.4
2		-26.0	-11.5	-22.2	-7.0	-8.1	-12.6	-27.6
3			-18.9	-9.6	-6.2	-6.2	-12.7	-29.8
4				-21.0	-13.0	-14.1	-10.8	-9.1
5					-27.5	-7.5	-12.0	-10.0
6						-30.1	-18.2	-15.6
7							-25.0	-18.5
8								-22.0

Table 1: *S-Parameter Matrix in dB.*