Flexible 8 channel receive only array for elbow imaging

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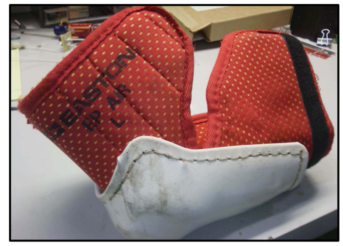
Introduction: The lure of desirable loading conditions and increased SNR has made experiments in flexible coil arrays of great interest in recent years. The elbow anatomy is an excellent candidate for a dedicated flexible array due to the significant obstacles met with a flexible design. Light-weight and unobtrusive coil size is imperative to accommodate 'arm-at-side' position which is far more comfortable than a 'superman' position. Additionally, a rigid coil design will exclude most patients with trauma to the elbow due to pain and discomfort possibly caused by fitting the coil for a scan. Indeed, patient and coil size constraints have made designing an RF coil that can provide high resolution elbow images a very difficult task for commercial interests as evidenced by the lack of products offered. We attempted to meet these obstacles by designing a coil that has a high degree of flexibility combined with high (8) channel count. Due to the difficulties of prototype construction, poor element to element isolations will be tolerated, instead emphasizing maximizing resistive losses [1] associated with loading and also by utilizing very low impedance preamplifiers placed at the input to each element [2]. The attainment of flexibility is of greatest concern as the benefits include greater sample loading and closer element to anatomy proximity for higher signal reception. The coil will be designed for a 1.5T system as this represents the application with reasonably high market penetration in order to be able to reach the largest patient population.

Materials and Methods: An excellent source to start with when looking for a mechanical former that can attain close proximity to human anatomy is sports equipment. In the case of protective padding, development work has already been done in creating a form-fitting material that can attach itself to a large population of subjects. We chose a hockey sports pad made by Easton, shown to the right. The drawback is that the pad was originally designed to keep arms bent to a 90 degree angle. It is desirable to have the elbow bent closer to 20 degrees in order to position the ligaments of the elbow for diagnosis. To achieve this, we deconstructed the pad by removing the hard plates meant for protection from blunt impacts, and then cut the pad in half. An auto-upholsterer was then employed to sew the pad back together at an optimal angle and also to add a hole for repeatable elbow placement. The hole allows palpation of the elbow to obtain consistent optimal placement within the coil.

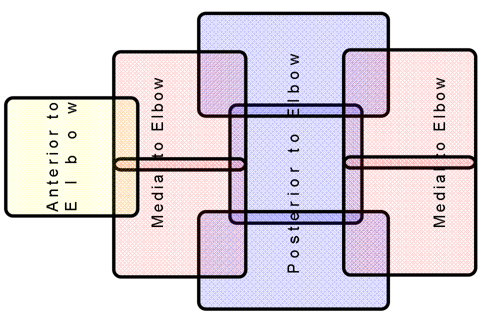


In regards to safety, a flame retardant spray was applied to the fabric material prior to construction. Additionally, a safety cover (not shown) was also constructed to shield the patient from hazardous shock.

In order to create channel elements while achieving the desired flexibility, a stranded wire was chosen to serve as the conductors for loops elements that were to be placed where the elbow will fit inside the coil. This allows the elbow pad to retain the ability to wrap and attach to the arm around the elbow. The advantage is that the coil can wrap around small (less than 7cm diameter) and large (greater than 12cm diameter) elbows. In choosing the stranded wire, resistive loss was measured in several types of wire and the flexibility was judged subjectively. The best candidate was found to be 16 AWG (19/29) silver plated copper wire coated in a Teflon jacket. The element layout was chosen to give 14cm S/I coverage as well as to accommodate the coil wrapping around very small and very large elbows. Constructing the element layout onto the coil was done by threading the stranded wire through the integral fabric of the sports pad.

Tuning the array was performed on a live elbow. Mentioned previously, element overlap was not optimized for best isolation. Element to element isolation was attempted to be measured, but coupling was so strong that measurement was problematic. The next design iteration should include an emphasis on overlap to aid in further element to element isolation.

The figures below show, from left to right, a conceptual illustration of the element layout, the array shown opened fully, and the array closed to the tightest diameter.



Results and Conclusions: The advantages of flexible, high-channel count RF coils have been further demonstrated. This design proved capable of imaging on a wide range of possible subjects, from a 110 lb female volunteer to a 300 lb male volunteer. Radiologist feedback on image quality was very positive. Technologist feedback was also significantly encouraging from the perspectives of patient comfort and work flow. The quality of results, even despite the poor isolation, show that further investigation into the flexible coil concept may produce powerful new coil designs.

Further demonstrating the benefit to the highly flexible design, the ability to image smaller pediatric knees was investigated. Though not the initial goal of the design of the array, still it represents an unanticipated beneficial point of interest. Images were comparable to the current 8-channel industry standard knee coil.

References: [1] *The Signal-to-Noise Ratio of the Nuclear Magnetic Resonance Experiment.* DI Hoult, RE Richards – Journal of Magnetic Resonance, 1976.
[2] *The NMR Phased Array.* Roemer, et al. – Magnetic Resonance In Medicine, 1990, vol. 16.