Local intensity shift: a comparison of loop and micro-strip receivers at 3.0T

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Introduction: In standard loop receivers, the sensitivity on a given coronal plane is highest not at the center of the loop, but in a region to the left or to the right of center, depending on the direction of the main field (B_0). This local-intensity-shift artifact (LISA) [1], due to wavelength effects, is more prominent at high fields, and is independent of and additional to any artifacts due to transmit field inhomogeneity. The LISA effect carries over to multi-channel arrays, leading to sometimes-pronounced intensity shifts in coronal or axial imaging. We have performed simulations and experiments comparing the intensity shift of loop receivers to microstrip receivers at 3.0T, and conclude that microstrips exhibit the lowest shifts, particularly if a dielectric matching layer is used between the coil and the imaging subject.

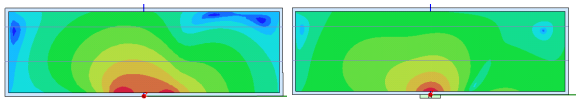

Fig. 1. Simulation results: Axial plane sensitivity of loop receiver (left) and microstrip receiver (right).

Fig.2. Microstrip receivers

Methods: The sensitivities of loop and microstrip receivers were modeled using full-wave electromagnetic simulations (HFSS, Ansoft, USA). In each case, a geometric model of a phantom with receiver underneath was created. Using the reciprocity theorem, the receiver sensitivity was estimated by considering the receiver as a transmitter. The receiver was energized at 128MHz, magnetic flux within the phantom obtained, and B1- calculated [2].

For experimental validation, loop and microstrip receivers were built, and used to acquire MR images from phantoms. The loop receiver was a square 8 cm on each side. The microstrip was designed as a half-wavelength resonator, comprising a cascade of two quarter-wave sections. Each quarter-wave section was designed following a method used to reduce the electrical length of transmission lines by placing two equal lumped capacitors at either end [3]. The resulting half-wave resonator has equal lumped-element capacitance at either end of the microstrip and a lumped element of twice that capacitance at the center.

The microstrip resonators were fabricated using 5-mm-thick Rogers RO3210 (Rogers Corp, CT, USA) substrate material. The microstrip was 5 mm wide, 18.5 cm long and had a 3-cm-wide ground plane. The microstrip was connected through vias to the ground-plane side and all the lumped element components were placed on the ground-plane side, resulting in a planar surface on the imaging side. Assembled microstrip resonators are shown in Fig.2.

Each receiver was placed on top of a saltwater phantom (W=40 cm, L=40 cm, H=12 cm) and axial images taken in a 3.0T Signa scanner (GEHC, WI, USA). The images were imported to Matlab (Mathworks, MA, USA) and the SNR of each image calculated as the pixel intensity divided by the noise. The noise was roughly estimated by calculating the standard deviation of pixel intensity in a corner of the image.

In addition, phased-array images were obtained using two loop receivers or two microstrip receivers. In each case, the coils were placed on a saltwater phantom and coronal images were obtained.

Results: Simulation results are shown in Fig.1 for the central axial plane. As seen in this figure, the sensitivity of the loop receiver shifts to one side as the distance from the receiver increases. The sensitivity of the microstrip receiver is localized near the microstrip, with a reduced intensity shift. The sensitivities are individually plotted on a log scale.

Experimental results for a single receiver are shown in Fig. 3. The axial-plane SNR of the loop receiver (Fig. 3, left) displays higher SNR to one side, similar to the simulated receiver sensitivity shown in Fig. 1 (left). The SNR of the microstrip receiver, shown in Fig. 3, is more localized, similar to the sensitivity shown in the simulation results. Both plots are on a dB scale.

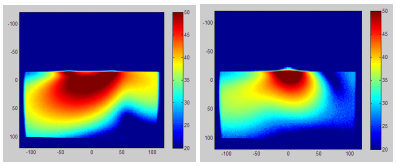

Fig. 3. Experiment results: The axial plane SNR of loop receiver shows intensity shift (left). The SNR of microstrip receiver (right) shows less intensity shift.

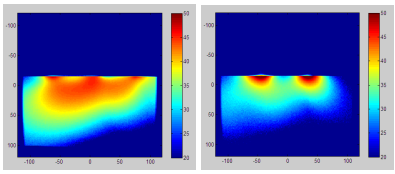

Fig. 4. Experiment results: SNR of two channel loop array (left) and two channel microstrip array (right)

Results from two-channel arrays are shown in Fig. 4. In the two-loop array, the SNR map is shifted to the left, demonstrating the intensity shift of loop arrays. With the microstrip receiver array, the SNR is localized near the microstrips, with a more uniform intensity distribution in the left-right direction.

Imaging results are shown in Fig. 5. In these coronal images, each receiver is positioned on the centerline of the phantom. In the image acquired from the loop receiver (Fig. 5, left), brightening of the image to one side of the centerline is seen. In the image acquired from the microstrip receiver (Fig. 5, right), there is less intensity variation on either side of the centerline.

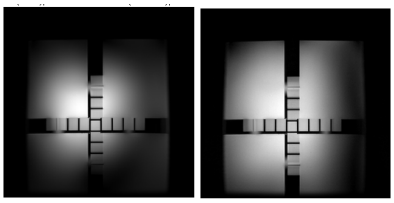

Fig. 5. Imaging results: Coronal image from loop receiver showing intensity shift from center line (left), image from microstrip receiver showing reduced intensity shift from center line (right)

Conclusions: The intensity shift of microstrip resonators is lower compared to loop receivers. These results indicate the feasibility of obtaining images with more uniform SNR using microstrips.

References: [1] Wardenier, P. H., SMRM Book of Abstracts, 1175, 1989 [2] Hoult, D. I., Concepts in Mag. Res.,12(4),173-187, 2000 [3] Mongia, et. al., "RF and microwave coupled line circuits", Artech House, 1999