Narrowband Phased Array Preamplifier Design Using an Integrated SAW Filter

Stephen Dodd[1], Chunqi Qian[1], Joseph Murphy-Boesch[1], and Alan Koretsky[1]
[1]*Laboratory of Functional and Molecular Imaging, NINDS, National Institutes of Health, Bethesda, MD, United States*

Audience: Engineers interested in phased array coils.

Purpose: For preamplifiers integrated into a phased array coil, out-of-band gain can cause instability and oscillations where the array presents many paths for feed-back from preamplifier outputs (1). Further, a preamplifier with a low-pass type input circuit may have significant gain at low frequencies, where feedback signals might find paths through high-frequency chokes and DC lines. SAW filters provide much narrower RF bandwidths than can be achieved with lumped element circuits, and their use has been proposed for time-domain multiplexing (2,3). With careful choice of the filter, insertion loss can be minimized. The main challenges in using them have been their availability with correct center frequency and bandwidth as well as availability in a case with low magnetism. Here we describe a cascode-type preamplifier a SAW filter has been integrated into its output for narrowband amplification at 500 MHz

Methods: The output circuit of a cascode-type preamplifier we have previously designed (4) was modified to include a SAW filter, as indicated in Fig. 1, but overall size of the preamplifier was kept the same. The SAW filter was an off-the-shelf device (Model SCT500N, Sawtron, San Diego, CA, USA) with a nominal central frequency of 500 MHz, a 3dB bandwidth of 7 MHz, insertion loss of 3.5 dB, and input/output impedance of 50 ohms. Dimensions of the filter are 5 x 5 x 1.2 mm, and its transfer characteristic is shown in Fig. 2. Using a small pick-up loop, the transfer characteristic of a 6 x 10 mm coil connected to a standard low input impedance preamplifier was measured and compared with the version with the SAW filter. Input impedance was 2Ω in both designs. A 2-element array using two of these coils was constructed and used to test the design. The coils were not overlapped, and had a separation of 2 mm, so the preamplifier was relied upon to decouple them. Images were acquired in an 11.7T animal scanner equipped with Bruker Avance III console.

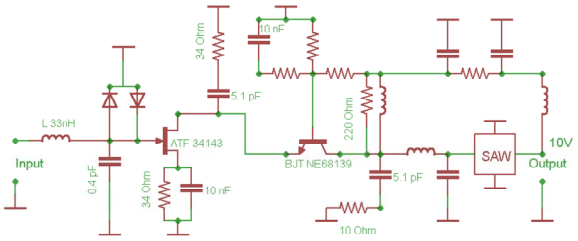

Fig. 1. Preamplifier modified to include SAW filter.

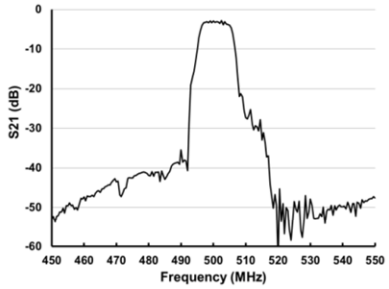

Fig. 2. SAW filter transfer characteristic.

Results:Fig.3 shows S21 plots showing the dramatic decrease in out of band gain for the SAW filter preamplifier. The gain showed a 4.4 dB drop from 30 to 25.6 dB. The noise figure of the SAW filter amplifier was measured with an HP 8970B noise figure meter and found to be 0.7 dB, vs. 0.66 dB for our standard preamplifier. The higher noise figure and decreased gain (above that of the insertion loss of the filter) maybe partially explained by the fact that an FR4 substrate was used in this prototype vs. a lower loss Rogers 3003 substrate. Gradient-echo images acquired from the two-element array using the modified preamplifiers are shown in Fig. 4, for each coil and for the combined coils with a sum-of-squares image.

Discussion: The results show that with adequate gain (Friis relationship), SAW filters can be incorporated in to a preamplifier without significant loss in noise figure. With narrowband gain, the sidebands ofnormally encountered with a phased array circuit are largely suppressed, and gain is eliminated at low frequency. At high frequency, the effect of package magnetism has been mitigated by using a small device (5mm x 5mm) and placing it at a distance (10 cm) from the phased array coil. Use of SAW filters in preamplifiers integrated into a coil will require fabrication of custom filters in low-loss materials and with mounting in packages devoid of Nickel and other magnetic materials. With proper packaging, a SAW filter can also function as a balun, providing RF isolation between its input and output.

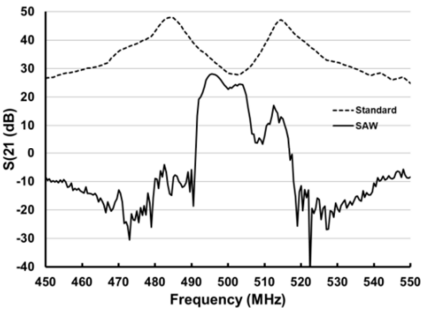

Fig. 3. Output characteristic of preamplifier with integrated SAW filter when connected to noise matched receive coil.

References 1. Grafendorfer, T., Scott, G., et al. Frequency Selective Negative Feedback to Avoid Preamplifier Oscillation in Multi-Channel Arrays. ISMRM 2010; 18: 650.
2. Porter, J., Wright, S., and Famili, N. A Four-Channel Time Domain Multiplexer: A Cost-Effective Alternative to Multiple Receivers. MRM 1994; 32: 499-504.
3. Shen G, Proc 9th ISMRM, Glasgow, Scotland, 2001, p1151
4. Dodd S, Murphy-Boesch J, Merkle H, Silva A, Koretsky A. Proc 20th ISMRM, Melbourne, Australia, 2012, p437.

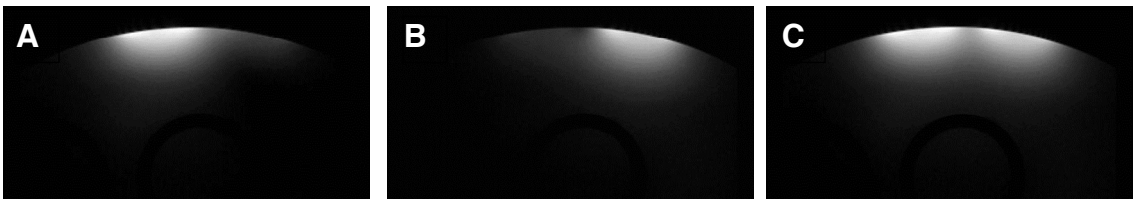

Figure 4. Images from 2 coil system **A, B** individual coils images and **C** sum of squares image