Miniaturized two-stage preamplifiers for receive-array coils at 400 MHz

E. Fischer[1], A. Peter[2], D. Sonner[3], H. Massler[3], J. G. Korvink[2,4], J. Hennig[1], and M. Zaitsev[1]
[1]Radiology, University Medical Center Freiburg, Freiburg, Germany, [2]Microsystems Engineering – IMTEK, University of Freiburg, Freiburg, Germany, [3]Hochfrequenz-Bauelemente und -Schaltungen, Fraunhofer IAF, Freiburg, Germany, [4]Freiburg Institute of Advanced Studies (FRIAS), University of Freiburg, Freiburg, Germany

Introduction: Array coils have become popular in recent years because of their higher intrinsic SNR and their advantages for parallel imaging. In experiments with localized gradients (e.g. PatLoc = parallel imaging technique using localized gradients) they are necessary because of their ability to resolve the ambiguous spatial encoding [1]. Together with more coils, larger numbers of preamplifiers are needed. Typically, they reduce available space and create susceptibility problems. The size of a preamplifier unit is important and here we present an integrated miniaturized low-noise amplifier (LNA) prototype suitable for MR resonance frequencies close to 400 MHz. Also, when using larger numbers of preamplifiers, low power consumption is preferred.

Methods: The LNA prototype has been created by an extrapolation of the theory of ultra low-noise GaAs amplifiers, valid at frequencies around 100 GHz, down to MR frequencies below 1 GHz [2]. LNA core and the interstage network are components integrated on chip, while hybrid circuits for input- and output-matching to 50 Ohm, along with the bias network, have been realized by lumped SMD components to form the complete two-stage amplifier. Figure 1 (a) shows a chip photo of the LNA core together with a photo of the hybrid setup inside the metal case used for RF shielding (metal cover has been removed), Fig. 1 (b). In order to use the prototype inside an MRI spectrometer, crossed diodes for protection of input, output and power supply, together with SMA connectors for easy connection, have been added. Thus, an amplifier prototype inside an aluminium box with dimensions *l* x *b* x *h* = 32 mm x 44 mm x 10 mm and a power consumption of 0.01 Watt has been created. For a test of the performance of a single amplifier, a simple quadratic surface coil (copper, width 1 mm, 3 cm x 3 cm on PCB) was used for detection. Tune/Match to 400MHz/50Ohm was realized via trimmer capacitors. The surface receive coil was placed at an angle of 90° to the transverse magnetic field produced by a commercial linear transmission resonator, to decouple coils geometrically. In order to restrict maximum power, crossed diodes were also added after the tune/match network. Finally, for good mechanical stability, the surface coil, the phantom and the preamplifier were mounted on dielectric PMMA support shown in figure 1(c).

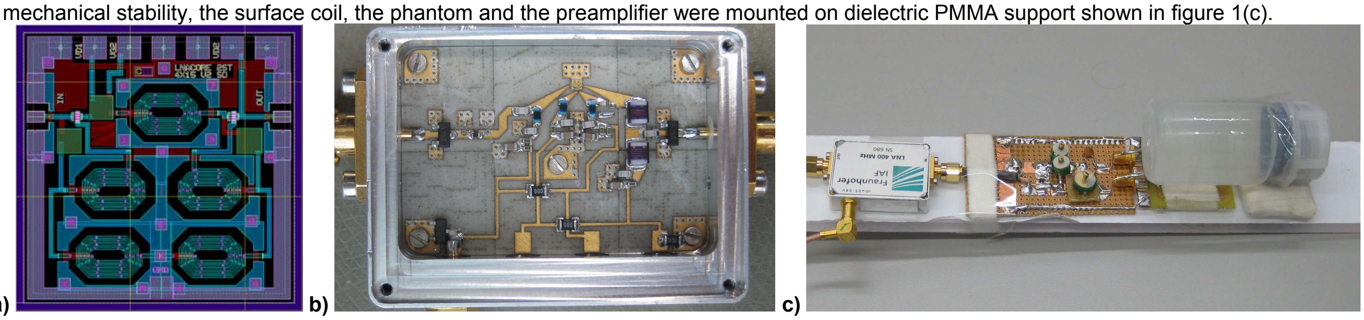

Figure 1: (a) LNA core, (b) Photo of the complete LNA, (c) Arrangement of amplifier, simple surface coil and ionized water phantom.

MRI experiments were performed on a Bruker AVANCE III MRI spectrometer, using standard pulse sequences and coil configurations. Using a commercial Bruker linear resonator, d_i = 72 mm, for transmission, cross-coil gradient echo experiments were performed in which signals from a phantom of ionized water (see figure 1) were recorded. Either no preamplifier, or the preamplifier of the MRI spectrometer, gain = 20 dB, or the two-stage hybrid amplifier, gain = 25 dB were used to amplify signal prior to demodulation. SNR was determined for axial slices from circles inside the phantom close to the surface coil and from circles recording noise. After successful tests with a single amplifier, for multi-parallel reception with several amplifiers in parallel, a cylindrical eight-channel array coil was created according to results shown in [3,4]. Here, an active decoupling network with PIN diodes has been realized, actively shifting resonance frequencies of all receive coils from 400 to 340 MHz during RF transmission pulses.

Results:

In identical cross-coil experiments with the linear Bruker resonator for transmission and the simple surface coil for reception, SNR values of 35 were found, when no preamplifier was used, compared to 111, when the preamplifier of the Bruker system was employed. In comparison, an SNR value of 127 was determined for the new amplifier which, for that phantom, is slightly higher than the value for the preamplifier of the Bruker MRI spectrometer. Experiments also have been performed with the self-built eight-channel receive array coil, where a phantom of silicone oil, OD = 45 mm with a small air bubble on top was used. Here, coil profiles were recorded simultaneously with the receive array inside a Bruker linear resonator, d_i = 72 mm and parallel amplification of received signals by eight new amplifiers in parallel. Figure 2 shows the corresponding coil profiles. The low signal seen for coil 5 and 6 clearly reflects the presence of the air bubble.

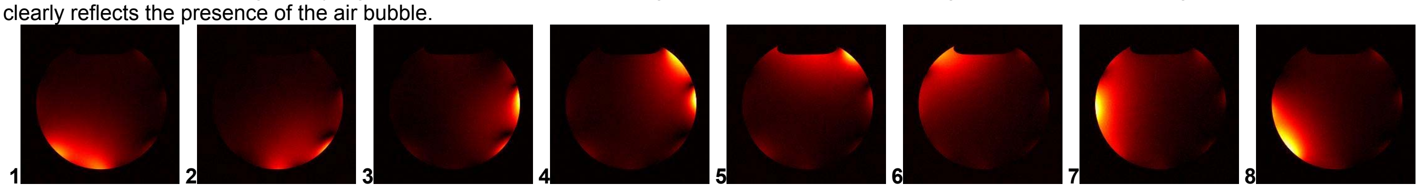

Figure 2: Axial slice of a cylindrical silicone oil phantom, reconstruction: shuffle images

In this experiment the eight new amplifiers were located outside of the RF transmission coil but still inside the magnet bore. Subsequent experiments with preamplifiers inside and outside of the magnet showed nearly identical results. Care was taken to orient the gates of the GaAs amplifiers parallel to the magnetic field, thus safely ruling out any possible Hall effects predicted in [5].

Discussion and Conclusions:

It was shown that our new two-stage preamplifier prototype provides signal improvement that is comparable to what is realized in a commercial MRI spectrometer. Being able to specifically change the matching network, input or output impedance of the new amplifier unit should allow for further size reduction. Also, signal improvement is expected from the size reduction of the amplifiers in a multi-channel array coil together with better coil decoupling by low impedance input in the vicinity of receive coils.

References: [1] J. Hennig et al., Magnetic Resonance Materials in Physics, Biology and Medicine, 21, 1-2 (2008). [2] D. Sonner, master thesis, Fraunhofer IAF, Freiburg (2010). [3] L. DelTin et al., Proc. Intl. Soc. Mag. Reson. Med. 17 (2009) 3050. [4] E. Fischer et al., Proc. Intl. Soc. Mag. Reson. Med. 17 (2009) 2988. [5] C. Possanzini, and M. Boutelje, Proc. Intl. Soc. Mag. Reson. Med. 16 (2008) 1123.

Acknowledgements: This work is a part of the INUMAC project supported by the German Federal Ministry of Education and Research, grant #13N9208, and the German Federal Ministry of Education and Research, grant #01EQ0605.