A Preamplifier for 7T MRI with Extended Dynamic Range and Integrated Cable Trap

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Introduction

In 7T MRI systems the power levels of the received signals are significantly higher than in commercially used 3T and 1.5T systems. In order to make use of the full dynamic range of 7T MRI systems, the preamplifier must be able to handle these high power signals without nonlinear effects such as amplitude compression or intermodulation distortion. The increased operating frequency of about 300 MHz also makes 7T loop arrangements much more sensitive to asymmetric stray capacitances at the preamplifier input. They are responsible for common mode signals and sheath waves causing unwanted feedback to the loop antenna or even self oscillation of the antenna-preamplifier subsystem. Thus, special care has to be taken in suppressing common mode signals in high field MRI systems.

Methods

Commonly, a cascode type design consisting of a low noise FET and a bipolar transistor is chosen for MRI preamplifiers. The maximum input power is usually limited by the first stage FET. In the proposed preamplifier for 7T, two FETs are used in a parallel configuration (Fig. 1). This results in halve the noise-optimum source impedance compared to a single FET input stage and in the case of noise-optimum input transformation in a reduction of the gate-source voltage by a factor of $\sqrt{2}$. This means that the maximum input power for a given tolerable level of distortion can be increased by 3 dB. In practice the increase is slightly less than 3 dB as the bias current of each input FET is also halved in order to maintain the original bias power consumption. An additional benefit that comes with the parallel input stage is the lower transformation ratio at the input of the FETs associated with a smaller inductance value. In order to suppress common mode signals the patented design with an integrated cable trap between the two gain stages of the amplifier was used [1]. This concept has already been successfully integrated in Siemens 3T and 1.5T preamplifiers [2]. The design of the cable trap has been adapted to 7T and improved to further reduce differential to common mode transmission.

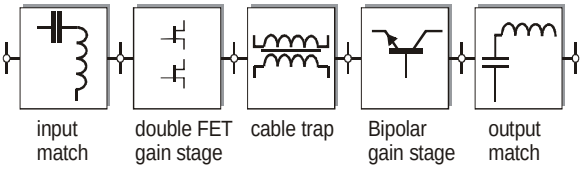

Fig. 1: Basic design of the 7T-preamplifier

Results

The new 7T preamplifier shown in Fig. 2 is capable of handling input powers of up to -15.6 dBm with a gain compression of less than 0.1 dB (Fig. 3). Its power consumption nevertheless could be kept well below 250 mW, which is benefitial especially to reduce heat dissipation from electronics in high channel array coils. The noise figure is about 0.6 dB although a standard-sized inductor with moderate Q-factor is used at the input. The common mode transmission is measured to be as low as -45 dB (Fig. 4) in a high impedance measurement setup equivalent to the common mode impedances in MR-loop arrangements. As the common mode suppression is extremely broadband no tuning of the cable trap is necessary. The actual size of the preamplifier PCB including the integrated cable trap is only about 41 mm x 18 mm which makes it ideal for large phased array antennas. For a first test within a 7T MRI system a 3-channel loop has been built (Fig. 5). The signal to noise ratios achieved with this simple arrangement are extremely high with values up to 1900 in the peripheral regions and up to about 400 in the center of the phantom (Fig. 6).

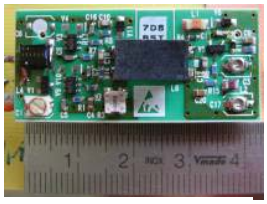

Fig. 2: Amplifier printed circuit board, size 41 mm x 18 mm

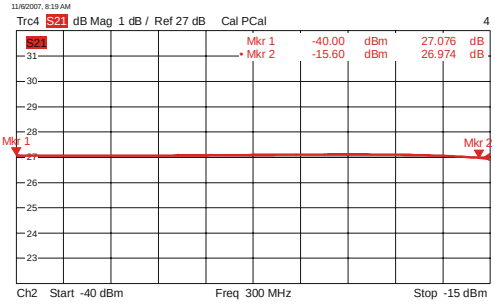

Fig. 3: Amplifier gain as a function of input power

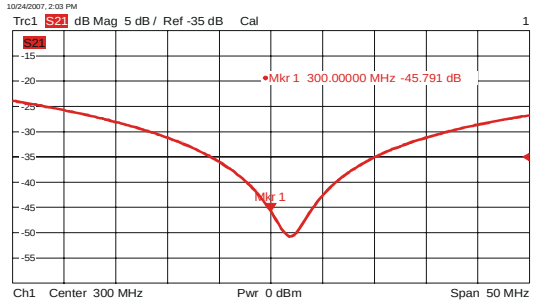

Fig. 4: Common mode suppression

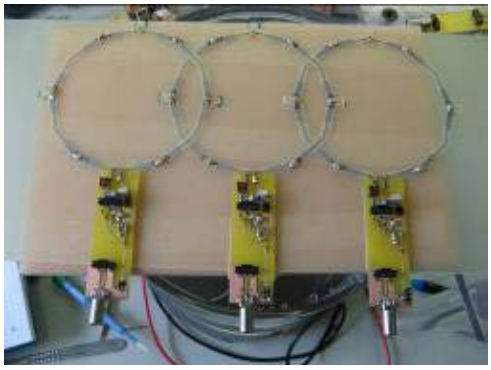

Fig. 5: 3-channel loop array for amplifier evaluation

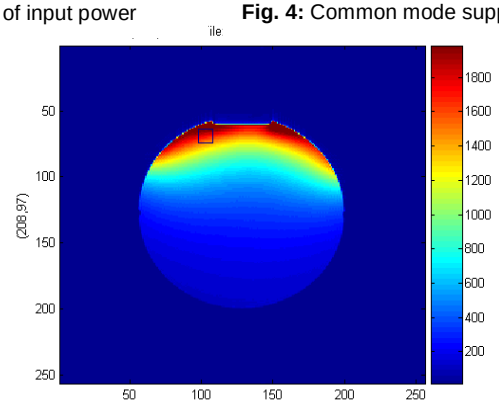

Fig. 6: Signal to noise ratio

References

[1] Oppelt R., Vester M.: "Antennenverstärker für eine Magnetresonanzantenne sowie Magnetresonanzantenne mit einem Antennenverstärker", German patent # DE 10 2004 026 713, see also: „Antenna Amplifier, in Particular for a Magnetic Resonance Antenna", Pub. No. US2005/0270031

[2] Hergt M., Oppelt R., Vester M., Reykowski A., Huber K., Jahns K., Fischer H.: Low Noise Preamplifier with Integrated Cable Trap, ISMRM annual meeting 2007, Berlin