Scalable Low-profile Linear Amplifier Module for Parallel Transmission in MRI

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Introduction

Parallel transmission has been suggested as a method to improve RF excitation, in paticular, multi-dimensional and spatially selective excitation at high fields [1]. Both B_1 shimming and Transmit SENSE require multiple channels of RF amplifiers, though at lower power levels than may be required with single channels. Particularly as the number of channels increases, the power level requirement per channel drops to values that lend themselves to modular compact construction. This abstract reports our progress in developing a low-profile, linear, high-gain amplifier with a high degree of noise blanking. The module reported here generates 45 watts per channel and offers high efficiency, high linearity, low cost and plug-in modality which make it attractive for scalable parallel transmission systems. It could also serve as a driver stage for whole body Transmit SENSE [2]. This work is designated to be used with a vector modulator designed in-house [3].

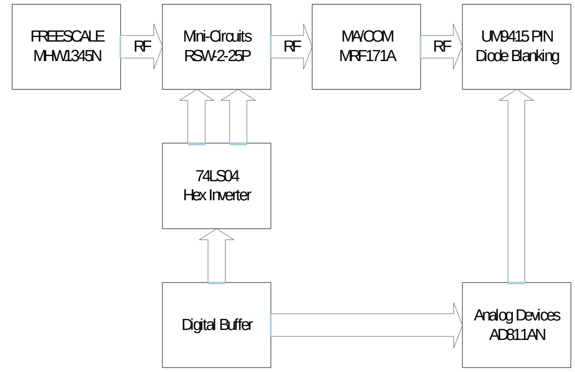

Figure 1. Plug-in amplifier architecture

Method

The plug-in amplifier module is fabricated on a standard FR-4 board with a dimension of 3" by 9", tuned for 4.7T. A FREESCALE MHW1345N serves as the 1st stage of amplification, followed by a trigger controlled 1st stage reflective switch. A hex inverter is added to convert the digital buffer to HIGH and LOW TTL gates to control the switch. An MRF171A, which is a VHF power MOSFET with maximum output power of 45 watts, used as a 2nd stage amplifier. Bias voltages are optimized for proper gain and thermal performance [4]. Following the final gain stage, a PIN diode blanking circuit is added to further reduce the noise while receiving. It was found that two blanking stages were needed to provide adequate noise reduction. A single OP AMP compares the TTL and the reference voltage and outputs enough current to forward bias the PIN diode. When the gate is OFF, a reverse bias voltage is applied to block the RF. Figure 1 shows the architecture. All the trigger line and DC power lines are seperated from the RF lines to prevent from EM interefrence and therefore fed through the card edge connectors etched at the bottom of the board. Two heatsinks with proper thermal resistance are added to each module. An 8-channel mother board is constructed to fit in a standard 19" rack mount box. A slot distance of 1.85" is chosen to provide compact size, access for cooling, and tolerable isolation.

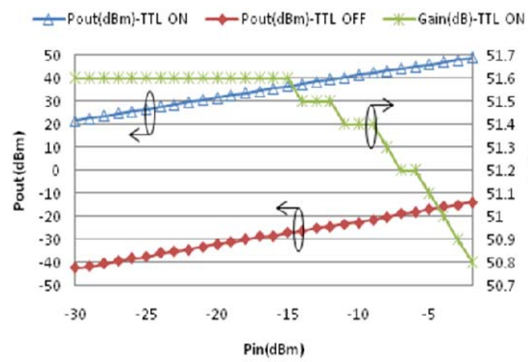

Figure 2. I/P & O/P linearity and gain variation

Results

The amplifier was designed for use with our vector modulator system [3] which has an adjustable output power from -60dBm to -6dBm, well in the linear region of the amplifier as shown in Figure 2. A comparison of two curves in Figure 2 shows that the gain while the gate is on is around 63dB higher than that while the trigger is off and the gain variation is 0.4dB within our interested input range and can be easily calibrated out. We can expect a gain drop when the output power reaches maximum, yet still within 1 dB. This creates a stable gain over a large range of dynamic range and a good noise blanking while the pulse train is off during each TR. Due to the noise blanking, we could attain high SNR comparable to low-cost commercial wideband pulse amplifiers without blanking. While the gate is on, we attain a 1-dB compression point over 45 watts which gurantees a good linearity over a large dynamic range. For the maximum output condition, the PAE (power added efficiency) is ~73% which makes the whole amplifier module in Class AB for large signal operation. The adajacent channel isolation is measured as -30dB. Higher isolation could be obtained by wider spacing of the modules or better shielding. Nonetheless those were not chosen due to compact design. Figure 3 shows two modules in an eight-channel mother board. 8-channel power amplifier modules are plugged into a mother board with a compact dimension of 14" by 4.6". With a fan, local heating will not be a problem even with maximum output power.

Discussion

These power amplifier modules present an affordable alternative method for implementing transmit array systems when multiple commercial amplifiers are cost-prohibitive. Due to their low cost and small footprint, this design is easily scalable. Its high linearity and high degree of noise blanking offer stable performance for parallel tramission in MRI experiment. Also it provides a plug-in modality which expedites the normal procedure of debugging and testing methods.The proposed design allows for low-profile large-scale multi-channel parallel transmit systems and potential for large-scale Transmit SENSE.

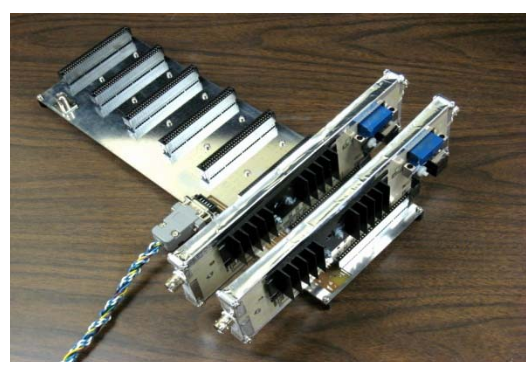

Figure 3. An eight-channel power amplifier module

References

1. Katscher U, *et al*, *NMR Biomed.* 2006; **19**: 393-400
2. Katscher U, *et al*, *Magn. Reson. Med.* 2003:**49**(1):144-150
3. Feng K, *et al*, *ISMRM*. 2008 (submitted for publication)
4. MA/COM MRF171A Secmiconductor Technical Data Rev2

Acknowledgements

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