Analysis of Gain and Noise Relationship in RF Feedback Power Amplifier Linearization for Use at 1.5T MRI

Jonathan Y Lu[1], Pascal P. Stang[1], John M. Pauly[1], Marta G. Zanchi[2], and Greig C. Scott[1]

[1]Dept of Electrical Engineering, Stanford University, Stanford, CA, United States, [2]School of Medicine, Stanford University, Stanford, CA, United States

Introduction In this work, we analyze the potential of noise improvement in a closed-loop RF Cartesian feedback system [1,2] for power amplifier linearization by reducing the attenuation in the feedback loop of the system while making no change in the loop gain of the system. Ideally, the feedback path noise should dominate the total noise within the loop bandwidth of the system [3], and thus we would expect that the gain block inside the feedback path could play a role in manipulating the total noise reflected at the output. We could test this in the system by essentially reallocating some of the gain from the forward stage to the reverse stage, or vice versa, which is equivalent to shifting the position of our RF input into the system. Since this reduction in noise of the system involves changing the gain in the feedback path, the tradeoff here appears to be between the amount of noise in the linearized output signal of the closed loop system output and the gain of the system. Verifying if such a relationship holds would be useful in our understanding of the system and provide an extra degree of freedom for noise reduction.

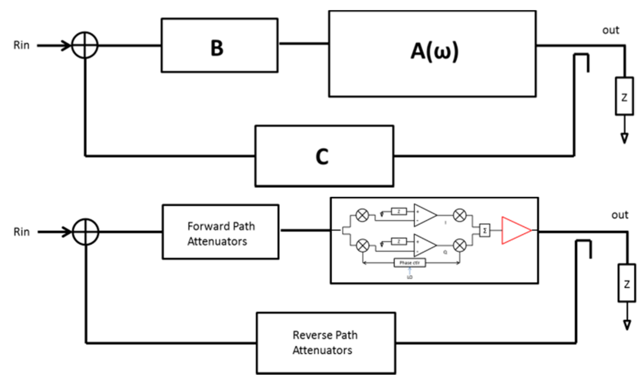

Figure 1. The configuration setup. (Top) The abstracted picture of the system modules (Bottom) Inside of each block. A includes power amp and cmx 998 chip, B and C blocks comprised of attenuators.

Materials and Methods We tested this on an RF Feedback system with Cartesian Compensation [1-2] for use at 1.5T. For the Cartesian feedback, we used the CMX998 chip (CML Microcircuits) that allowed us to adjust attenuation and phase response of our loop gain to ensure stability of the loop gain. The setup included a 60dB 200 W power amplifier. In Fig 1, block A contains the CMX998 and amplifier and has a transfer function response resembling a band-pass filter centered at 63.88MHz, or 1.5T. External attenuators indicated as block B and C in Fig 1 are added to set the loop filter response to have the desire peak gain and phase to ensure stability. We used the Medusa console [4] from our lab to drive the input of the system and to read a reference output signal.

To examine the change in noise with respect to gain of our system, we reallocated the attenuators between block B and C and measured the output of the closed loop system, to see how moving the RF input port within the loop could change noise properties at no cost in the loop gain. To examine potential effect on signal-to-noise ratio, for the different values of C block attenuation values, we adjusted the input signals such that each of the adjusted configurations have the same output reference voltage. We then measured and calculated the standard deviation of the noise at the output.

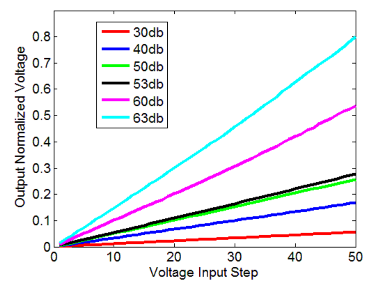

Figure 2. Output reference voltage gain plotted for different values of reverse path

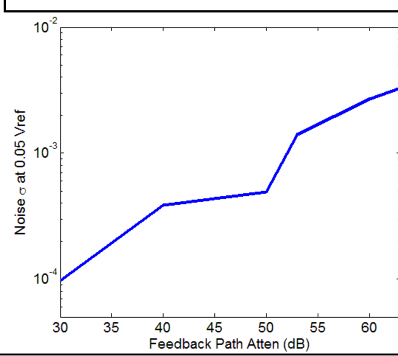

Figure 3. Noise standard deviation at set (0.05 Vref) reference voltage output as function of feedback path attenuation.

Results and Discussion We altered the attenuation inside the feedback back across a range from -63db up to -30db by moving our RF input location. The loop gain peak for all configurations was set to approximately 20 dB. This means that the total attenuation of block B and C in Fig 1 will remain constant across all measured setups. The closed loop gain of the system, from quick analysis of the block diagram, should be at $|H(\omega)|=|BA(\omega)/(1+BA(\omega)C)|$. We would thus expect the reverse path attenuators in C to set the closed loop gain when loop gain is sufficient and as expected, we see that with decreasing attenuation in the feedback path, we see increasing gain (Fig 2). By varying our attenuation from -63dB to -30dB, we noticed that our gain has decreased by a factor of 44 (33dB).

We also measured the noise performance of the feedback loop. Looking at the standard deviation of our measured voltage noise, we found that the system noise going from a feedback attenuation block from -63dB to -30dB decreases by a factor of 33.7 (31 dB).

Conclusion Our results suggest that in this RF feedback configuration, by moving the location of the RF input and changing the closed loop system gain, we can control the amount of noise that is added into our system. This implies that in the future, we can consider lowering our gain with this technique in order to reduce noise and then drive our system with higher power inputs to achieve the desired output signal magnitude. We can use this gain and noise tradeoff in order to achieve linearity and desired noise performance from our feedback system.

References [1] Faulkner, IEEE Vehicular 1998 [2] Voyce, IEEE Microwave 1989 [3]Kenington, High Lin. RF Amp Design, 2000 [4] Stang, ISMRM 2007

Acknowledgements Stanford Graduate Fellowship, National Science Foundation, NIH grant support: R01EB008108, P01CA15999, GE Healthcare research support.