LDMOS RF Amplifier Linearization using PowerSDR mRX Pure Signal
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INTRODUCTION

This paper will demonstrate the use of software to improve the IMD performance of a 50 volt LDMOS kW RF amplifier utilizing an NXP BLF-178 device on 6 meters.

The software utilized is PowerSDR mRX Pure Signal. This is specifically written for use with OpenHPSDR hardware.1,2,3

I highly recommend that you read the latest Pure Signal document that can be found here:

http://users.burlingtontelecom.net/~n1jez@burlingtontelecom.net/images/PureSignal.pdf

This document, written by Warren Pratt, NR0V who is the primary architect of Pure Signal, goes into quite a bit of detail on the system. I won't repeat a lot of it here, but simply offer a synopsis.

In an ideal world, the signal we inject into an RF amplifier would be reproduced with no detrimental changes other than an increase in gain. In the real world, RF amplifiers suffer from various types of non-linearity. One of the results of this is Inter-Modulation Distortion or IMD. This distortion manifests itself in various ways, but one we're most familiar with is splatter. We've all heard wide signals like this on the bands. So what can we do about it?

On the hardware end, we can design and operate our amplifiers in the most linear fashion possible. This is always desirable but only goes so far. The approach presented here augments the hardware with a software solution.

Pure Signal utilizes a technique known as "Predistortion". Essentially, the software "predistorts" the input signal to the amplifier to correct for non-linearities in the output. The system continuously monitors output vs input and makes changes based on varying conditions. It uses "Adaptive Predistortion".

One of the effects that limits Pure Signal's ability to compensate for non-linearities is what is called "memory effect". The Pure Signal pdf file4 goes into some detail on this. For solid state amplifiers, tests so far suggest that LDMOS amplifiers using higher voltage supplies produce the best results. That is what is tested here.

HARDWARE

The hardware utilized in this test is as follows:

- OpenHPSDR Hermes board
  - 250 mW output on 50 MHz - DUC/DDC architecture
  - Ability to transmit and receive simultaneously - full duplex mode
- 0.5 watt in to 5 watt out Class A driver amplifier
- LDMOS amplifier using an NXP BLF-178 kW device operating at 48 volts
- Anritsu MS-2721B Spectrum Analyzer
- Dielectric Wattmeter - Average and Peak reading
- Bird 4275s adjustable signal sniffer
- Bird kW load
- Various fixed and adjustable pads
- FT-817 receiver with common IF tap at 68.33 MHz
- FUNcube Dongle SDR
- HDSDR software

To be able to use Pure Signal, we must provide a 'feedback' path of the actual transmitted signal. This is fed to the Hermes receiver running in duplex mode.

The following is very important! Pure Signal can only correct based on what is fed back to it. It's important to provide the cleanest RF sample from the output of your amplifier as you can. It must be attenuated appropriately so as to provide sufficient amplitude without overloading the Hermes receiver input. Here is a block diagram of my test setup.

Various fixed and adjustable pads are used between the output of the Bird Sniffer and the Spectrum Analyzer and Hermes receiver input.

This is the secondary receiver system setup. This was used for additional audio and spectrum analysis.

SOFTWARE

The PowerSDR mRX PS software used here was version 3.2.9 with Hermes firmware 2.5b. The software includes a two-tone test generator which was used for these tests. Pure Signal
presents a window from within the software where various parameters can be set. Their use is outlined in the Pure Signal pdf file referenced in the beginning of this paper.

![PureSignal software window][1]

**TEST SETUP**

For these tests, the LDMOS amplifier was driven to 300 watts average power out using the two tone generator in PowerSDR mRX PS. At this power level, drive levels on the Hermes and Class A driver amplifier were quite conservative. Measurements were made through each stage of the system, but ultimately, it was treated as a system as the only measurement that was of real interest to me was on the output of the LDMOS amplifier.

It should be noted that the Pure Signal system has a finite "correction bandwidth". It only corrects within approximately 40 kHz or +/- 20 kHz from the center transmit frequency. Typically this is where most of the IMD energy is generated.

For each test, the two tone generator was turned on, and attenuation was adjusted on the Hermes receiver to a point 1 dB before ADC overload as indicated in the software Panadapter display. The input reference level to the Anritsu Spectrum Analyzer was set to -20 dBm.

Screen captures of the Spectrum Analyzer are shown first without Pure Signal activated and then with Pure Signal turned on. There is a marker table that summarizes the IMD levels under "Delta Amp" on the bottom right side. I placed the delta markers on the worse case IMD products when there was a difference between upper and lower sidebands. The transmit center frequency is 50.140 MHz.

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[1]: #/image.png
**THE MEASUREMENTS**

The first tests were on the bare Hermes board with Pure Signal off. For reference, IMD levels are -46.3 and -52.91 below the two tones.

![Fig 1 - Bare Hermes - Pure Signal off](image1)

Here is the Hermes board with Pure Signal on. For reference, IMD levels are -63.93 and -77.71 below the two tones.

![Fig 2 - Bare Hermes - Pure Signal on](image2)
The next test was on the Hermes and Class A Driver combination. Pure Signal off. IMD levels are -40.16 and -49.82 below the two tones.

![Fig 3 - Hermes and Class A Driver - Pure Signal off](image)

The next test was on the Hermes and Class A Driver combination. Pure Signal on. IMD levels are -61.20 and -75.25 below the two tones.

![Fig 4 - Hermes and Class A Driver - Pure Signal on](image)
The next test was on the Hermes, Class A Driver and LDMOS amplifier combination. Pure Signal was off. IMD levels are -46.11 and -42.42 below the two tones.

Finally, the Hermes, Class A Driver and LDMOS amplifier combination. Pure Signal was on. IMD levels are -57.63 and -64.82 below the two tones.
SUMMARY

It should be noted that no special effort was made to optimize parameters such as amplifier bias, or drive levels. However, all stages were run well below their maximum output.

Several items mentioned in the Pure Signal documentation were observed during the testing.

- You need to provide a good clean feedback signal for Pure Signal.
- Pay close attention to the attenuation of the feedback signal. One would hate to destroy the front end of a receiver.
- There needs to be enough feedback signal to reach the ADC overload point - too little feedback and Pure Signal can't do its job.
- The design of your amplifier has an effect on the amount of correction that can be obtained and maintained. Minimize the "memory" effects.
  - minimize voltage drop/supply sag. Higher voltage/lower current helps
  - heat sinking!
  - temperature compensating active bias - in use on the LDMOS amp tested.

It was found that on 6M, there appears to be a 'sweet spot' for the feedback level for Pure Signal. This was about 5 dB below the ADC overload point. IMD reduction was on the order of 3-4 dB better at that point. I can say that other testers have not seen similar results at HF so at this point, it appears to be a 6M effect. More testing is indicated.

Overall IMD reductions were impressive. I have no doubt that with some careful tweaking and tuning, that these levels could be reduced further.

ADDENDUM

On the HPSDR reflector, a suggestion was made that a Class B LDMOS amplifier might be "linearized" using Pure Signal. This intrigued me. With the LDMOS amp set for Class AB, it's dissipating ~ 75 watts of heat just sitting idling. Class B bias could drop that to ~5 watts. I reset the bias on the BLF-178 to 100 ma total. As expected, higher drive power was needed, but the Hermes and Class A driver had no problem developing it. The following measurements are of the complete system.
Here is the Hermes, Class A driver and LDMOS amp set for Class B with Pure Signal off. IMD is at -22.40 and -28.36 below the two tones.

![Spectrum Analyzer Data](image)

**Fig 7 - Hermes, Class A Driver and LDMOS amp Class B - Pure Signal off**

Here is the Hermes, Class A driver and LDMOS amp set for Class B with Pure Signal on. IMD is at -55.57 and -63.04 below the two tones.

![Spectrum Analyzer Data](image)

**Fig 8 - Hermes, Class A Driver and LDMOS amp Class B - Pure Signal on**

While the Pure Signal correction looks good with two tones, I wanted to see if the spectral output was as good as the numbers indicated. I used the FT-817 receive system and captured the waterfall display. The signal received on the FT-817 was ~ S9 +20. The software was HDSDR. I'm using SSB first with Pure Signal off and then turning it on about half way through. It's pretty evident where I switched it on. You can easily see the sideband reduction.
An interesting observation was the overall power in the 3 kHz receive bandwidth. In HDSDR, when the audio begins, the signal is peaking at S9 +15. Once Pure Signal is engaged, the signal within the bandwidth increases to S9 +20. Energy that was wasted in the sidebands is now concentrated within the passband.

There is an I&Q audio file of this test. See footnote #5 for the URL. You can play it back in any program that can handle I&Q. You will hear the reduction in distortion on my voice as Pure Signal is turned on. I would also suggest tuning +/- 3 kHz and listening to the sideband energy reduction with Pure Signal off/on.

Footnotes

1.) [http://openhpsdr.org/](http://openhpsdr.org/)
2.) [https://apache-labs.com](https://apache-labs.com)
4.) [http://users.burlingtontelecom.net/~n1jez@burlingtontelecom.net/images/PureSignal.pdf](http://users.burlingtontelecom.net/~n1jez@burlingtontelecom.net/images/PureSignal.pdf)
5.) [http://users.burlingtontelecom.net/~n1jez@burlingtontelecom.net/images/ClassB.zip](http://users.burlingtontelecom.net/~n1jez@burlingtontelecom.net/images/ClassB.zip)