Digital Predistortion with Low Precision ADCs

Chance Tarver and Joseph Cavallaro
Department of Electrical and Computer Engineering
Rice University, Houston, TX 77251
Email: tarver@rice.edu cavallar@rice.edu

***Abstract*—Digital Predistortion (DPD) is a popular technique for linearizing a power amplifier (PA) to help reduce the spurious emissions and spectral regrowth. DPD requires the learning of the inverse PA nonlinearities by training on the output of the PA. In practical systems, the analog output of the PA will have to go through an analog-to-digital converter (ADC) so that training can be done on a digital processor. The quantization degrades signal quality and may limit performance of a DPD learning algorithm. However, a lower resolution ADC may cost less and allow for less computational complexity in the digital processing. We study this tradeoff to try to find how much precision is needed in DPD systems.**

I. Introduction

The power amplifier (PA) is a component of wireless systems that has a nonlinear transfer function. The nonlinearities are undesirable in that they lead to distortions such as spectral regrowth around the main carriers and intermodulation distortions (IMDs) in scenarios with multiple, noncontiguous carriers. This is exacerbated with modern signals such as OFDM with high PAPR.

Digital predistortion (DPD) is a method for linearizing a power amplifier (PA). With DPD, the nonlinearities are estimated so that they can be corrected before the PA with their inverse. To do this, we must train our predistorter by observing the signal after the PA. In practical situations, we need a feedback bath after the PA that has a downconverter and an ADC. For wide bandwidth signals, the sampling rate of the ADC must be fast. In mobile applications where power and cost are a concern, one option for reducing the complexity of the system is to use a low precision ADC. By reducing the precision, the DPD algrothim can be performed with shorter word lengths which would save area and power in an implementation. Low precision ADCs are usually cheaper and consume less power. Moreover, ADCs that support a faster sampling rate are often lower precision.

This is a common thing being explored in MMWave and massive MIMO

In this paper, we test the performance of our previous DPD solutions for varying ADC precision.

II. Full-Band DPD

Most DPD is a variation of what we refer to as full-band DPD where the entire transmit band near the main carriers is linearized. This can reduce the magnitude of multiple spurious emissions such as the third and fifth intermodulation products and the spectral regrowth around the main carriers. However, this comes with a considerable computational complexity

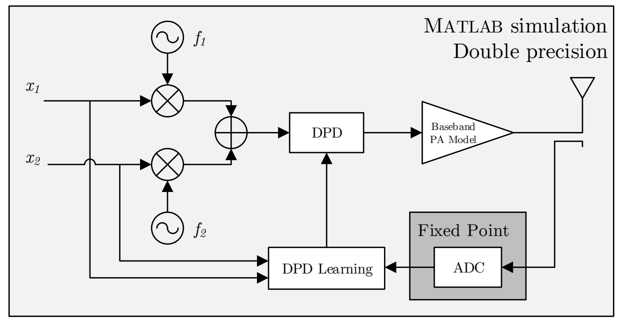

Fig. 1. Block diagram of the simulation performed. The signal generation, amplification, DPD learning, and DPD application are performed with double precision in MATLAB. We emulate an ADC by quantizing the feedback from the PA to the DPD learning.

especially as the spacing between the carriers becomes large. Moreover, the cost of the ADC rapidly increases as the sampling rate grows.

One potential way to ease this cost and reduce complexity with only a small loss in performance is to reduce the precision of the ADC. We illustrate this in Figure 2. Here, we have two noncontiguous signals like what may be found in LTE-Advanced carrier aggregation. They are each 5 MHz in bandwidth. They are broadcast through a fifth-order, nonlinear PA model with memory effects implemented in MATLAB. Intermodulation occurs occurs and introduces large spurious emissions through the nearby spectrum as seen by the black curve.

When we perform the DPD algorithm where the feedback into the DPD learning block is the full, double-precision values computed by MATLAB, we get suppression shown by the solid blue curve. We then use MATLAB's fixed point toolbox to convert the values to a signed, fixed-point representation. This introduces quantization noise and degrades the performance. However, for as low as 6-bit ADC, the performance degradation is mostly insignificant. For example, there is only a 2 dB difference in suppression on the right-hand IM3 spur. The 4-bit ADC still suppress throughout the spectrum, but there is a significant performance degradation (14 dB on the right-hand IM3).

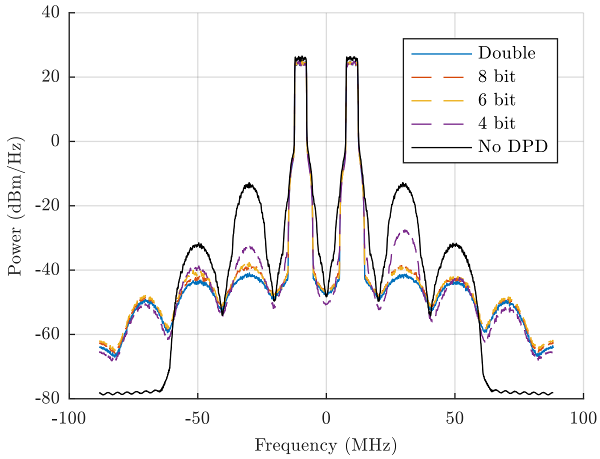

Fig. 2. PSD output when performing full-band DPD on a scenario with two, noncontiguous, 5 MHz LTE uplink carrier with a low precision ADC feedback path. Here, performance for the 8 bit and 6 bit ADCs are similar with about 2 dB less IM3 suppression when compared to the double precision PA simulation.

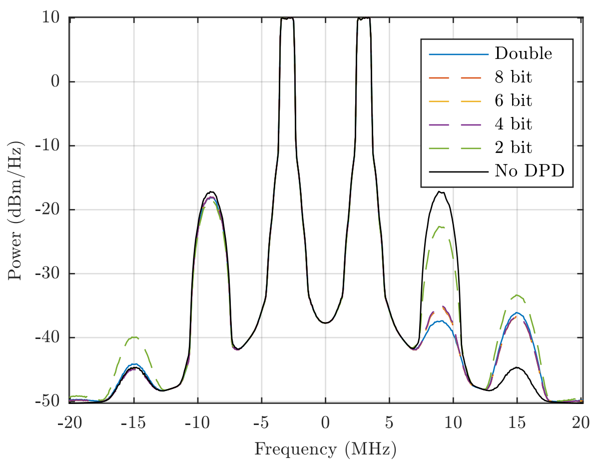

Fig. 3. PSD output when performing sub-band DPD on a scenario with two, noncontiguous, 1.4 MHz LTE uplink carriers with a low precision ADC feedback path. Here, performance for 8, 6, and 4 bit observations are similar with about 2 dB less IM3 suppression when compared to the double precision PA simulation.

III. Sub-Band DPD

An alternative to the full-band DPD is what the authors refer to as sub-band DPD. With this method, one targets specific sub-bands such as an intermodulation product to suppress. This has the effect of drastically reducing sample rates which in turn reduces the running complexity of the algorithm. This method also provides freedom in the sense that specific sub-bands can be targeted as needed.

The complexity can further be reduced if we limit the resolution of the ADC.

IV. Conclusion

Digital predistortion is a valuable method to linearize PAs that does not need to be computationally costly and does not require a complicated hardware overhead. When designing a system with DPD, one consideration should be the width of the ADC. With a low precision ADC with a resolution of four or six bits, the performance of the DPD training can remain mostly intact.

References

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.