APPLICATION NOTE

Digital Predistortion using vProtean

For Battery Powered RF Communications

Overview

In the modern wireless world, battery operated transmitters have become a ubiquitous tool to move information over long distances. Whether the application is 4G/5G cellular, human or machine, military, medical, industrial, or otherwise, saving battery power is essential to extend operational time in the field. The key to long battery life in transmitters is high power amplifier efficiency. However, the enemy of high efficiency in amplifiers is the necessary back off overhead on the power amp to maintain linearity for waveforms requiring high Peak to Average Power Ratios (PAPR); for example, OFDM signals like those used in 5G.

Digital Predistortion (DPD) has become one of the most effective linearization techniques in modern communication. DPD uses feedback from the transmitter output to compensate for non-linear effects by distorting the digital transmit samples in a way that output towards the desired signal [1]. DPD can reduce the required backoff in power amplifiers. The ADRV9002 transceiver from Analog Devices includes a built in DPD function to improve amplifier efficiency and increase battery life, all other things being equal. This application note describes how to use DPD on the vProtean SDR.

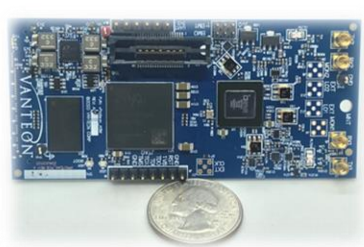

Figure 1: Vanteon vProtean Software Defined Radio (SDR)

The Vanteon vProtean® SDR is built around the Analog Devices ADRV9002 RF Transceiver. The ADRV9002 is the industry's first high performance, highly integrated transceiver IC that operates from 30 MHz to 6 GHz, capable of handling narrow band and/or wideband signals from 12 kHz to 40 MHz. The ADRV9002 has dual-channel transmitters, dual-channel receivers, integrated synthesizers, and built in Digital Signal Processing (DSP) functions.

DPD Application Details

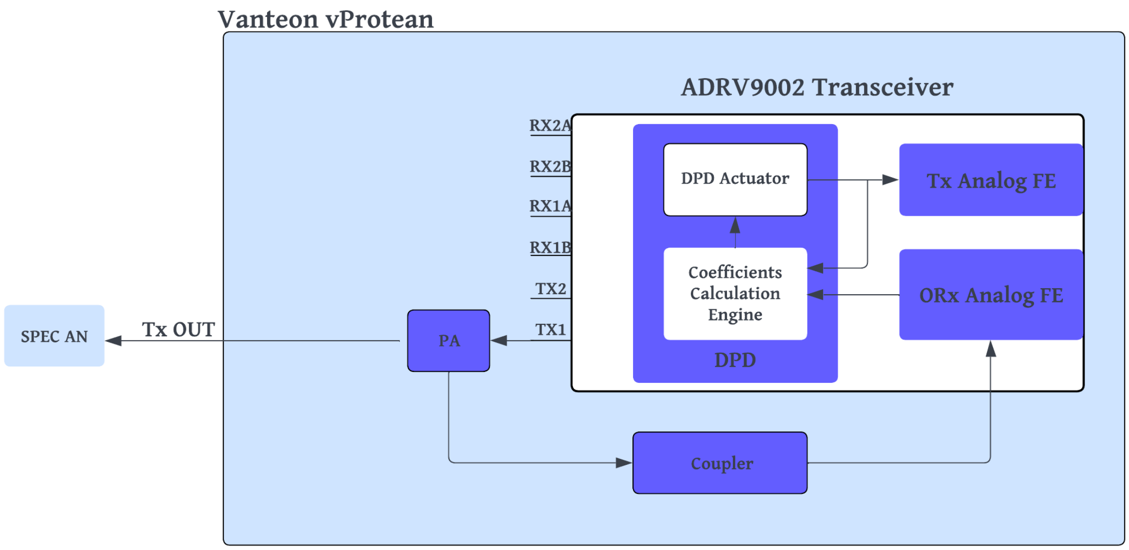

Figure 2. Top Level View of DPD on vProtean

Figure 2 shows a top-level view of the DPD data path on the vProtean SDR. The ADRV9002 RF Transceiver utilized on the vProtean handles the signal processing needed to linearize the signal. The ADVR9002 requires the transmit signal (Tx OUT) to be fed back into the device in order to characterize the distortion. The path between the output and the observation port is essential. Vanteon takes an integrated approach to this requirement using an on-board loopback path to feed the attenuated transmit signal to the observation receive channel.

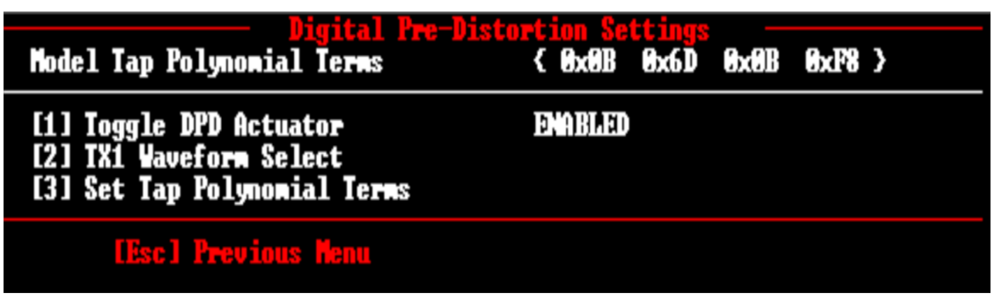

Figure 3 : vProtean DPD UI

The user interface (UI) for the vProtean includes a setting for DPD in the provided firmware. The menu gives the user access to the DPD actuator and Model Tap Polynomial Terms, similar to the Analog Devices TES GUI. The DPD actuator referenced in Figure 2 is dependent on the results from the coefficients calculation engine. The DPD actuator's state determines whether the transmitted signal will have the inverse PA model applied to it. The Model Tap Polynomial Terms, on the other hand, allow the user to "curve fit" the nonlinearity effects of the output signal. The polynomial terms for each tap are entered as 8-bit hexadecimal values on the UI for the transceiver to interpret them as the MSB (Most Significant Bit) representing polynomial terms [4...7] and LSB (Least Significant Bit) regarded as terms [0…3]. For suggested tap values refer to Table 83 in reference [2].

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Reference/Sample Design

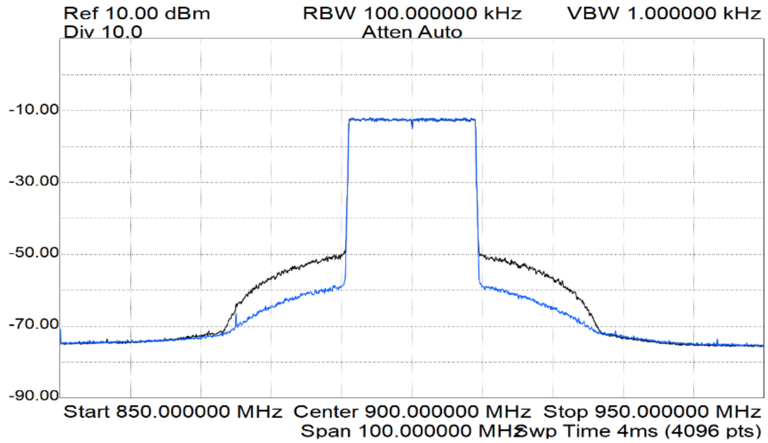

Figure 4 : LTE Waveform @900MHz LO

To test DPD, a cellular (LTE) waveform is transmitted at a carrier frequency of 900 MHz with 5dB of combined front end and digital attenuation.

Trace 1 (**BLACK**) on Figure 4 is the original LTE waveform transmitted from the vProtean. By inspection, without DPD, the nonlinear behavior of the Power Amplifier has generated significant spectral regrowth (i.e., broadening of the spectrum) onto the adjacent channels.

Trace 2 (**BLUE**) is the same waveform with the DPD actuator enabled and the Tap Polynomial Terms set to the following:

TAP	MASK VALUE
0 & 1	0x19
2	0x3F
3	0x1E

Table 1 : Model Orders for Taps

The ADRV9002 Transceiver calculated the inverse characteristic of the PA to help linearize the LTE waveform, which resulted in an improvement of nearly 10 dB in spectral regrowth.

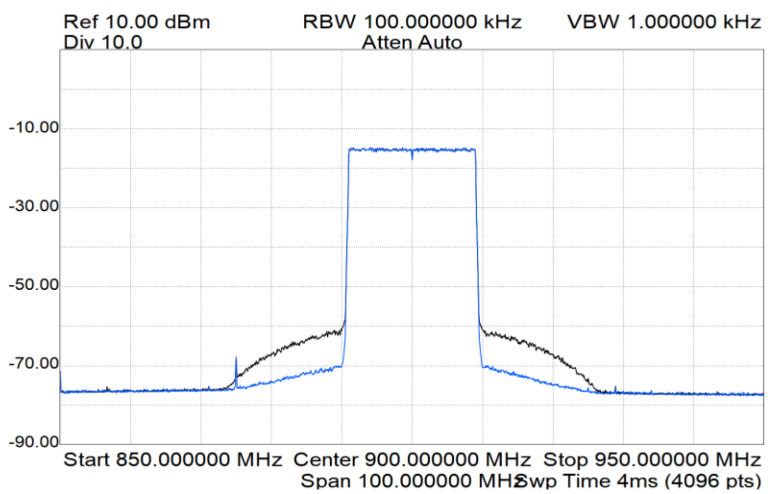

Figure 5 : LTE Waveform @P1dB (900MHz LO)

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As shown in Figure 5, by adjusting the RF front end attenuation to 8dB, the output power is lowered to the 1dB compression point, resulting in less distortion of the original waveform (i.e., without DPD). Therefore, Trace 1 (**BLACK**) has less spectral regrowth at the adjacent channel when compared to Figure 4 (without DPD). When DPD is activated in this case, a 10 dB improvement in spectral regrowth nearly eliminates the non-linear sideband energy.

NOTE:

For the Observation Receive Channel (ORx) to receive the attenuated output signal and start pre-distortion calculations, the receive channel needs to be "PRIMED". Failing to do so may result in unexpected DPD behavior.

Conclusion

Waveforms with high peak-to-average power ratio (PAPR) like Orthogonal Frequency-Division Multiplexing (OFDM) require large Input Back Off (IBO) which leads to higher power consumption and less PA efficiency. When it comes to linearizing, Digital Pre-Distortion helps to minimize the required IBO, resulting in a more efficient power amplifier design without sacrificing adjacent channel performance. For cellular systems utilizing OFDM, inadequate linearity leads to distortions which disrupt the fidelity of the transmitted signal. The Vanteon vProtean Software Defined Radio, utilizing the built in DPD capability of the ADRV9002, is a very effective strategy to improve radio efficiency where it matters most, such as battery powered applications or dense radio designs with minimal heat dissipation capability.

To learn how Vanteon's expertise can help, contact us at info@vanteon.com.

References

[1] Claire Masterson. "Digital Predistortion for RF Communications: From Equations to Implementation." *Analog Dialogue*, Vol. 56, April 2022

[2] *ADRV9001 System Development User Guide*