TAMPERE UNIVERSITY OF TECHNOLOGY

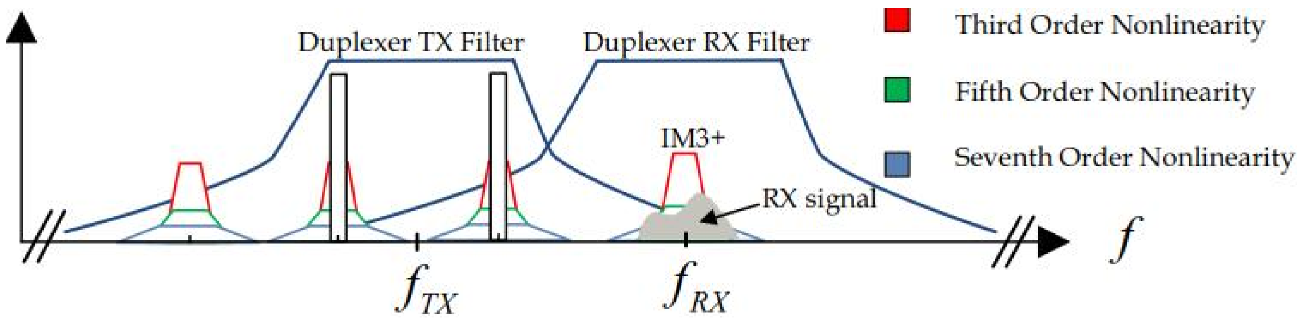
DIGITAL PREDISTORTION FOR MITIGATING TRANSMITTER-INDUCED RECEIVER DESENSITIZATION IN CARRIER AGGREGATION FDD TRANSCEIVERS

Mahmoud Abdelaziz

Lauri Anttila

Mikko Valkama

Problem motivation



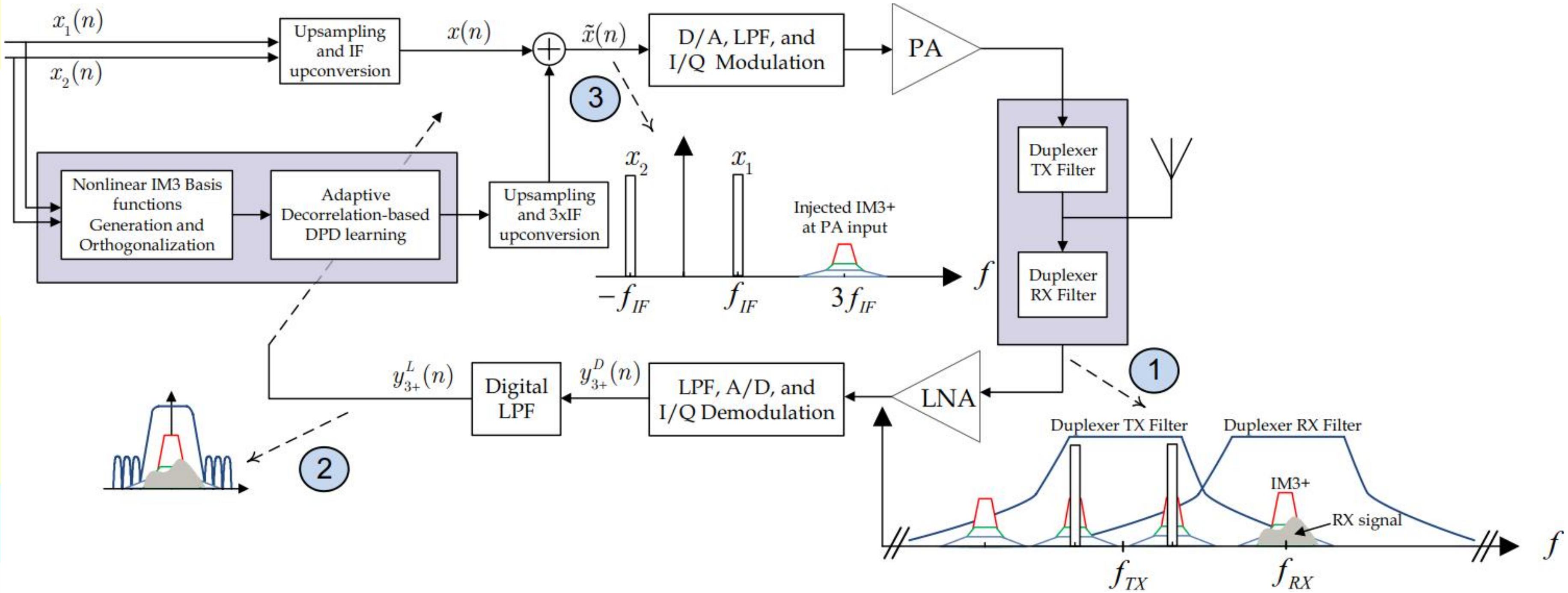
- Carrier aggregation (CA) in LTE-A combines multiple component carriers (CCs) at different RF frequencies.
- Power efficiency is improved when the CCs are combined at the power amplifier (PA) input, whenever feasible, compared to combining them after the PA.
- This leads to additional unwanted spurious emissions at the PA output.
- These emissions can violate the emission limits regulated by the standardization bodies.
- Additionally, the generated spurious components can also overlap with the device's own receive band, causing own receiver desensitization.

Problem motivation

- Straight forward solutions are:
  - Increasing the duplexer isolation:
    - More bulky and costly duplexer filters.
  - Reducing the TX power:
    - Implies using larger and more expensive PAs operating in the linear region à higher CAPEX
    - Moreover, this leads to reducing the energy efficiency and increasing the energy needed for cooling à higher OPEX

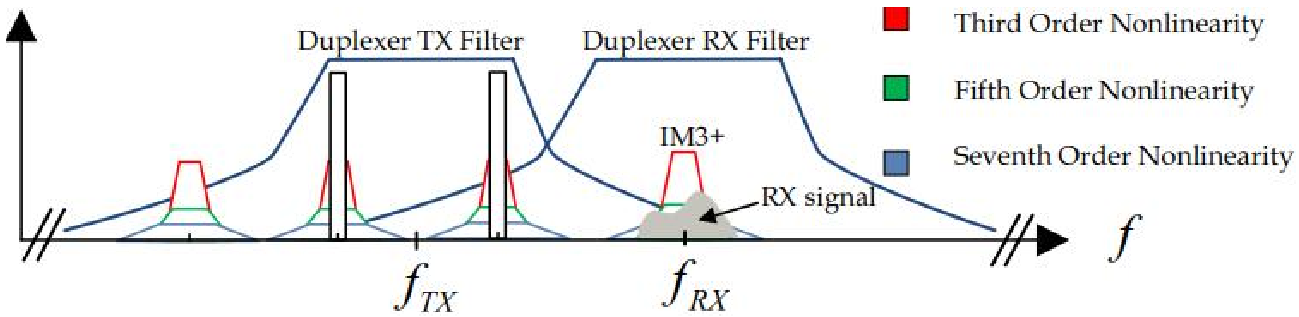
- Both solutions are not suitable, in particular for small devices. An alternative is required!

Proposed DPD solution



- A novel spur-injection sub-band DPD solution is proposed.
- It uses the device's own RX for learning, and thus does not require any extra observation RX, as in classical DPD.
- The proposed DPD learning solution is based on evaluating and minimizing the correlation between the observed spurious emissions at the RX band, and specific locally generated basis functions representing these emissions.
- The parameter learning approach is very simple and does not require any computationally intensive operations.
- Moreover, the unwanted emissions are suppressed before the LNA input, and thus the RX dynamic range can be fully utilized for the desired RX signal. This is not the case in RX cancellation methods.

System modeling



$$x(n) = x_1(n)e^{j2\pi f_{IF} n} + x_2(n)e^{-j2\pi f_{IF} n},$$

$$y(n) = \sum_{p=1,p \text{ odd}}^{P} f_{p,n} \star |x(n)|^{p-1} x(n),$$

PA input output assuming a Pth order PH model

$$y_{3+}(n) = \sum_{p=3,p \text{ odd}}^{P} f_{p,n}^{3+} \star u_p(n) \quad \text{where} \quad f_{p,n}^{3+} = LPF\{e^{-j2\pi 3 f_{IF} n} f_{p,n}\},$$

PA output at the IM3+ sub-band

$$u_3(n) = x_2^*(n) x_1^2(n),$$

$$u_5(n) = u_3(n)(2|x_1(n)|^2 + 3|x_2(n)|^2),$$

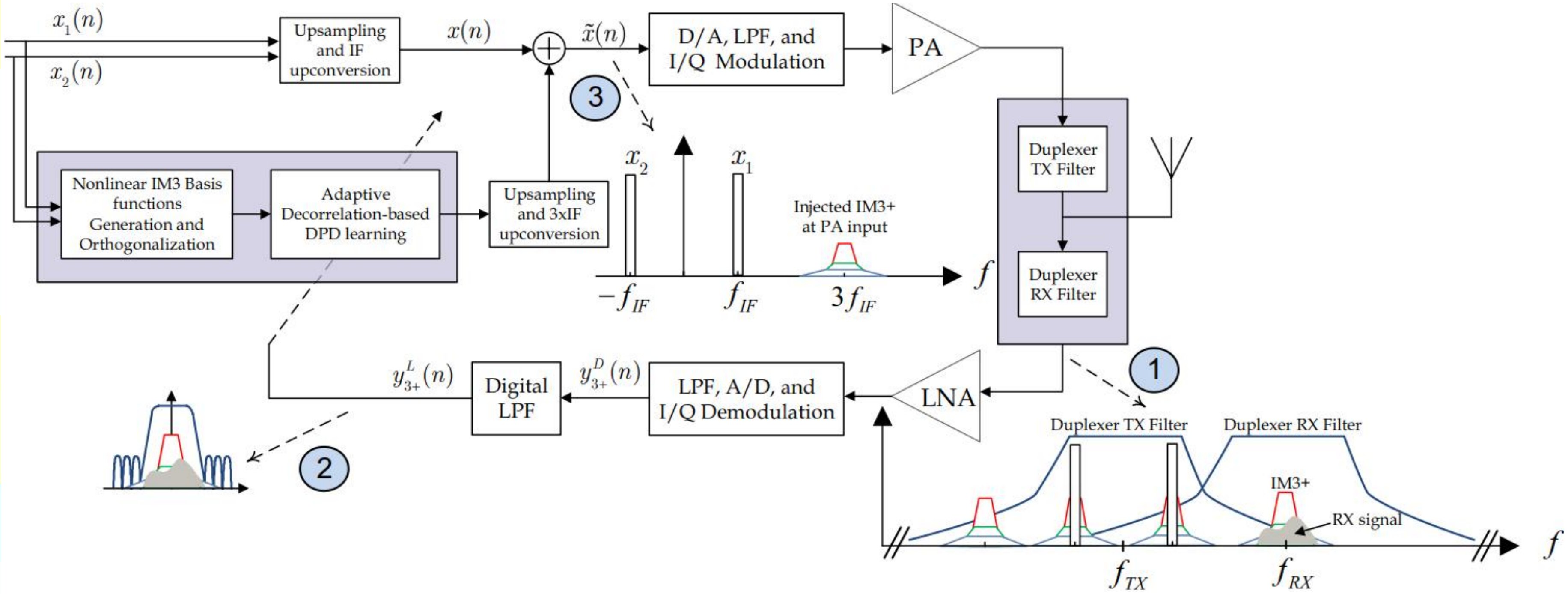
$$u_7(n) = u_3(n)(3|x_1(n)|^4 + 6|x_2(n)|^4 + 12|x_1(n)|^2|x_2(n)|^2)$$

Basis functions representing PA nonlinearity at the IM3+ sub-band

$$y_{3+}^D(n) = h_n^D \star y_{3+}(n) \quad \text{where} \quad h_n^D = h_n^{RX} \star \left(h_n^{TX} e^{-j2\pi 3 f_{IF} n}\right)$$

IM3+ leakage after the duplexer

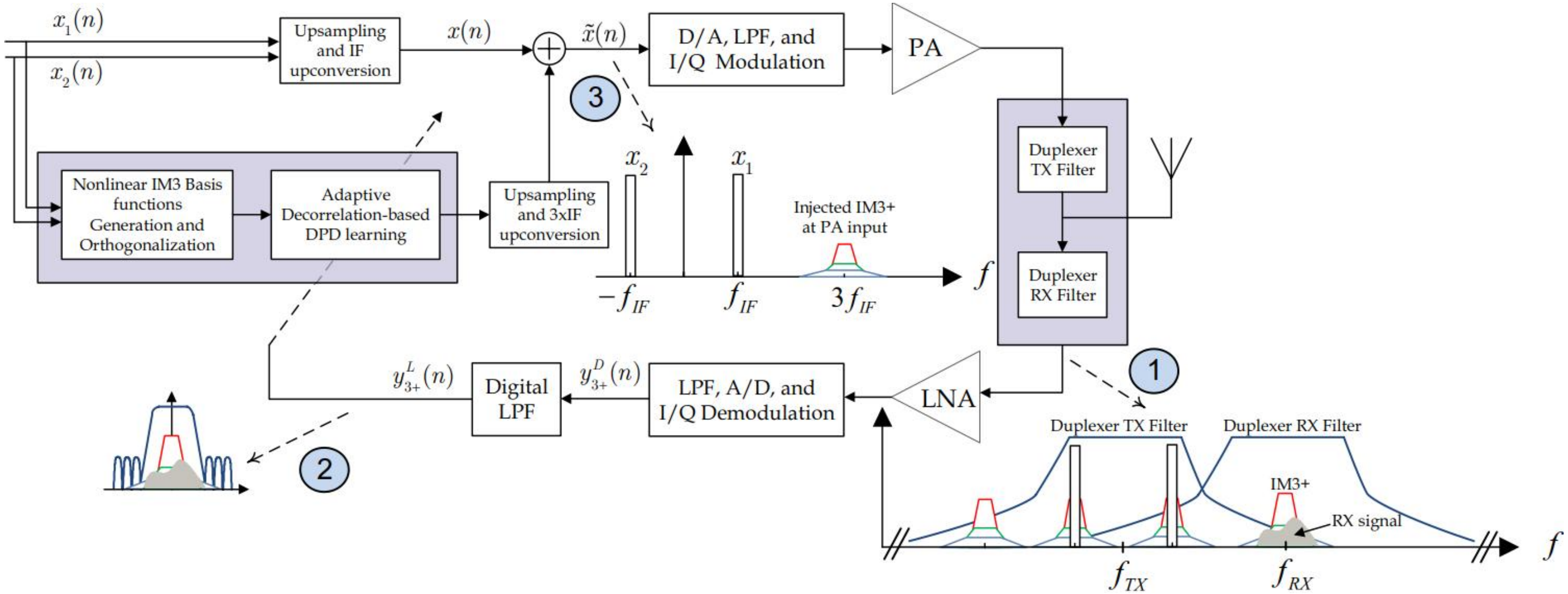
System modeling



$$y^L_{3+}(n) = h^{CSF}_n \star y^D_{3+}(n)$$ } IM3+ leakage after the CSF at the RX

$$y^L_{3+}(n) = \sum_{p=3,p \text{ odd}}^{P} h^L_{p,n} \star u_p(n) \quad \text{where} \quad h^L_{p,n} = f^{3+}_{p,n} \star h^D_n \star h^{CSF}_n$$ } IM3+ leakage is a filtered version of the SNL basis functions

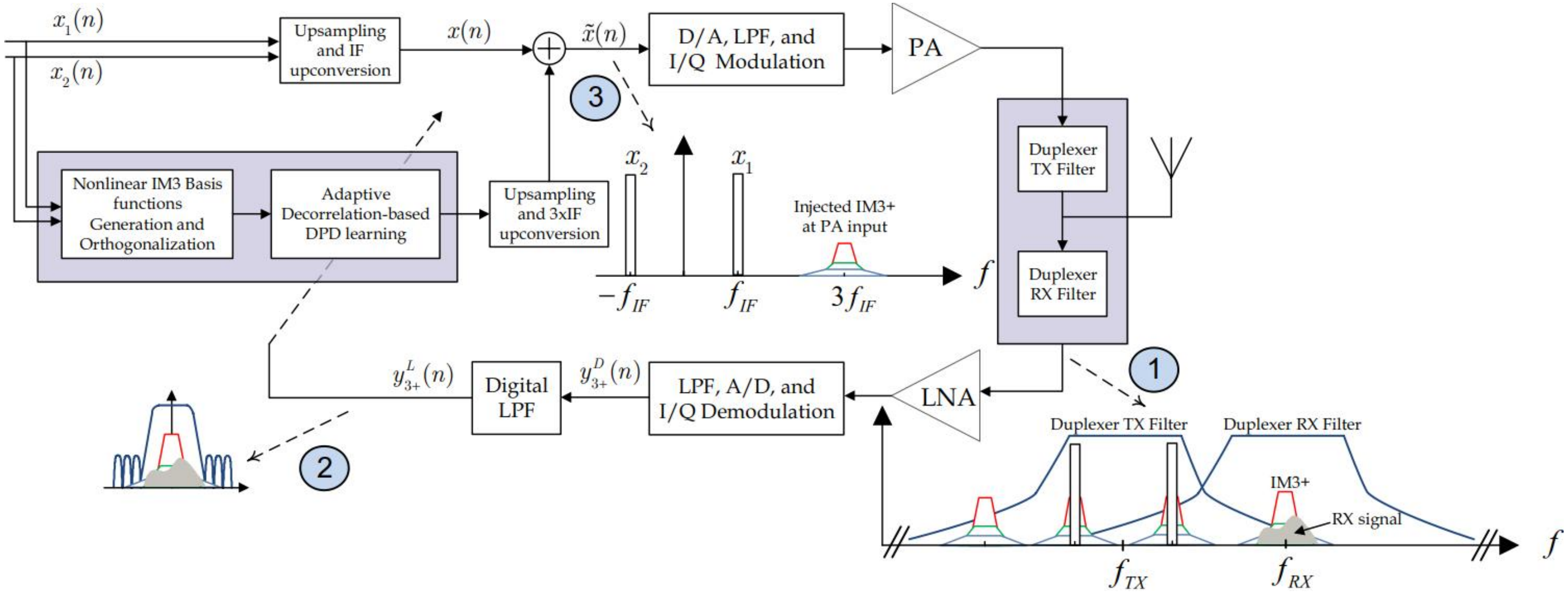
Proposed DPD structure



- The previous modelling showed that the IM3+ leakage at the RX is a filtered version of the SNL basis functions representing the nonlinear distortion.
- The key idea of the proposed DPD is to inject a proper additional low-power cancellation signal at the IM3+ sub-band (in this example), such that the emissions at this sub-band are mitigated.
- This injected signal is a filtered version of the IM3+ SNL basis functions.
- Incorporating such DPD processing with polynomial order Q, the composite baseband equivalent PA input signal reads

$$\tilde{x}(n) = x(n) + \left[\sum_{p=3,p \text{ odd}}^{Q} \alpha_{p,n} \star u_p(n) \right] e^{j2\pi 3 f_{IF} n}$$

Proposed DPD learning



- The proposed decorrelation-based DPD learning is formulated such that the correlation between the observation at the RX CSF output and the SNL basis functions is minmized.
- The DPD adaptive learning update then reads:

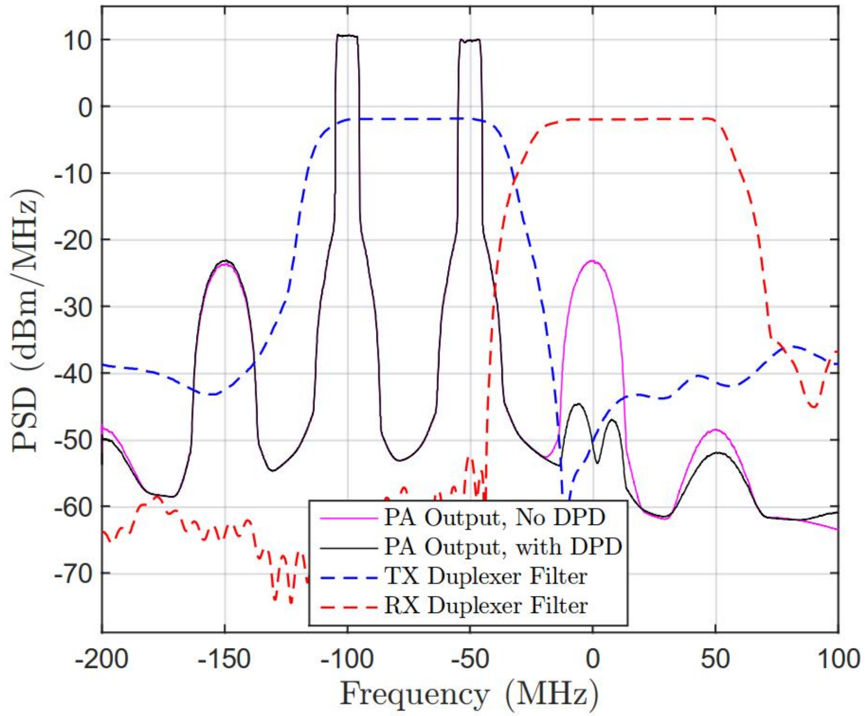
Orthogonalized and filtered DPD basis functions block of samples (and delayed replicas) combined in matrix format.

$$\bar{\boldsymbol{\alpha}}(m+1) = \bar{\boldsymbol{\alpha}}(m) - \mu\,\bar{\mathbf{S}}(m)\mathbf{e}^*(m)$$

TAMPERE UNIVERSIT Error signal vector (residual emissions at the CSF output

Simulation results

- Two 10 MHz LTE-A UL component carriers with QPSK subcarrier modulation, and the CC spacing is 50 MHz.
- The PA model is a PH fifth-order model whose parameters have been identified using a true mobile PA transmitting at +23 dBm.
- The desired RX signal at the RX antenna is assumed to be a 10 MHz OFDM LTE-A DL signal with QPSK subcarrier modulation.
- The PSD at the PA output with and without DPD is shown.



Simulation results

- The block-adaptive decorrelation-based DPD parameters are:
  - Nonlinearity order Q = 5
  - Memory order N = 4
  - Block size M = 10k
  - Number of blocks used for estimation = 130
- The PSD at the Duplexer output, for the same example, with and without DPD is shown.
- The desired RX signal is assumed to be 10 dB above the noise floor in this figure. 9 dB RX noise figure is assumed.
- Up to 25 dB gain in SINR is achieved when operating at +23 dBm, thus significantly improving the performance, without sacrificing the TX power efficiency, cost, or size of the overall transceiver.