DNN-Based Power Amplifier Pre-Distortion for Communications in Contested Environments

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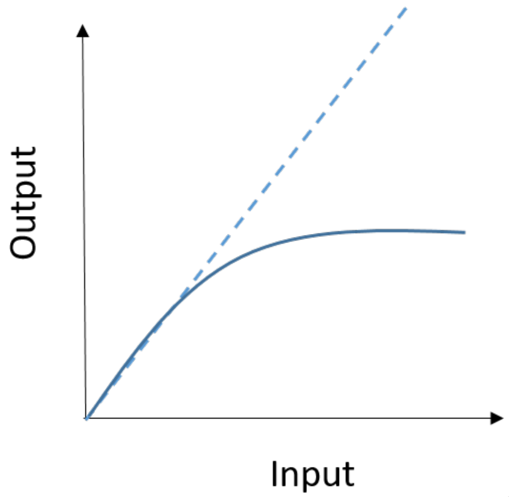
Power Amplifier in Communication Systems

- Hardware limitations can be key issues in efficient communications in complex and contested environments.
- Power amplifiers (PA) are crucial and most common elements in many hardware implementations.
- Ideal power amplifiers operate linearly.
- Real-world PA encounters many non-linearities.
- Non-linearity leads to:
  - Spectrum growth
  - Constellation distortion
- Performance degradation in communications.



Digital Pre-Distortion & PA Modeling

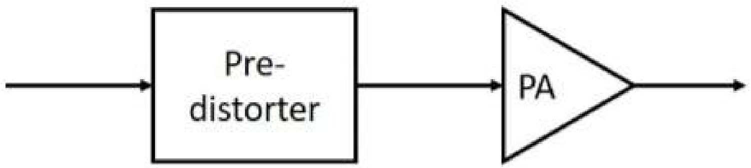
- Digital pre-distortion is an efficient method to compensate PA non-linearities (flexible and re-configurable).

- Traditional methods: In order to design the pre-distorter, the first step is often to have a good model of PA.

- Classic PA models:

  - Memoryless model, e.g., Saleh

  - Models with <u>memory</u>, e.g., Volterra



Indirect Learning and Direct Learning in Pre-Distorter Design

- Key steps:

\- Step 1: Train/fit the model by optimizing the model parameters using the reversed Input-Output PA measurements.

\- Step 2: Duplicate the fully trained Post-Distortion model and use it as a Pre-Distortion model.

- Can lead to a biased solution, but still very popular and widely used.

- Two-stage process:

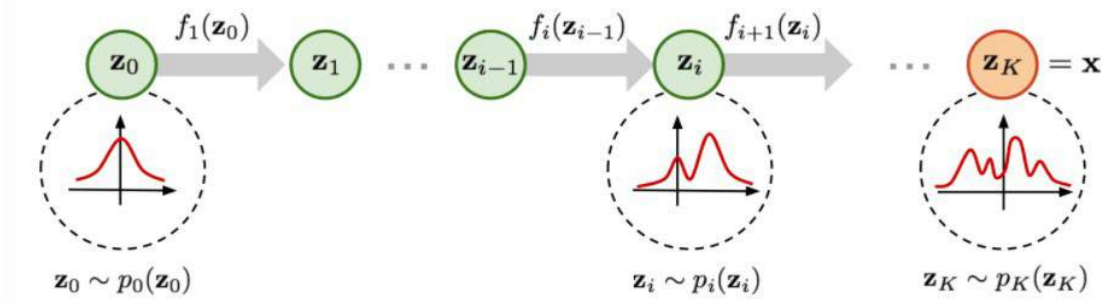
\- Stage 1: First identify and model power amplifier.

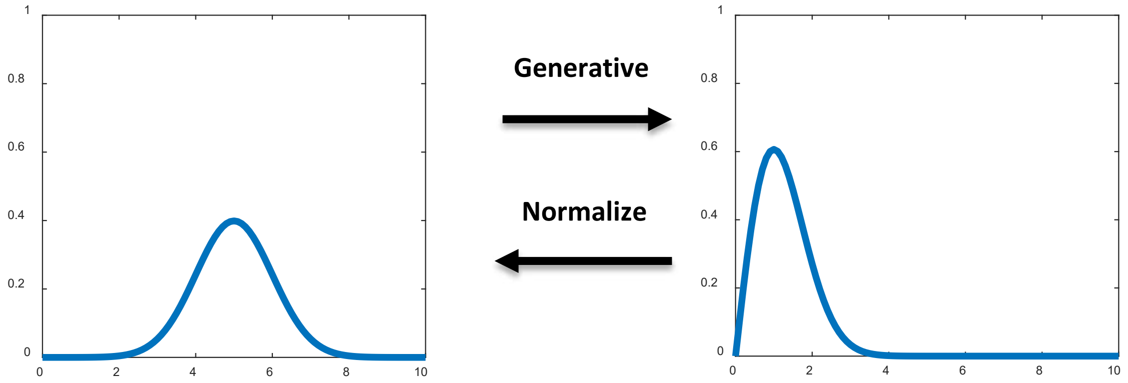
\- Stage 2: Fixed PA model and identify Pre-distorter.

- Two networks needed (PD & PA) with special overall training.

Pre-Distorter Design via Normalizing Flow based Neural Network

The idea of normalizing flow:



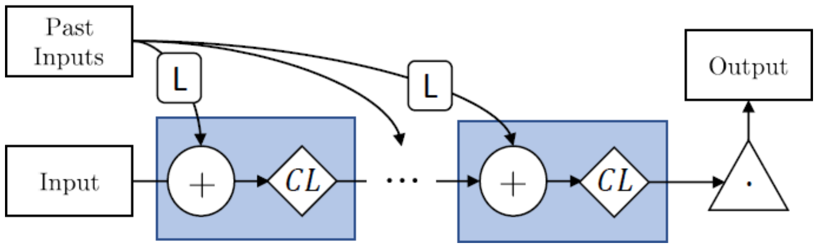


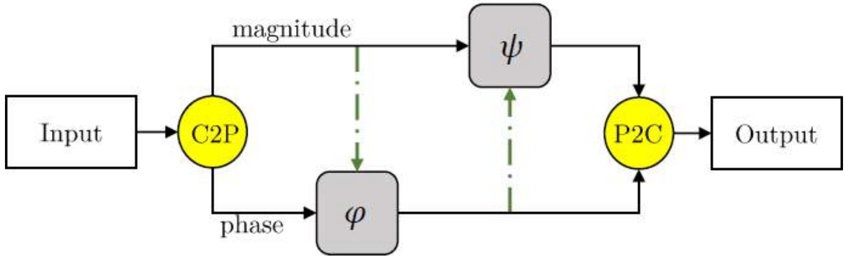
Pre-distorter design idea:
- Model the non-linearities using reversible neural networks with forward/backward mode.
- Train the network in the forward mode for the power amplifier modeling, and

directly use trained neural network in the backward mode as pre-distorter (for power amplifier system inversion).

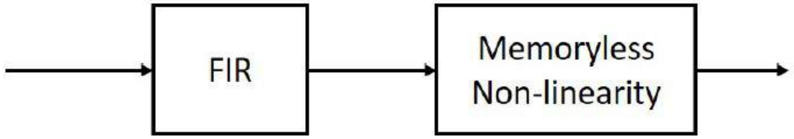
Reversible Neural Network Structure and PA Datasets

- Gaussian input/output training datasets
- Higher probabilities for selecting larger PA input power data while forming training batch
- Test: OFDM signal samples (4x oversampling)





Construct training sets (input/output of PA) using Wiener model

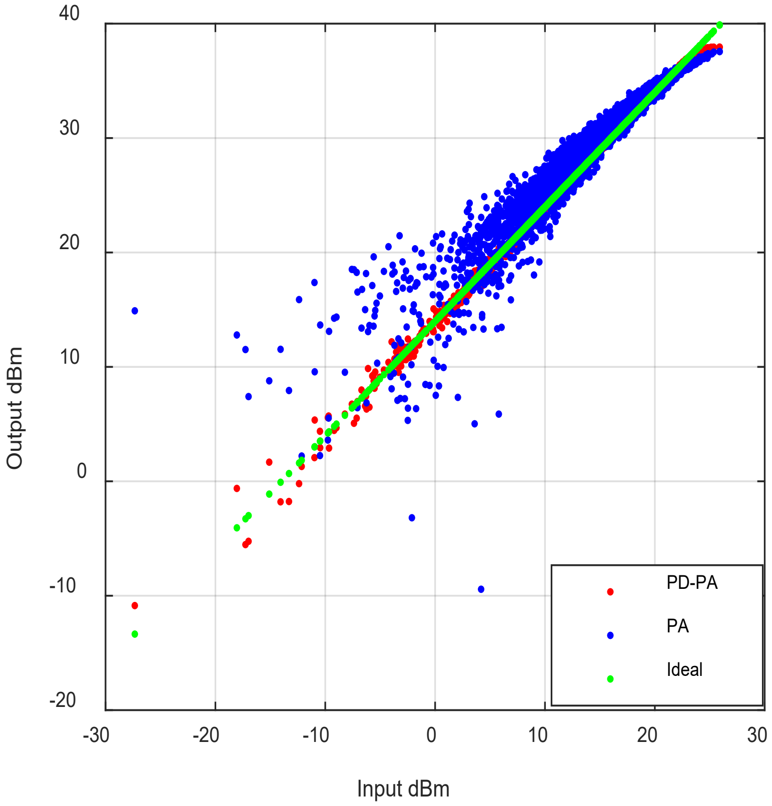


$$H(z) = 1 + 0.154z^{-1} + 0.077z^{-2},$$

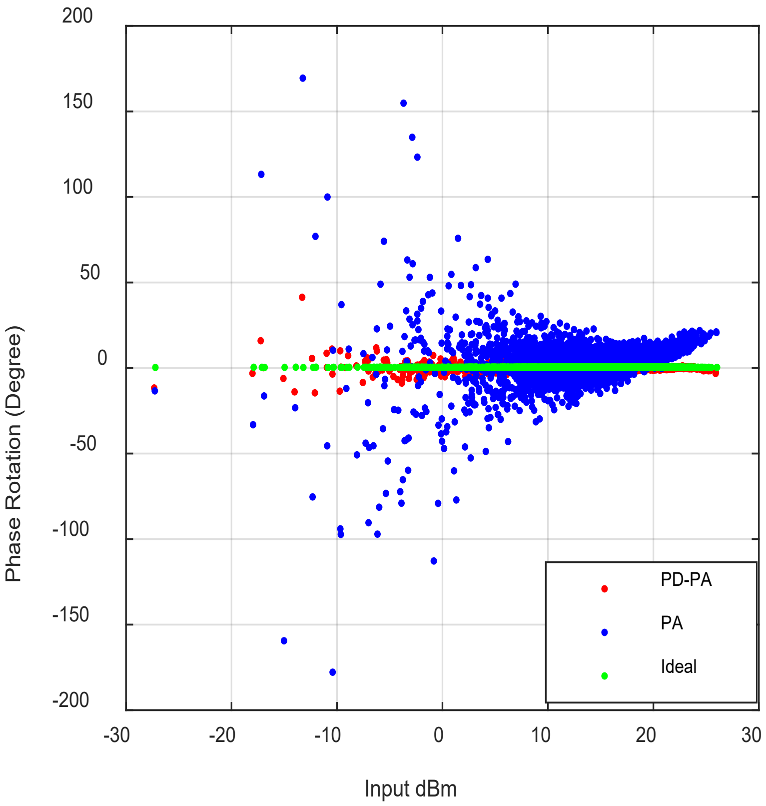
$$|y_s(n)| = \frac{\alpha_a |x(n)|}{1+\beta_a |x(n)|^2}$$
$$\angle y_s(n) = \frac{\alpha_p |x(n)|^2}{1+\beta_p |x(n)|^2}$$

$$\alpha_a = 5,\ \beta_a = 1,\ \alpha_p = \pi/3,\ \beta_p = 1.$$

Flow-based Neural Network Predistortion



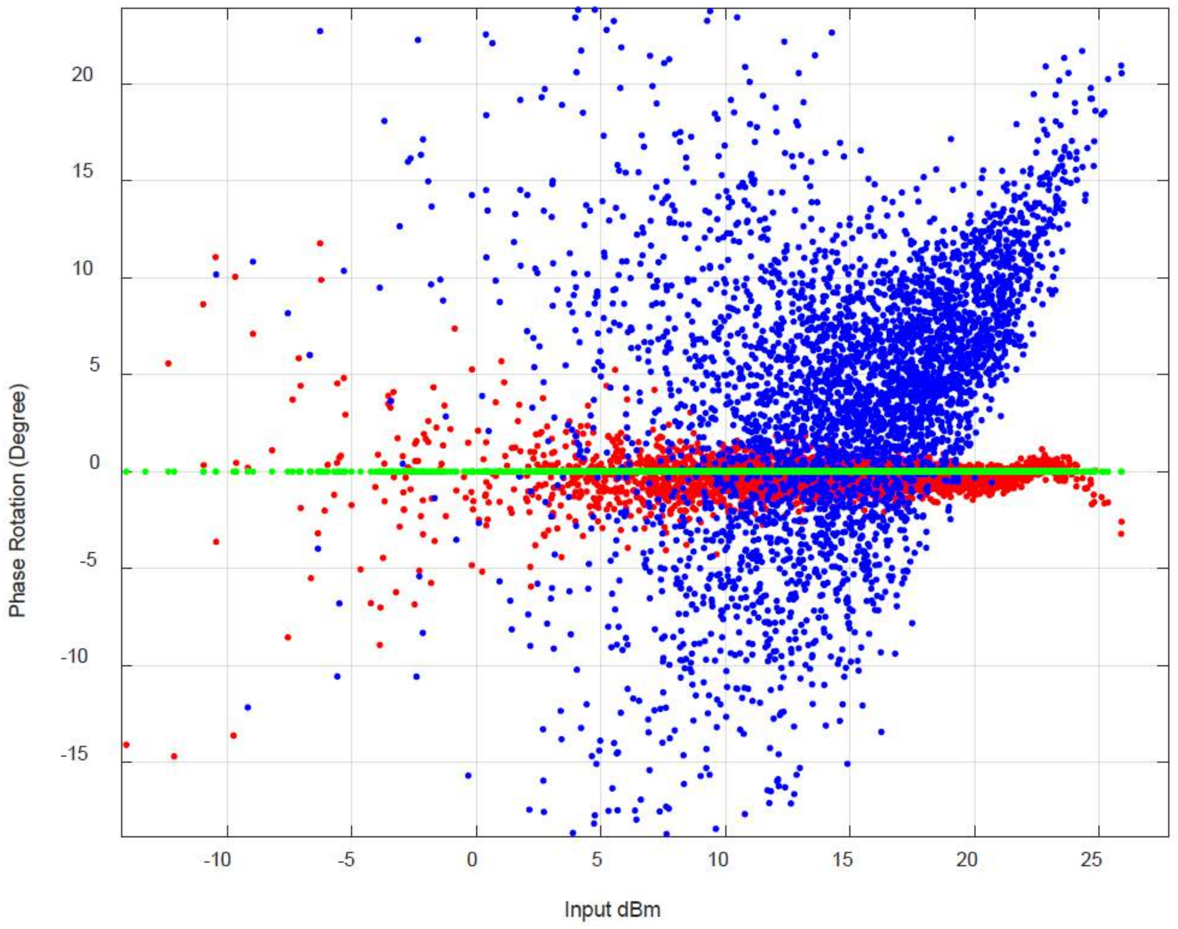
(a)



(b)

- Static vs dynamic non-linearities
- Linearization performance

Phase Linearization



Linearized	Mean (degree)	Std (degree)
All region	-0.2468	1.2361
5-25 dBm	-0.2590	***0.6009***

Original	Mean (degree)	Std (degree)
PA signal	3.5753	***12.2959***

Performance Metrics

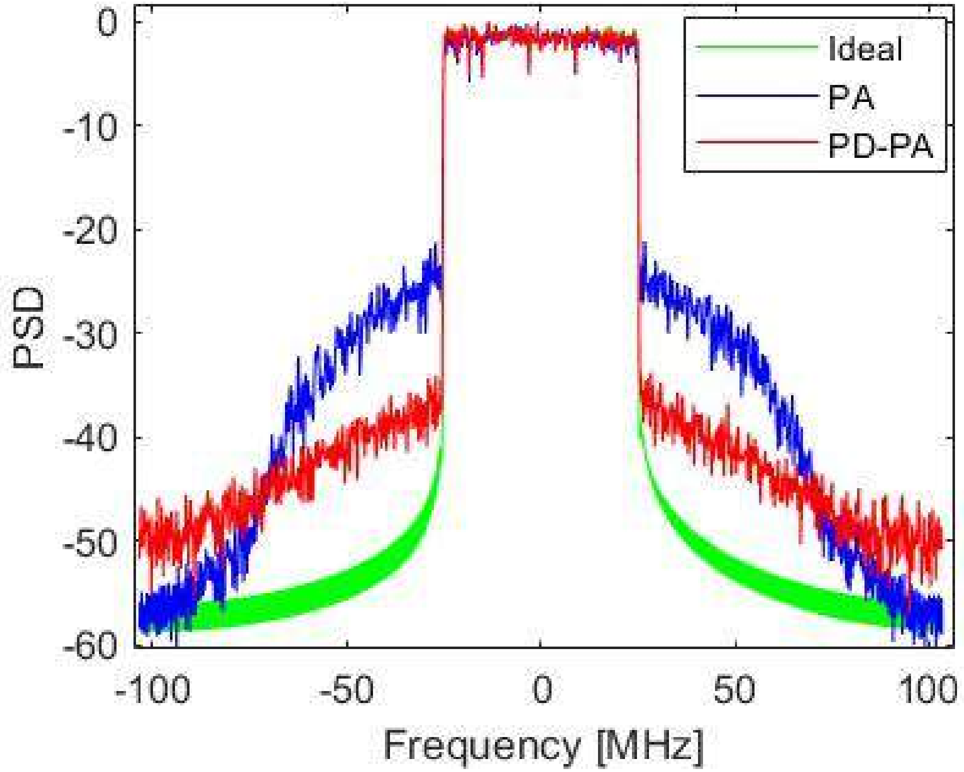


TABLE I
PERFORMANCE PARAMETERS

	PA	PD-PA
NMSE	-13.9	-32.1
ACPR	-22.7	-26.7
EVM	0.1915	0.0196
P_{clip}	49.54%	0.83%

Summary

- Proposed a *reversible* neural network for doing non-linear power amplifier modeling & pre-distortion.
- Can be used as *add-ons* to non-linear power amplifiers in the wireless communication systems for linearization improvements (for both static and memory non-linearities).
- Can provide better performance in communications, e.g., inter-carrier interference reduction, in complex and contested wireless environments.
- Can be combined with additional PAPR reduction pre-processing techniques, e.g., coding, clipping and filtering.