Centre Tecnològic de Telecomunicacions de Catalunya

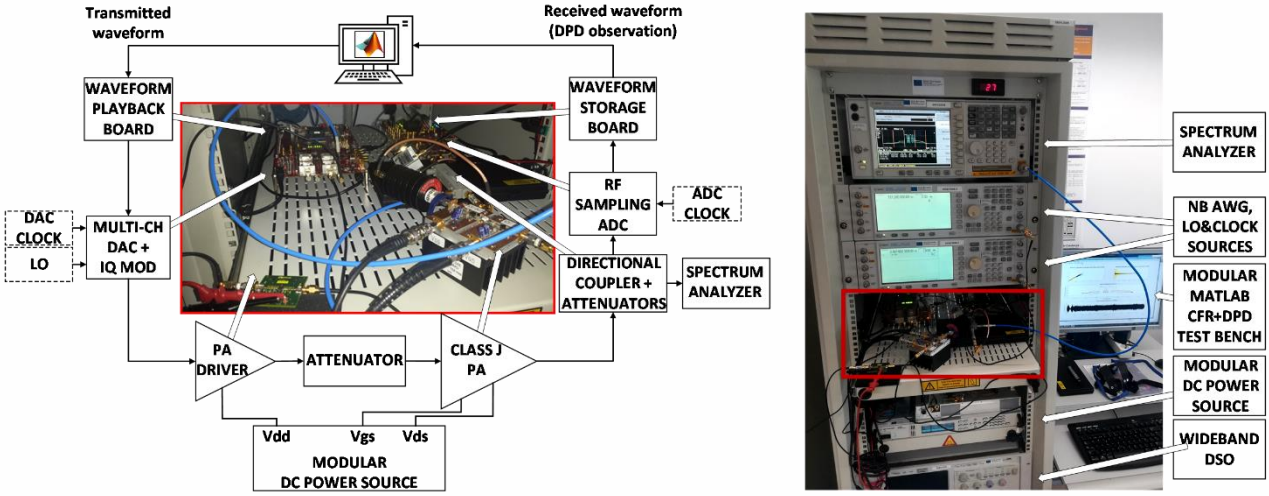
SHAPER

1. IN A NUTSHELL

SHAPER: Solutions for wideband Highly lineAr and efficient PowER amplification

SHAPER is a Software Defined HW demonstrator that provides rapid and cost-effective prototyping and validation of radiofrequency (RF), microwave (uW), and millimeter wave (mmW) power amplifier (PA) linearization techniques, such as digital predistortion (DPD) and crest factor reduction (CFR).

The demonstrator, a part of which is fruit of a collaboration with UPC University, nowadays comprises a Matlab Testbench including the baseband TX PHY, RX PHY, DPD & CFR blocks, which is able to interface either high-end laboratory instruments or COTS boards (such as pattern generators, A/D, D/A and FPGA/DSP evaluation boards). SHAPER may also enable HW/SW co-simulation and validation of DPD and CFR building block implementations in FPGA bridging the gap between applied research and end-product prototyping and validation.



SHAPER digital linearization platform for a given test setup

The benefits brought by the digital linearization techniques will have a significant impact on the performance increase and reduction of the equipment Total Cost of Ownership (TCO) in the next generation radio access, wireless terrestrial and satellite backhaul, cable distribution, and optoelectronic communication systems.

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2. USAGE AND FEATURES

SHAPER can be used to:

Extract and validate PA behavioral models or characterize the performance of PA designs.

Design, simulate, validate and experimentally benchmark Matlab DPD & CFR algorithms for multiple PA technologies and both wired and wireless standards and multi-channel|band|rate configurations.

Emulate HW constraints (i.e.A/D and D/A bits, data finite precision) before implementation and experimentally evaluate techniques to reduce digital linearization HW complexity & resources.

Validate product-oriented FPGA prototyping through Matlab HW/SW cosimulation.

SHAPER features:

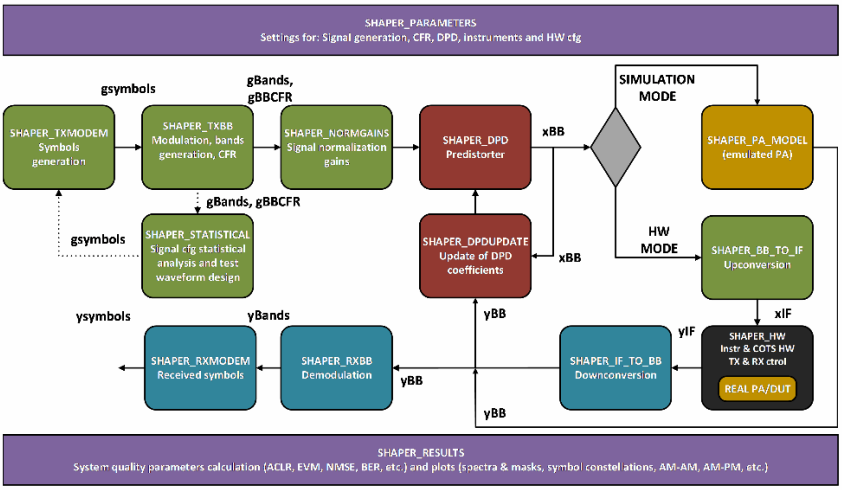
Multi-channel waveform synthesis and acquisition for different BB/BBIQ/IF/RF DUT interfacing modes reaching up to 1 GHz DPD bandwidth for RF-to-mmWave transceiver operation.

Key parameter multi-dimensional analysis: i.e. NMSE, ACLR, EVM, rawBER versus Output power, DPD coefficients, peak-to-average power ratio (PAPR) reduction, complexity reduction, CFR/DPD variants, or any combination of the previous.

Design of statistically representative experiments and waveforms (Modulated signal full PAPR statistical characterization & waveform design).

Supports remote operation from any PC with Matlab and internet connection thanks to a waveform upload/download FTP Matlab server/client application.

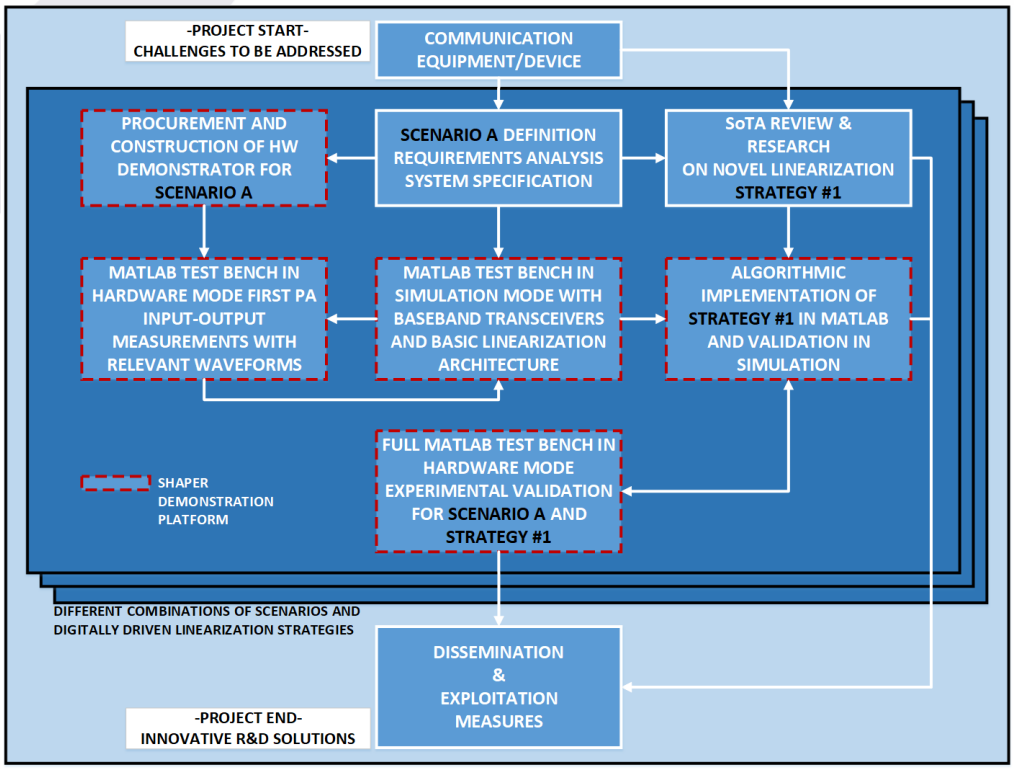
The modular Matlab test bench has been created to be flexible and scalable and thus ease the inclusion of new modems and digital linearization algorithms, or provide different complexity usage levels. It is also featuring full setup and results traceability and high measurement repeatability.



SHAPER's modular Matlab test bench

3. WORK METHODOLOGY

From technical challenges to innovative solutions:



SHAPER's work methodology

4. PROJECTS AND DISSEMINATION

Relevant project developments:

ORIGIN (national, 2021-ongoing): SHAPER's multidimensional DPD expansion to allow for digital linearization and RF impairment correction of mm-wave hybrid beamforming transceiver architectures for Ka-band 5G-NR, evaluate sub-6 GHz supply-modulated LUT-based wideband UE FPGA DPD, machine learning techniques to reduce polynomial and neural network MIMO DPD schemes, and new RU-to-EDGE distributed DPD processing paradigms boosting B5G transmitters' energy efficiency.

5G-TRIDENT (national, 2019 – 2020): SHAPER's MIMO DPD expansion to allow for digital linearization and RF impairment correction of digital MIMO architectures for sub-6 GHz 5G-NR. Inclusion of artificial neural network based digital linearization strategies, hybrid linearization approaches and multi-dimensional DPD schemes.

ITERATE (industry, 2018): Design and implementation of a real-time digital front-end of a multi-antenna 5G remote radio head (RRH) with CFR & DPD blocks, for up to 200 MHz BW signals (with digital linearization blocks) and 400 MHz BW signals (without digital linearization)

DPD4CABLE (industry, 2017-2019): Research and experimental evaluation of CFR & DPD techniques for Cable TV PA systems operating under waveforms with high-PAPR and up to 1 GHz bandwidth (BW).

FUTURETX (industry, 2017): Study on efficient transmitter architectures such as digitally assisted Doherty, envelope tracking (ET), outphasing and all-digital for next generation systems.

AEThER (national, 2015-2018): Research, fast prototyping and T&M engineering of digital linearization techniques (CFR & DPD) for: a) 5G radio access with microcell BS at UHF band, b) 5G radio access with femtocell BS and UE at S-band (at UE side considering also envelope tracking), c) 4G radio access with macrocell BS at S-band, d) uW wireless backhaul at C-band and e) mmWave wireless backhaul at E-band.

GRE3N (national, 2014): CFR+DPD demonstrator targeting the improvement of linearity and efficiency of power amplifiers with COTS HW boards + Matlab and move towards Matlab HW/SW cosimulation and real-time polyphase HDL implementation.

DI-PRE-DATORS (industry, 2012-2013): Design and development (programming) of a Matlab SW defined instrumentation testbed to extract and validate PA behavioral models, simulate and experimentally evaluate CFR & DPD techniques, and benchmark different PA technologies (GaAs, GaN) for wideband single/multi-channel M-QAM wireless backhaul signal configurations.Extract and validate PA behavioral models or characterize the performance of PA designs.

Dissemination activities:

About 20 publications (Q1 journals, intl. and natl. conference papers and book chapters) have been produced over the last 7 years. Two PhD thesis and two master thesis have benefited from using SHAPER for applied research, nonlinear characterization, and design and experimental validation of digital linearization techniques. In 2015 the CTTC-UPC student team won the PA linearization competition at the International Microwave Symposium, and UPC-CTTC organized the 2017 edition with record participation.

5. TEAM

CTTC

David López-Bueno (Researcher). Role: Platform coordinator, digital linearization researcher, T&M engineering.

Nikolaos Bartzoudis (Senior Researcher, ADAPT Research Unit Head). Role: Digital baseband architect

Pepe Rubio (Researcher). Role: FPGA prototyping

in collaboration with UPC

Pere Gilabert (Assoc. Prof. and Senior Researcher). Role: Digital linearization researcher and PhD thesis supervisor.

Gabriel Montoro (Assoc. Prof. and Senior Researcher). Role: Digital linearization researcher and PhD thesis supervisor.