Power Amplifier Linearization through Digital Pre-Distortion (DPD)

Sponsoring MTT-S Technical Committees

MTT-9 (Digital Signal Processing)
MTT-11 (Microwave Measurements)

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Competition Summary

Digital predistortion (DPD), after about 20 years development, has become the most popular distortion cancellation method of choice to relax the linearity-efficiency compromise of wireless systems. Nowadays, in order to accommodate the growing demands of users for faster data rate and higher quality services, modern wireless communication systems must evolve to support subscribers at the same time, which enables the wide application of multiple-input multiple-output (MIMO) system. However, the MIMO systems suffer from stronger signal distortion effects as the result of the presence of crosstalk in the linear or nonlinear forms between the transmit (TX) paths, which makes DPD technique more complicated than the case in single-input single-output systems.

The goal for the sixth edition of this Student Design Competition (SDC) is to maximize the total drain efficiency of two GaN HEMT based power amplifiers (PAs) designed for 2-channel MIMO transmitter with coupling effect under specific linearity constraints, coupling factor and realistic waveform operation.

Following the previous editions of the DPD Student Design Competition, a remote-controlled measurement setup (WebLab) consisting of the PA to be linearized and proper instrumentation will be made available for the competitors prior to IMS. Measurements can then be performed remotely using this virtual laboratory setup in order for the competitors to develop and tune their DPD algorithms.

Detailed Competition Description and Rules

The objective of this SDC is to design a DPD algorithm appropriate to linearize 2-channel MIMO transmitter with cross-coupling effect. The complete transmitter chain to be linearized comprises the following devices and instrumentation:

- Two GaN HEMT based PAs designed for MIMO transmitter.
- Commercial couplers.
- Vector signal generator, or Wideband direct RF/uW arbitrary waveform generator (AWG), or Wideband I/Q AWG and modulator (depending on the specific instrumentation made available by the equipment sponsor).
- Signal analyzer.

The participants will be able to remotely (via the web) upload 1) the predistorted envelope signals (baseband I/Q signals) and 2) supply wave to the corresponding signal generators (taking into account of the necessary delay compensation between both I/Q and supply signals). The PA response will be retrieved by the signal analyzer. The scoring results will be also provided. The participants' DPD algorithms will be run off-line, similarly to the earlier editions of the DPD-Competition, and a realization of the target input signal used in the competition will be made available to the participating teams. A realistic orthogonal frequency division multiplex (OFDM) telecommunications signal will be used as input, which will cover a significant part of the PAs' available bandwidth.

Through a dedicated web site, the participating students will be able to test and essay their algorithms with the hardware setup, by remotely uploading the input predistorted signals and supply waves, and capturing the respective output signals. Both the web site and the input signal format to be considered in the DPD-Competition will be made available well in advance to the competition.

In the DPD-Competition, to be held in the IMS-2019, the same hardware test setup (or other samples of the same devices) will be made available to the participating students, where they will be able to tune their DPD algorithms and upload their predistorted and supply signals. Each team will have a period of 15 minutes to tune its DPD model. When ready (or at the end of that 15 minutes period) the target input signal will be given to the team and its DPD will generate the predistorted signals, which will be uploaded to the signal generators in different branches. At that moment, the jury will measure (and register) the performance metrics used to compute the overall score achieved by the team.

Evaluation Criteria

The DPD-Competition goal is to maximize a numerical score, which is used to rank each participating students' team. It will be calculated by a formula, defined long before the competition (and made available to the teams), which increases with the total efficiency of two PAs, although restricted to a specific spectral emission mask and normalized mean square error (NMSE). The computational complexity of the DPD algorithm will also be measured in terms of minimum number of required resources, for example particularizing in the number of coefficients used by the DPD algorithm. In addition, the coupling factor will be considered in the measurement, which is positively related to the total score. Hence, the ranking score will depend on the following performance metrics:

- The total 2-channel drain efficiency constitutes the desired optimization target, provided that the other linearity constraints are met. It will thus positively contribute to the score.

- The out-of-channel distortion mitigation (ACPR) will be assessed according to an appropriately defined spectral emission mask set following real communication scenarios of the specified signal format. The amount of power violating this mask will negatively contribute to the score.
- The overall signal error will be measured using the NMSE between the (scaled and time-aligned) output signal and the input signal. The amount of violation of the limit NMSE (which is also provided ahead) will negatively contribute to the score.
- The computational complexity will be measured in terms of number of resources used by the DPD algorithm. For example, assuming a parameter-based DPD, a high number of required coefficients will have a negative impact on the final score.
- The coupling factor between the two channels, which can be prior controlled in the test instrument platform, will has a positive impact on the score.

The exact score formula will be designed and adjusted based on our assessment of the device to be linearized (if found adequate, the metrics above described will be adjusted).

A MATLAB script will calculate the score based on the defined performance metrics. This same script will provide the scoring values in the remote access web site (before the IMS-2019 competition) and during the IMS-2019 competition. The script will be available in the web site for downloading by the participants.

Undergraduate and graduate students' DPD algorithms will not be separately judged under two distinct contest levels, but combined.

How to Participate

Participants must register to the IMS Student Design Competition according to the rules posted on the IMS-2019 homepage. At the same time as the registration to IMS-2019 is made, the competitors must also register with the organizers of the competition. This is done by sending an e-mail containing the name of the team members and their contact details (e-mail preferred) to chenwh@tsinghua.edu.cn and to x-liu17@mails.tsinghua.edu.cn with the subject line "IMS-2019 SDC: Registration DPD competition" no later than the official deadline announced on the IMS-2019 SDC homepage.

At least one member from each team must be present at the competition held during the IMS-2019. After the registration period ends, a time-table for the competition day will be made available, with the schedule of the 15 minutes slots of the participating teams. If no team member is present at the competition site within its slot, then the team may be considered as absent.

The MATLAB scripts required by each team to implement and tune their DPD algorithm at the competition must be brought on a USB memory stick. At the IMS-2019 competition, the hardware setup will be controlled by a PC to which the teams will have access during their 15 minutes time slot. It will not be possible for participants to connect their own computers to the hardware setup during the competition. The scripts and files brought by the teams will not be stored, but deleted from the PC after the participation of each team.

In accordance with IMS general rules, it is required that the designed algorithms are principally the work of the students.

Please also see the general IMS student design competition rules on the IMS-2019 SDC homepage.

Student Eligibility Criteria

The DPD-Competition is open to teams of undergraduate and/or graduate students that are registered at a university or other educational institution. The maximum number of participants per team is three. Participants cannot be associated with more than one team. Students currently affiliated with the Tsinghua University, China, cannot participate in the competition.

Awards

1st team gets $1200 and 2nd team $800.