Direct Learning Techniques for Digital Predistortion of Power Amplifiers

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***Abstract*—Different techniques have been developed for digital predistortion of power amplifiers to this day. Specifically, there are two main fields of digital predistortion, indirect learning architectures and direct learning architectures. In particular, this work has been focused on making a comparison between some direct learning techniques, implementing them and performing experiments to analyze the advantages and disadvantages of using each of them. Results and some graphics are included in this report. In addition, the student's career plans are explained.**

***Index Terms*—Power amplifiers (PA), Digital predistortion (DPD), Direct learning architectures (DLA).**

I. Introduction

THE efficiency of the power amplifier (PA) is greater at higher powers. Therefore, it is necessary to operate at high power levels but this, in turn, causes the appearance of distortion effects, which is inconvenient. On the other hand, the most recent communication standards use signals with high peak-to-average-power ratio (PAPR) that require working with lower operating points and thus decrease the device efficiency. For this reason, DPD is currently presented as a proper solution to this problem.

The DPD consists in applying signal processing to the transmitted signals in such a way that, when these signals are distorted by the PA, the resulting signals are equivalent to the output of a nearly linear system. There are different types of architectures to implement the DPD, but the most outstanding ones are Indirect Learning Architecture (ILA) and Direct Learning Architecture (DLA). ILA consists in obtaining a postdistorter by inverting the non-linear model of the PA and then, this is used as a predistorter. This technique presents some drawbacks, since the inverse of the non-linear model could not be computable for certain ranges of input amplitude and using a postdistorter as predistorter could not always present a proper performance. For these reasons, it could be recommended using DLA, which aims to estimate the input-output relationship in a PA and then, to compute the predistorter parameters using iterative processing to minimize an error signal.

Particularly, in this work, different DLA techniques have been implemented in order to compare them. In Section II, these techniques will be briefly reviewed, and results will be provided in Section III. Lastly, in Section IV a conclusion with student's future career plans and MTT-S Scholarship impact will be described.

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II. EXPERIMENTAL SETUP AND TECHNIQUES

A. *Experimental setup*

The experimental setup was originally intended to be implemented in the laboratory of the Department of Signal Theory and Communications at Universidad de Sevilla. However, due to the pandemic conditions, experiments were performed using the Chalmers' WebLab [1], which was also being used for preparing the *IMS Digital PreDistortion Student Design Competition* in 2020, also cancelled for the same reason. This setup is mainly composed of a Vector Signal Analyzer (VSA), a PA, an attenuator and a PC which allows to launch experiments via Internet sending the resulting measures for a given signal.

B. *Implemented techniques*

Since all tested techniques are different kinds of DLA, the main structure is quite similar. In fact, the first technique, which can be referred to as DLA with closed loop can be considered the basis of the rest of the techniques in this work.

This first technique presents the blocks diagram shown in Fig. 1, where the DPD equation is also represented. By applying this equation to an input signal **u**, the predistorted signal **x** is generated to be sent to the PA. Then, the received signal **y** is used to compute an error signal **e**, which is used in the DPD adaptation algorithm shown in the Fig. 1. This process is carried out a determined number of iterations to compute the weights **w** which will be used in future predistortion.

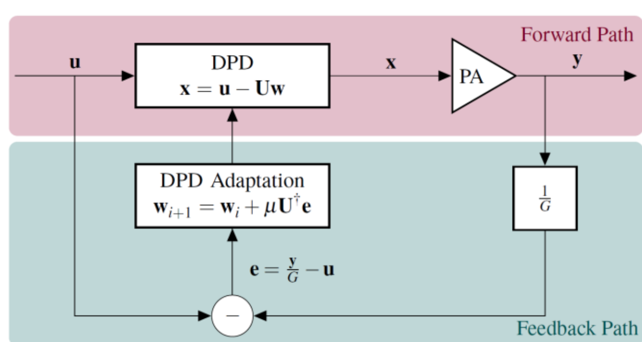

Fig. 1. Blocks diagram of the direct learning technique with closed loop.

Since the computation of the pseudoinverse of the PA model denoted as **U** requires high computational cost, different techniques have been studied to avoid this operation. One of these approaches consists of an adaptive basis DLA [2], which uses a similar structure to the Fig. 1, but computing $\mathbf{U}\mathbf{w}_{i+1}$ and removing the pseudoinverse computation. Other of the implemented techniques is based in [3] where the pseudoinverse is substituted by the covariance matrix.

Although some more techniques have been implemented, just one more of them will be mentioned for the sake of brevity. This consists of implementing the first method together with the DOMP selection components technique, presented in [4].

III. Results

After implementing the techniques mentioned above, some experiments were performed using the WebLab and generating an OFDM signal with a downlink LTE-like format, with some features such as a carrier separation of 15 kHz, a bandwidth of 15 MHz, and an average input power of −22 dBm.

Using this signal, different experiments were performed in order to compare the DLA approaches in terms of figures of merit such as ACPR, EVM and NMSE of the output signal. Both with the first technique and the one using the covariance matrix, ACPR and NSME presented an improvement of 7 dB, approximately, while the EVM decreased from almost 4% to 1.7%, approximately. An example of the learning evolution with the original closed loop approach is represented in Fig. 2, where the ACPR of the output signal is shown along the different iterations, presenting an ACPR near to −36 dBc when DPD is not applied and becoming about −43 dBc after the learning. In this figure, the differences between setting different ponderation factor values μ can also be appreciated, showing that the ACPR tends faster to the final value with a greater μ. However, if this parameter is smaller, the solution tends to be slightly better.

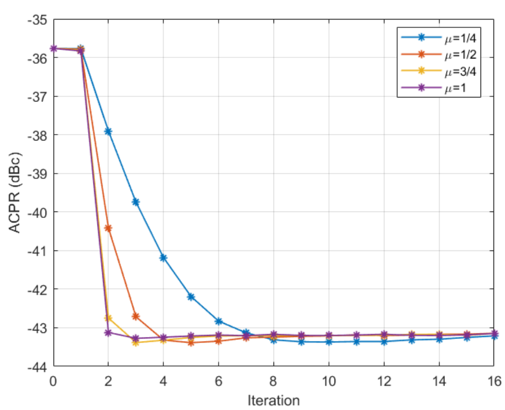

Fig. 2. Upper channel ACPR evolution along the iterations in DLA with closed loop.

The adaptive basis approach offers better results during learning, but when a validation signal (different from training) is transmitted, the results, which can be seen in Fig 3, become similar to those of the first approach, so overfitting may be occurring with this technique.

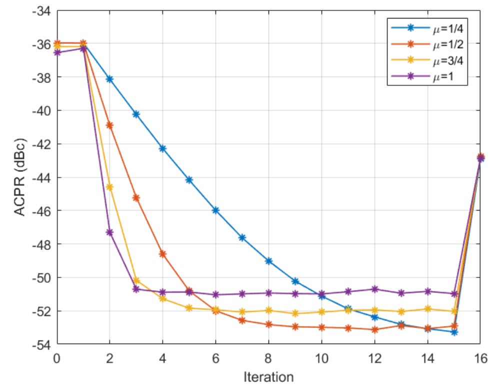

Fig. 3. Upper channel ACPR evolution along the iterations in adaptive basis DLA.

These techniques were also analyzed in terms of computational cost, and the results showed that the approach using the covariance matrix requires less learning time than the other approaches, what was precisely its objective. Moreover, despite the original closed loop approach takes longer to learn, if DOMP method is introduced, this time becomes even less that using covariance matrix. In addition, using DOMP maintains a good linearization performance, so this technique is very recommended to be applied.

IV. Conclusion

A. *Future career plans*

The student has just graduated his M. Sc. degree in Telecommunications Engineering at the Universidad de Sevilla in October 2020. He has just been hired by a company dedicated to WiFi communications, where he has just started his working life. Although he plans to continue his learning in the industry, he does not rule out the possibility of following a Ph. D. program.

B. *MTT-S Scholarship impact*

Due to the pandemic situation happening currently worldwide, some original experiments could not be performed, such as implementing these techniques in an evaluation board. Moreover, attending to an MTT-S sponsored conference was not possible unfortunately. Nevertheless, during the scholarship the student kept remotely working to achieve very interesting results, and it has been a great experience working on this project, which has served as a first contact with researching.

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