



Application Notes

WebLab: A Web-Based Setup for PA Digital Predistortion and Characterization

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The WebLab that is described here was initially motivated by the 2014 IEEE Microwave Theory and Techniques Society International Microwave Symposium's (IMS2014's) Student Design Competition on Digital Predistortion (DPD) Linearization, described in "Accurate Linearization with Low-Complexity Models Using Cascaded Digital Predistortion Systems," by Barradas et. al on page 94 in this issue of *IEEE Microwave Magazine*. To make a comparison of DPD algorithm performance, it is necessary to have one device under test (DUT), a Doherty power amplifier (PA), and one measurement setup for everybody to use. This was not a problem for the finals of the competition because the competitors would all be physically present at the same location. However, for the preparations starting half a year in advance, this posed a serious problem. The solution we implemented takes advantage of the fact that most universities today provide a decent Internet connection for their employees and students. A remotely accessible WebLab seemed to be a viable solution to the problem of letting the competitors practice on the actual DUT using the same measurement setup before the final competition at IMS2014. We decided to construct a Web-based

remote-controlled PA measurement setup that allowed any user (not only the competitors) to upload his or her own input data and download the resulting measured output data. The Web page and instructions for using it can be found at <http://dpdcompetition.com>.

Web labs for various purposes have been implemented elsewhere. Some only provide simulated results and are usually used only for teaching, whereas others have taken the step of providing remote access to measurement facilities [1]–[3]. To the best of our knowledge, the setup proposed in this article is the first setup intended for RF PA characterization and DPD.

Accessing the WebLab

The Web interface is a standard HTML page that accepts file uploads from a Web browser using a standard form request and stores the uploaded file on the Web server. A standard commercial Web hosting service provider was chosen for this service. The uploaded data file is downloaded from the server by the measurement PC. Before being used in a measurement, it is necessary to control all settings related to power levels to make sure that the PA under test will not be damaged. The tolerable limits for peak and root-mean-square (rms) power levels had been predetermined. After these checks, the measurement PC uploads the in- and quadrature-phase (IQ)-data to the signal generator and measures the output using the signal analyzer. To also give the user information of the PA efficiency, an ammeter measures the consumed rms current. If requested by the user, a Web camera connected to the measurement PC captures a photo of the entire setup during the measurement to bring more life to the

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measurement. The measured output data together with the measured rms current and the photo, if requested, are then uploaded to the Web server. Meanwhile, the user is given a link to where the data are going to be available so that he or she can download the data and the photo once they are available on the Web server.

To provide the Web page visitors a quick idea of the capabilities, we implemented a demo measurement function that they could use without having to create any IQ data. When a special demo button on the home page is pressed, a predefined set of IQ data is loaded and used in a measurement. The input data have the same characteristics as the signal used in the IMS2014 student design competition. The spectra of the input and resulting measured output signal are shown in Figure 1 together with information on drain efficiency, peak output power, rms output power, and dc power.

Accessing the WebLab for Automated Measurements

We expected that most users would prefer to directly use MATLAB to connect to WebLab instead of manually uploading and downloading their data in a Web browser, and so a MATLAB m-script interface was prepared for this purpose. The script uses the Web capabilities built into MATLAB to upload and download data directly to/from the Web server. The Web server responds by returning a page containing the link to where the data can be found once they have been uploaded by the measurement PC. The MATLAB script automatically checks whether the data file is present and downloads it if it is found; otherwise, it waits for some time and checks again. On a typical 10-Mbit/s Internet connection, one measurement using 1 million samples required approximately 1 min. Of this, nearly all the time was spent in transferring data, whereas the actual measurement was completed in less than 1 s.

WebLab Setup

The measurement instruments that were used in the WebLab were kindly provided by Rohde & Schwarz (R&S). For the signal generation, an R&S SMW200A was used and for the analysis, and an R&S FSW26 signal analyzer was used. Both instruments had options for generation/analysis of signals with up to 160-MHz bandwidth.

The PA that acted as the DUT was an NXP demo board for the BLD6G22L-50 integrated laterally diffused metal oxide semiconductor (LDMOS) Doherty PA, preceded by a semilinear driver. The chosen center frequency was 2.14 GHz. The measurement setup is illustrated in Figure 2.

Restrictions in the WebLab

A number of limitations had to be imposed on the measurement system to make it less likely

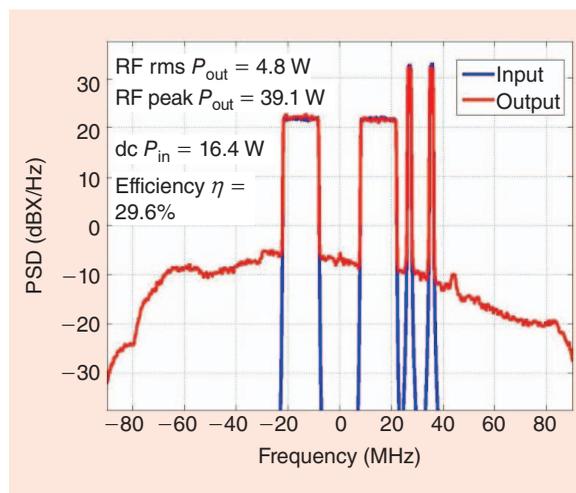


Figure 1. The spectra of the input and output signals when using the demo measurement tool on the home page. The signal is of the same type as the one used in the IMS2014 Student Design Competition on DPD. Information on output signal peak and rms power together with dc power and drain efficiency are also displayed.

that the PA under test would be damaged, to avoid erroneous measurements, and to make it simpler to use. Only a few of all the possible settings were available to the users. These were, apart from the IQ data, the signal generator output rms power and sampling rates in the signal generation and acquisition. The signal level and input attenuation in the signal analyzer was fixed such that the input mixer and the analog-to-digital converter would not contribute to significant compression or clipping at the peak power level. This, of course, meant that dynamic range in

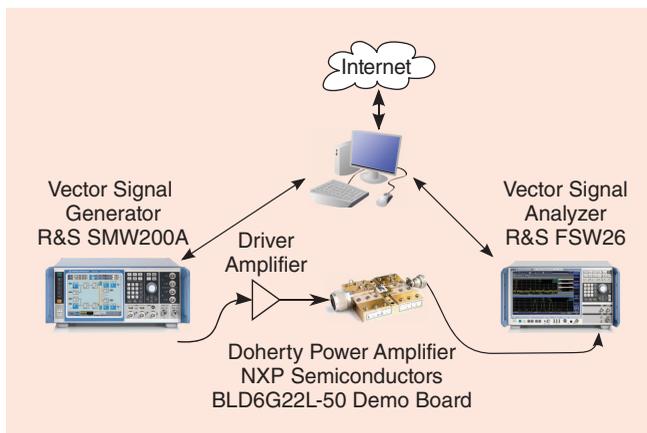


Figure 2. The measurement setup used for the DPD competition and for the WebLab. The instruments are controlled by a PC running MATLAB. When used in the WebLab, this PC communicates with a Web server where remote users upload their files containing the IQ data. The PC takes this data, uploads it to the R&S SMW200A signal generator, and measures the output using the R&S FSW26 signal analyzer. The measured output data are then uploaded to the Web server where the remote user can download it and perform the necessary signal processing.

In communication theory, it can be of some interest to have measured data to see how realistic distortions affect performance.

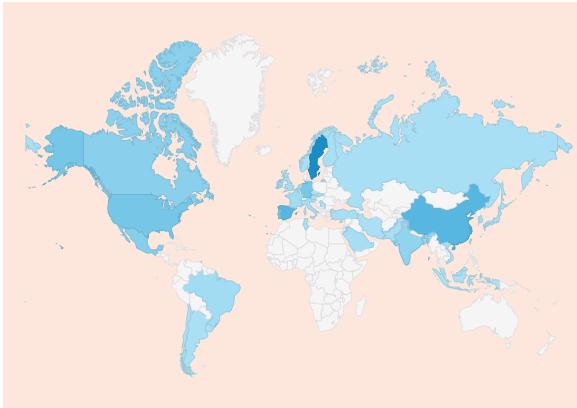


Figure 3. A world map showing which countries tested the WebLab, according to the calls to Google Analytics. The darker colors mean more unique users.

the measurement had to be sacrificed, compared with using optimized settings for each single power level.

Where Were the Users From?

To have as many users as possible and to attract as many people as possible to the competition, we decided to make the WebLab available to everybody, not just the students participating in the DPD competition.

So did this result in any interest in using the WebLab? The map in Figure 3 shows which countries have used the setup. In total, about 600 users from 45 different countries and five continents visited the site. Of these, around 200 used the MATLAB interface. The five countries with the largest number of visits to the WebLab were Sweden, the United States, China, Germany, and Spain. During the time the setup was available, a total of more than 10,000 measurements were performed, not counting the demo measurements that were only displayed on the home page.

The Future?

Thanks to the large number of measurements and positive reception of the setup, we hope to make the WebLab permanently available and increase its functionality. The current plans for improving and extending the functionality are to include different kinds of amplifiers (LDMOS, GaN, Doherty, dual-band) by means of RF switches, reference level, and attenuator settings in the signal analyzer, center frequency, and automatic aver-

aging, and improving the speed for the data transfers to and from the remote user. If you have any thoughts on other improvements/features and what you would like to see done first, please contact us.

So what can the WebLab be used for other than for the DPD competition? It does provide students, as well as professors, simple access to high-performance measurement equipment and modern PAs. This is, perhaps, not so important for most students and professors specializing in DPD because they already have access to such equipment. However, it can be of some interest to have a setup where everybody can compare the performance of their algorithms.

There are also other fields of research where an easily used measurement setup can be valuable. In communication theory, it can be of some interest to have measured data to see how realistic distortions affect performance in communication systems instead of simply assuming that the distortions are additive noise. In signal processing and system identification, it is common to only use mathematical models, but the WebLab now provides these with the possibility to use measured data. There are certainly many other applications and fields of research where this setup could be found to be useful, but this will be up to the individual researchers themselves to judge. We encourage you to visit <http://dpdcompetition.com> and explore the possibilities yourself.

Acknowledgments

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