Demo Matlab code for Simulation of Digital Predistortion (DPD) algorithms in Transparent Multicarrier Satellite Link

E. Zenteno [*1,2], R. Piazza[†3], B. Shankar[‡3], and D. Rönnow[§1]

[1]Department of Electronics, Mathematics and Natural Sciences University of Gävle, Gävle, Sweden.
[2]Department of Signal Processing, The Royal Institute of Technology KTH, Stockholm, Sweden.
[3]Interdisciplinary Centre for Security, Reliability and Trust (SnT). University of Luxembourg, Luxembourg.

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[*]Efrain.Zenteno@hig.se, E. Zenteno is now with Universidad Catolica San Pablo: ezenteno@ucsp.edu.pe
[†]r.piazza.86@gmail.com
[‡]Bhavani.Shankar@uni.lu
[§]Daniel.Ronnow@hig.se

Abstract

The enclosed files contain Matlab code for the simulation of digital predistortion (DPD) mitigation techniques in a 3-carrier transparent satellite link. All carriers have the same data rate and modcod, that is, the same modulation and code rate. The carrier signals are compliant with DVB-S2 specifications [1, 2].

1 Description

The enclosed Matlab files are implementations of different DPD mitigation techniques in a 3-carrier satellite link. The carriers are frequency spaced to 1.25 times the symbol rate. Each carrier has a analog bandwidth corresponding to 7 MHz, the pulse shape filter is a SRRC with 0.25 roll-off factor, and the IMUX, OMUX 3 dB bandwidths are 28 and 32 MHz, respectively. The high power amplifier at the satellite transponder is simulated using a Saleh model. The implemented DPD schemes are:

1. MIMO memory polynomial data DPD [3].
2. MIMO reduced-complexity memory polynomial data DPD [4].
3. MIMO Symbol Rate Signal DPD [5].

2 Size

The total size of the enclosed files is approximately 85 KB.

3 Platform

The files were tested using MATLAB Version: 7.14.0.739 (R2012a) running in Windows 7.

4 Environment

The demo requires: - Matlab R2012a or superior, - Communication system toolbox.

5 Download

The Matlab files can be downloaded from:

`https://dl.dropboxusercontent.com/u/106958743/Demo_MC_Sat.zip`

6 Major description

The enclosed files provide a simulation tool for comparing different types of DPD schemes used in a 3-carrier transparent satellite link. The user can configure several system settings and mitigation settings. The performance evaluation is based on Signal to Interference ratio (SIR) that is computed on noiseless symbols and displayed in dB scale and Bit error Rate (BER). The BER is estimated from a number of sent frames and estimated at a configurable Es/No (specified in dB).

The files for user simulation are:

- Demo_MIMO_DPDs.m: Estimate the SIR enhancement for several MIMO DPDs schemes.
- test_BER_MIMODPD.m: Test the BER for certain Es/No in a MIMO DPD deployment.

The DPD settings (by default) in the enclosed files were chosen to maximize system performance enhancement.

6.1 Matlab function files

They are accessory files to simulate the 3-carrier satellite link.

- Amp_Saleh_model.m: Saleh model for the High Power Amplifier (HPA).
- APSK_Const_Gen.m: Generate complex-valued symbols for the channel according to DVB-S2 [1].
- createH_data.m: regression matrix for reduced complexity data DPD[4].
- createH_MP.m: regression matrix for memory polynomial [3].
- createH_SRS.m: regression matrix for symbol rate signal DPD [5].
- MC_Core_channel.m: channel model at base-band level from Tx to Rx.
- pulse_shaping_filter.m: pulse-shape filter.
- retardo.m: sample delay.

7 Instructions

The parameters that can be set by the user are indicated in the first Matlab cell under the name of **'settings'**. Each one of these settings is explained in the Matlab files. For instance, it is possible to set: modulation (16,32 APSK / 8 PSK), code rate (according to DVB-S2), Es/No (in dB) for the estimation of the DPD, Es/No (in dB) for testing BER. Further, settings related to the DPD scheme as: the number of symbols to estimate the DPD model, the nonlinear order and the memory depths in the compensation.

For instance, the file 'Demo_MIMO_DPDs.m' has the following user defined settings:

```
Mod = 32;          % APSK modulation
Rate = 9/10;       % LDPC code rate
Es_NodB = 20;      % Es/No in dB for the DPD identification
IBO = 7.1;         % input back off the of HPA

Nsamp = 8000;      % # of symbols for the DPD identification

% DPD settings
% DPD scheme (set DPD_type): 'No' = NO DPD
%                            'MP' = memory polynomial MP data DPD
%                            'RMP' = reduced data MP DPD
%                            'SRS' = SRS DPD
DPD_type = 'SRS';
Pn = 3;            % nonlinear order
Mn = [3 1 0];      % memory depths [linear third fifth ...]
```

8 Output descriptions

The output appears in the command window as signal to interference ratio (SIR) in dB or as BER. In the SIR case, the performance of the channel with and without DPD is printed. Further, a plot of the constellation diagrams appears with the noiseless symbols with and without DPD.

For instance, the Matlab file 'Demo_MIMO_DPDs.m' prints into the command window:

```
 ---- NO DPD ---
OBO no DPD : -3.45
SIR (dB):   16.9  dB
SIR (dB):   17.2  dB
```

```
SIR (dB):   17.0  dB

 ----- DPD identification & noiseless test --------

----------------- SRS DPD --------------------

 ----- noiseless DPD Eval --------
OBO of the DPD signal: -3.81
SIR (dB):   26.7  dB
SIR (dB):   26.3  dB
SIR (dB):   26.6  dB
```

In the case of BER evaluation, the DPD model is estimated initially according to the settings. Further, the output appears in the command window. The output shows the evolution of the BER estimation (per frame transmitted through the channel). For instance, the output from the file 'test_BER_MIMODPD.m' with default settings provide:

```
--- Reference receiver noise Es/No = 25 dB -----  NO DPD ---
OBO no DPD : -3.39
SIR (dB):   16.7  dB
SIR (dB):   17.2  dB
SIR (dB):   16.9  dB

 ----- DPD identification & noiseless test --------

----------------- SRS DPD --------------------
OBO of the DPD signal: -3.77
SIR (dB):   26.6  dB
SIR (dB):   26.4  dB
SIR (dB):   26.8  dB


 ----- Evaluating BER --------

Es/No (dB): 16.20 dB    (added to nonlinear dist.)
iteration  1,   BER:  0.0e+00 0.0e+00 0.0e+00
iteration  2,   BER:  0.0e+00 0.0e+00 0.0e+00
iteration  3,   BER:  0.0e+00 0.0e+00 0.0e+00
iteration  4,   BER:  0.0e+00 0.0e+00 0.0e+00
```

```
iteration  5,   BER:  0.0e+00 0.0e+00 0.0e+00
iteration  6,   BER:  0.0e+00 0.0e+00 0.0e+00
iteration  7,   BER:  0.0e+00 0.0e+00 0.0e+00
iteration  8,   BER:  0.0e+00 0.0e+00 0.0e+00
iteration  9,   BER:  0.0e+00 0.0e+00 0.0e+00
iteration 10,   BER:  0.0e+00 0.0e+00 0.0e+00
.
.
.
iteration  999,  BER:  0.0e+00 0.0e+00 0.0e+00
iteration 1000,  BER:  0.0e+00 0.0e+00 0.0e+00

 # of tested information bits : 58320000.00

BER:   0.0e+00
BER:   0.0e+00
BER:   0.0e+00
```

References

[1] "Digital video broadcasting (DVB); second generation framing structure, channel coding and modulation systems for broadcasting, interactive services, news gathering and other broadband satellite applications (DVB-S2)," 2009-08.

[2] "Digital video broadcasting (DVB); second generation framing structure, channel coding and modulation systems for broadcasting, interactive services, news gathering and other broadband satellite applications; part 2: DVB-S2 extensions (DVB-S2X)," 2014-10.

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[5] E. Zenteno, R. Piazza, M. R. Bhavani Shankar, D. Rönnow, and B. Ottersten, "A MIMO symbol rate signal digital predistorter for nonlinear multicarrier satellite channels," *IET Communications*, to be published.