ANALOG DEVICES APPLICATION NOTE

One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com

CFR CORRECTION PULSE GENERATION

Introduction

LTE and 5G NR signal characteristics are immune to the channel fading but has a drawback with the high PAR due to the OFDM modulation. This drawback directly affects system power efficiency due to the back-off average power in power-hungry RF power amplifiers (PAs). In order to reduce the PAR by 2-4 dB, Peak Cancellation CFR is adapted in Madura's DFE and is located before DPD Half band filters (HBFs). Peak Cancellation (PC) CFR uses "subtraction process at the peak envelope location with the predefined CFR correction pulse". Therefore, in PC-CFR technique the optimization of CFR correction pulse is most important because it is directly related to the RF performance indices, EVM and ACLR. This document shows how CFR correction pulse is generated and optimized using MATLAB code.

Principle of Operation

Firls (Least Square FIR) is adapted to extract the impulse response (sync pulse) whose characteristics resemble OFDM carriers superpose to transmit data. The filter characteristics can be adjusted with the arguments such as passband and stopband, weight and goal index (Least Square optimization). Current code is predefined by those filter arguments but need to be validated more to the level of production.

To reduce the PAR, the correction pulse is subtracted in low rate at the peak location, but the peak signal is detected in high (DPD rate) because PAR of the signal should be the same as at the input of the RF PAs. Therefore, in addition to filter characteristics, oversampling rate is also an argument when the impulse response is extracted.

Running Simulation

To run and get the CFR correction pulse in MATLAB, user need to open and modify the main function in Figure 1. The others 4 m-file will be automatically called and processed. The detailed code hierarchy is provided and all both input and output variable explained in Appendix

Here is the main function (red) for user which is indicated by red arrow in MATLAB code in Figure 1.

- **Main Function: ex_gen_correct_pulse.m**

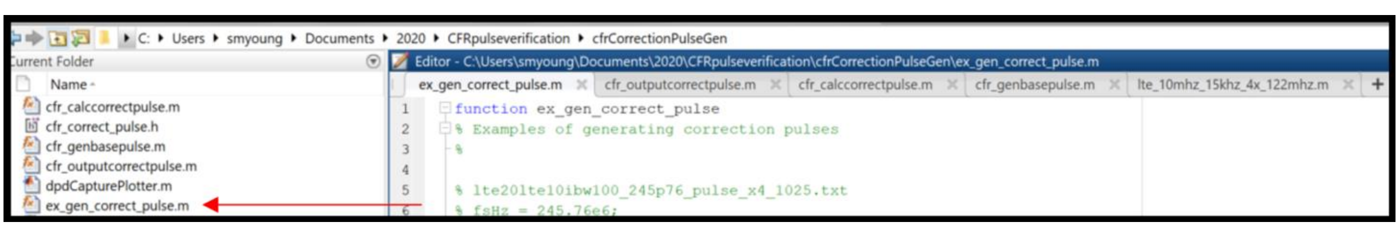

FIGURE 1. MAIN FUNCTION FOR CFR CORRECTION PULSE GENERATION

- **8 Inputs for specified CFR correction pulse.**
  - User need to fill out those 8 inputs in MATLAB's main function to generate CFR correction pulse in Figure 2. These inputs specify the CFR correction pulse characteristics.
  - Each input can be elaborated with 8 variables in Table 1. (Current setting in MATLAB: red)

Input Variables	Description	Range
fsHz	CFR rate in DFE	Fs=122.88MHz, 184.32MHz, 245.76MHz
osr	Oversampling rate of peak detection	1, 2, 4 (current setting)
bpid	Signal Bandwidth, Sub-carrier Offset bandwidth (15KHz, 30KHz)	LTE5MHz, LTE10MHz, LTE20MHz, NR20MHz, NR40MHz, NR80MHz, NR100MHz
freq	Frequency offset for Multi-Carrier Signal (Contiguous or Non-contiguous)	Function of OBW within IBW (-37.5M, 37.5M)
mags	Weighted for Multi-Carrier Signal (EVM optimization)	Normalization 1, [1, 1]
hframe	Header file generation for C header file	Not used
mbx	For mbx file generation (Hardware)	Not used
dfname	Output txt file (current)	User defined: CFR Correction Pulse

TABLE 1 INPUT PARAMETER WITH DESCRIPTION AND RANGE

Those input parameters are defined in MATLAB code as shown in Figure 2

```
fsHz = 122.88e6;
osr = 4;
bpid = {'LTE10MHZ15KHZ', 'LTE10MHZ15KHZ'};
freq = [-37.5e6, 37.5e6];
mags = [1, 1];
hfname = [];
mbxftag = [];
dfname = 'lte10lte10_122p88_pulse_x4_1025_37p5M_Offset_test.txt';
cfg = {bpid, freq, mags, hfname, mbxftag, dfname};
[c, cq] = cfr_outputcorrectpulse(fsHz, osr, cfg);
```

FIGURE 2. INPUTS FOR CFR CORRECTION PULSE

For specific signal characteristics, input parameter, bpid, is decided based on the predefined 11 case of filter characteristics in Figure 3. As mentioned, the filter and filter characteristics need to be optimized and validated to the level of the production.

```
if iscell(bpid) && length(bpid) > 1
  bptag = bpid{1};
  fsHz = bpid{2};
else
  bptag = bpid;
end
fstag = sprintf('%dmhz', floor(fsHz/1e6));
switch bptag
  case 'LTE5MHZ15KHZ'
    fns = sprintf('lte_5mhz_15khz_4x_%s', lower(fstag));
  case 'LTE5MHZ15KHZN256'
    fns = sprintf('lte_5mhz_15khz_4x_%s_n256', lower(fstag));
  case 'LTE10MHZ15KHZ'
    fns = sprintf('lte_10mhz_15khz_4x_%s', lower(fstag));
  case 'LTE10MHZ15KHZN256'
    fns = sprintf('lte_10mhz_15khz_4x_%s_n256', lower(fstag));
  case 'LTE20MHZ15KHZ'
    fns = sprintf('lte_20mhz_15khz_4x_%s', lower(fstag));
  case 'LTE20MHZ15KHZN256'
    fns = sprintf('lte_20mhz_15khz_4x_%s_n256', lower(fstag));
  case 'NR20MHZ15KHZ'
    fns = sprintf('nr_20mhz_15khz_4x_%s', lower(fstag));
  case 'NR40MHZ15KHZ'
    fns = sprintf('nr_40mhz_15khz_4x_%s', lower(fstag));
  case 'NR40MHZ30KHZ'
    fns = sprintf('nr_40mhz_30khz_4x_%s', lower(fstag));
  case 'NR80MHZ30KHZ'
    fns = sprintf('nr_80mhz_30khz_4x_%s', lower(fstag));
  case 'NR100MHZ30KHZ'
    fns = sprintf('nr_100mhz_30khz_4x_%s', lower(fstag));
  otherwise
    error('Unsupported BP ID')
end
```

FIGURE 3 11 CASES OF THE PREDEFINED FILTER CHARACTERISTICS

After the main function is run, user can obtain 4 outputs (3 figures and 1 txt file).

- **4 Outputs**

▪ Power Spectrum of CFR correction pulse

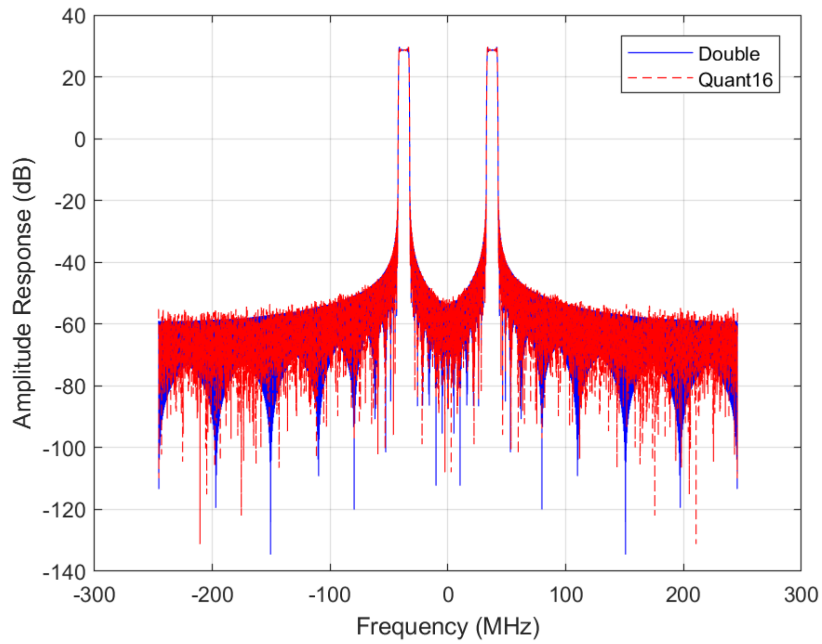

FIGURE 4. POWER SPECTRUM OF CFR CORRECTION PULSE (DOUBLE, 16BIT)

▪ CFR Correction Pulse (Real)

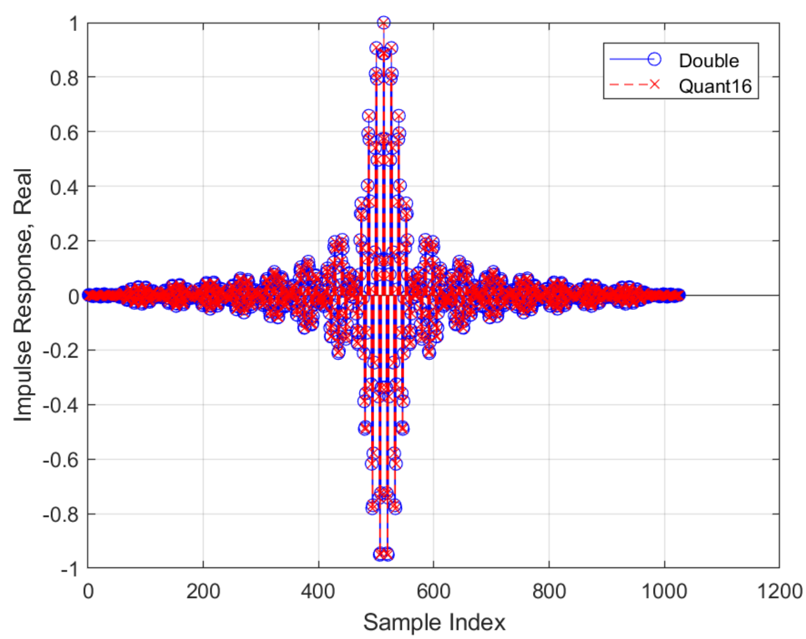

FIGURE 5. CFR CORRECTION PULSE (REAL)

- CFR Correction Pulse (Imaginary)

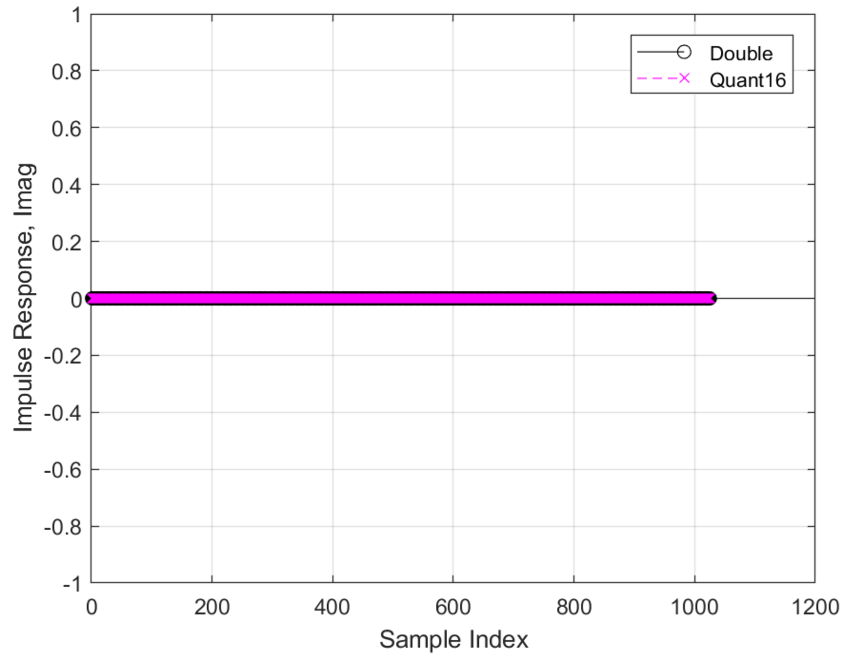

FIGURE 6. CFR CORRECTION PULSE (IMAGINARY)

- Output File: lte10let10_122p88_pulse_x4_1025_37p5M_offset_test.txt

Post Processing of Output File

After 1025 correction pulse is generated, user need to remove the upper values [513, 1025] because Madura DFE will generate the other half pulse with center tone using symmetrical properties (even, odd).

For example provided that asymmetrical frequency offsets are given [-37.25MHz, 30.5MHz], there is generated CFR correct pulse (real: even symmetry, imaginary: odd symmetry) as shown in Figure 7, Figure 8 respectively.

- CFR Correction Pulse (Real): even symmetry from the center tone

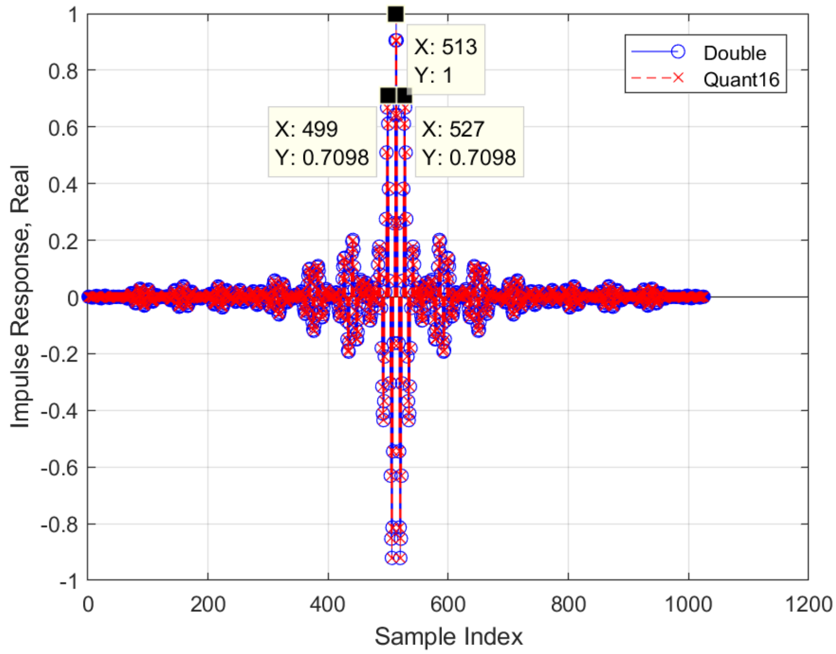

FIGURE 7 CFR CORRECTION PULSE WITH EVEN SYMMETRY (REAL)

- CFR Correction Pulse (Imaginary): odd symmetry from the center tone

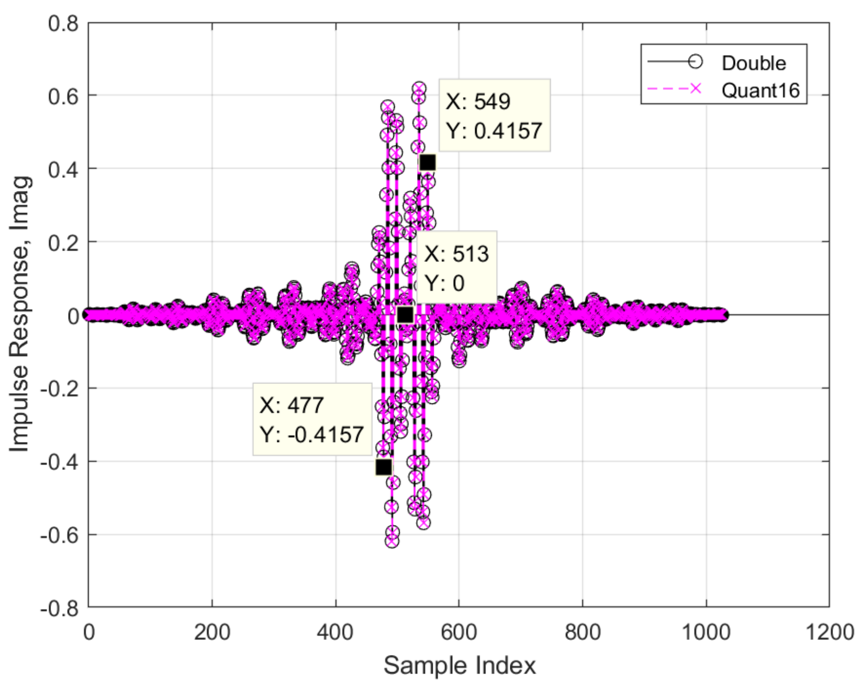

FIGURE 8 CFR CORRECTION PULSE WITH ODD SYMMETRY (IMAGINARY)