Action Needed On Implementation of Change #4 of Commit Request 4p7_4 and an Opportunity for Reducing Run Time

COM Commit Request Number 4p8_5

Hossein Shakiba
Huawei Technologies Canada
May 2025

Introduction

- Commit request 4p7_4 suggested 6 changes to fix bugs and improve accuracy of calculation of quantization noise (shakiba_3dj_COM_01a_250204.pdf)
- However, a recent review of these changes in COM version 480 revealed that change #4 of commit request 4p7_4 (slides 7-9 of the above reference) was not properly implemented (function “get_PSDs’)
- This change suggested calculating quantization noise during optimization iterations using the method used for COM calculation
- The method is more accurate, but requires computing PDF of the signal in every iteration of the optimization loop
- Simulations on many test cases reported an average of ~2x increase in the run time
- So far, the run time has been wasted due to improper implementation of the change which causes both methods to be executed but ultimately the results of the old method overrides the new method

Introduction

- Refer to slides 7-9 of shakiba_3dj_COM_01a_250204.pdf for details of commit request 4p7_4, change #4:
  - Slide 7 explains the change
  - Slide 8 shows first part of the change and was implemented correctly
  - Slide 9 shows second part of the change and was not implemented correctly (see next slide)

Review of Change #4 of Commit Request 4p7_4

- Lines 4956-4967 (before) should have been CHANGED to lines 4960-4971 (after)

```
4955 -      if(param.ENOB ~=0)
4956 -          if OP.INCLUDE_CTLE == 1
4957 -              eq_ir = TD_CTLE(chdata(1).uneq_imp_response, param.fb, param.CTLE_fz(1), param.CTLE_fp1(1), param.CTLE_fp2(1), G_DC, param.samples_per_ui);
4958 -              eq_ir = TD_CTLE(eq_ir, param.fb, param.f_HP(1), param.f_HP(1), 100e100 , G_DC2, param.samples_per_ui);
4959 -          else
4960 -              eq_ir = chdata(1).uneq_imp_response;
4961 -          end
4962 -          ctle_pulse = filter(ones(1, param.samples_per_ui), 1, eq_ir);
4963 -          ind_max = find(ctle_pulse == max(ctle_pulse));
4964 -          adc_clip = sum(abs([ctle_pulse(ind_max-param.samples_per_ui:-param.samples_per_ui:1); ctle_pulse(ind_max:param.samples_per_ui:end)]));
4965 -          adc_lsb = 2*adc_clip/(2^param.ENOB-1);
4966 -          sigma_Q = adc_lsb/sqrt(12);
4967 -          S_qn = sigma_Q^2/(length(result.S_rn)*delta_f)*ones(size(result.S_rn));
4968 -          result.S_qn = S_qn;
4969 -          result.qn_rms = sqrt(sum(result.S_qn)* delta_f);
4970 -      else
4971 -          result.S_qn=0;
4972 -          result.S_qn_rms = 0;
4973            %  result.S_n
4974 -      end
4975 -      result.S_n=result.S_rn+ result.S_tn+ result.S_xn+ result.S_jn+ result.S_qn;
4976 -      result.S_n_rms = sqrt(sum(result.S_n)* delta_f);
```

Code before change

4.2: Change to

4.3: Insert here

```
4959 -      if(param.N_qb ~=0)
4960 -          hext_txffe = filter(txffe, 1, hext);
4961 -          sig_after_ctle_pdf = get_pdf_from_sampled_signal(hext_txffe, param.levels, OP.BinSize);
4962 -          noise_after_ctle_pdf = sig_after_ctle_pdf;
4963 -          sigma_noise = sqrt(result.S_rn_rms^2+result.S_xn_rms^2+result.S_tn_rms^2+result.S_rj_rms^2);
4964 -          noise_after_ctle_pdf.y = 1/(sqrt(2*pi)*sigma_noise)*exp(-noise_after_ctle_pdf.x.^2/(2*sigma_noise^2))*OP.BinSize;
4965 -          sig_noise_after_ctle_pdf = conv_fct(sig_after_ctle_pdf, noise_after_ctle_pdf);
4966 -          sig_noise_after_ctle_cdf = cumsum(sig_noise_after_ctle_pdf.y);
4967 -          ctle_signal_sigma = sqrt(sum((sig_noise_after_ctle_pdf.x.^2).*sig_noise_after_ctle_pdf.y));
4968 -          adc_clip = -CDF_inv_ev(param.P_qc, sig_noise_after_ctle_pdf, sig_noise_after_ctle_cdf);
4969 -          adc_lsb = 2*adc_clip/(2^param.N_qb-1);
4970 -          sigma_Q = adc_lsb/sqrt(12);
4971 -          S_qn = sigma_Q^2/f_b*ones(size(hext));
4972 -          result.adc_clip = adc_clip;
4973 -          result.ctle_signal_sigma = ctle_signal_sigma;
4974 -          result.S_qn = S_qn;
4975 -          result.S_qn_rms = sqrt(sum(result.S_qn)* delta_f);
4976 -      else
4977 -          result.S_qn=0;
4978 -          result.S_qn_rms = 0;
4979            %  result.S_n
4980 -      end
4981 -      result.S_n=result.S_rn+ result.S_tn+ result.S_xn+ result.S_jn+ result.S_qn;
4982 -      result.S_n_rms = sqrt(sum(result.S_n)* delta_f);
```

Code after change

Change #4 of Commit Request 4p7_4 as Implemented

- The new lines were INSERTED before the old lines and are being overridden

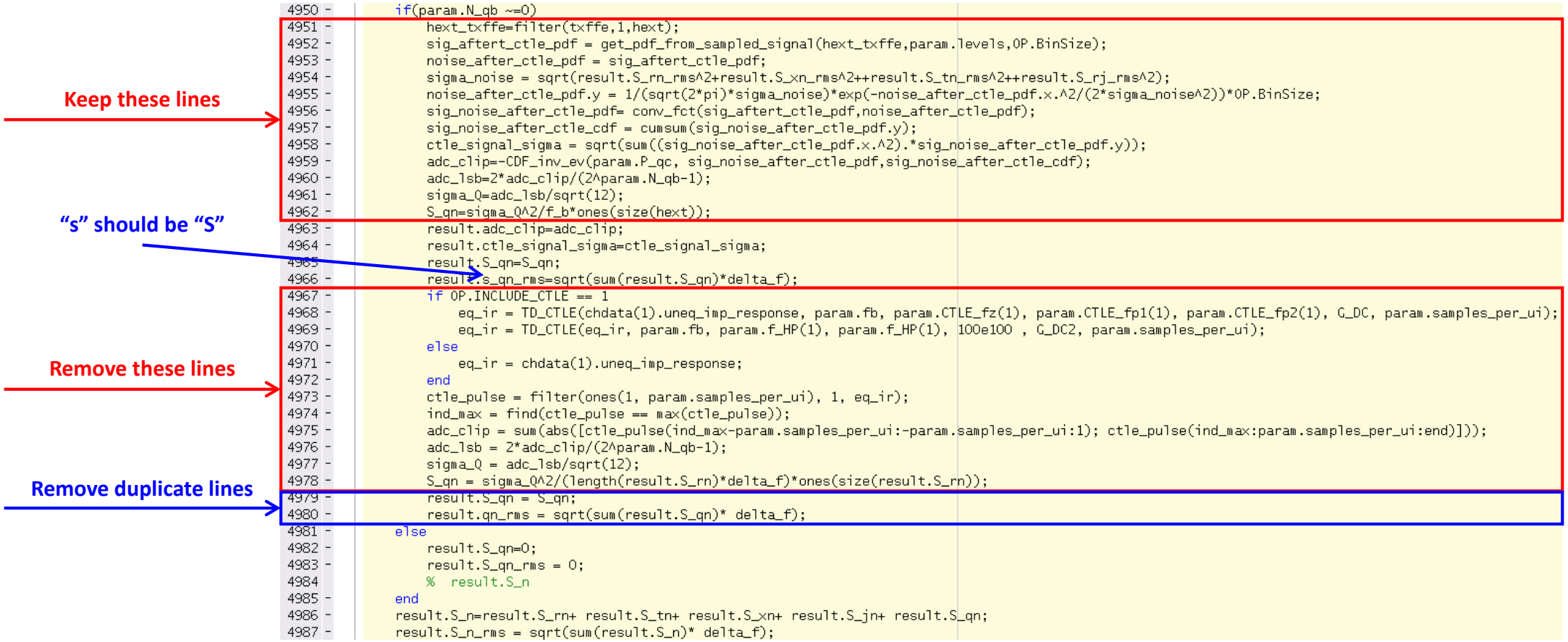
New lines are inserted

Old lines are not removed

```
4950 -      if(param.N_qb ~=0)
4951 -          hext_txffe=filter(txffe,1,hext);
4952 -          sig_aftert_ctle_pdf = get_pdf_from_sampled_signal(hext_txffe,param.levels,OP.BinSize);
4953 -          noise_after_ctle_pdf = sig_aftert_ctle_pdf;
4954 -          sigma_noise = sqrt(result.S_rn_rms^2+result.S_xn_rms^2++result.S_tn_rms^2++result.S_rj_rms^2);
4955 -          noise_after_ctle_pdf.y = 1/(sqrt(2*pi)*sigma_noise)*exp(-noise_after_ctle_pdf.x.^2/(2*sigma_noise^2))*OP.BinSize;
4956 -          sig_noise_after_ctle_pdf= conv_fct(sig_aftert_ctle_pdf,noise_after_ctle_pdf);
4957 -          sig_noise_after_ctle_cdf = cumsum(sig_noise_after_ctle_pdf.y);
4958 -          ctle_signal_sigma = sqrt(sum((sig_noise_after_ctle_pdf.x.^2).*sig_noise_after_ctle_pdf.y));
4959 -          adc_clip=-CDF_inv_ev(param.P_qc, sig_noise_after_ctle_pdf,sig_noise_after_ctle_cdf);
4960 -          adc_lsb=2*adc_clip/(2^param.N_qb-1);
4961 -          sigma_Q=adc_lsb/sqrt(12);
4962 -          S_qn=sigma_Q^2/f_b*ones(size(hext));
4963 -          result.adc_clip=adc_clip;
4964 -          result.ctle_signal_sigma=ctle_signal_sigma;
4965 -          result.S_qn=S_qn;
4966 -          result.s_qn_rms=sqrt(sum(result.S_qn)*delta_f);
4967 -          if OP.INCLUDE_CTLE == 1
4968 -              eq_ir = TD_CTLE(chdata(1).uneq_imp_response, param.fb, param.CTLE_fz(1), param.CTLE_fp1(1), param.CTLE_fp2(1), G_DC, param.samples_per_ui);
4969 -              eq_ir = TD_CTLE(eq_ir, param.fb, param.f_HP(1), param.f_HP(1), 100e100 , G_DC2, param.samples_per_ui);
4970 -          else
4971 -              eq_ir = chdata(1).uneq_imp_response;
4972 -          end
4973 -          ctle_pulse = filter(ones(1, param.samples_per_ui), 1, eq_ir);
4974 -          ind_max = find(ctle_pulse == max(ctle_pulse));
4975 -          adc_clip = sum(abs([ctle_pulse(ind_max-param.samples_per_ui:-param.samples_per_ui:1); ctle_pulse(ind_max:param.samples_per_ui:end)]));
4976 -          adc_lsb = 2*adc_clip/(2^param.N_qb-1);
4977 -          sigma_Q = adc_lsb/sqrt(12);
4978 -          S_qn = sigma_Q^2/(length(result.S_rn)*delta_f)*ones(size(result.S_rn));
4979 -          result.S_qn = S_qn;
4980 -          result.qn_rms = sqrt(sum(result.S_qn)* delta_f);
4981 -      else
4982 -          result.S_qn=0;
4983 -          result.S_qn_rms = 0;
4984          %  result.S_n
4985 -      end
4986 -      result.S_n=result.S_rn+ result.S_tn+ result.S_xn+ result.S_jn+ result.S_qn;
4987 -      result.S_n_rms = sqrt(sum(result.S_n)* delta_f);
```

Change #4 of Commit Request 4p7_4 as Intended

- Remove the old lines




```
4950 -      if(param.N_qb ~=0)
4951 -          hext_txffe=filter(txffe,1,hext);
4952 -          sig_aftert_ctle_pdf = get_pdf_from_sampled_signal(hext_txffe,param.levels,OP.BinSize);
4953 -          noise_after_ctle_pdf = sig_aftert_ctle_pdf;
4954 -          sigma_noise = sqrt(result.S_rn_rms^2+result.S_xn_rms^2++result.S_tn_rms^2++result.S_rj_rms^2);
4955 -          noise_after_ctle_pdf.y = 1/(sqrt(2*pi)*sigma_noise)*exp(-noise_after_ctle_pdf.x.^2/(2*sigma_noise^2))*OP.BinSize;
4956 -          sig_noise_after_ctle_pdf= conv_fct(sig_aftert_ctle_pdf,noise_after_ctle_pdf);
4957 -          sig_noise_after_ctle_cdf = cumsum(sig_noise_after_ctle_pdf.y);
4958 -          ctle_signal_sigma = sqrt(sum((sig_noise_after_ctle_pdf.x.^2).*sig_noise_after_ctle_pdf.y));
4959 -          adc_clip=-CDF_inv_ev(param.P_qc, sig_noise_after_ctle_pdf,sig_noise_after_ctle_cdf);
4960 -          adc_lsb=2*adc_clip/(2^param.N_qb-1);
4961 -          sigma_Q=adc_lsb/sqrt(12);
4962 -          S_qn=sigma_Q^2/f_b*ones(size(hext));
4963 -          result.adc_clip=adc_clip;
4964 -          result.ctle_signal_sigma=ctle_signal_sigma;
4965 -          result.S_qn=S_qn;
4966 -          result.s_qn_rms=sqrt(sum(result.S_qn)*delta_f);
4967 -          if OP.INCLUDE_CTLE == 1
4968 -              eq_ir = TD_CTLE(chdata(1).uneq_imp_response, param.fb, param.CTLE_fz(1), param.CTLE_fp1(1), param.CTLE_fp2(1), G_DC, param.samples_per_ui);
4969 -              eq_ir = TD_CTLE(eq_ir, param.fb, param.f_HP(1), param.f_HP(1), 100e100 , G_DC2, param.samples_per_ui);
4970 -          else
4971 -              eq_ir = chdata(1).uneq_imp_response;
4972 -          end
4973 -          ctle_pulse = filter(ones(1, param.samples_per_ui), 1, eq_ir);
4974 -          ind_max = find(ctle_pulse == max(ctle_pulse));
4975 -          adc_clip = sum(abs([ctle_pulse(ind_max-param.samples_per_ui:-param.samples_per_ui:1); ctle_pulse(ind_max:param.samples_per_ui:end)]));
4976 -          adc_lsb = 2*adc_clip/(2^param.N_qb-1);
4977 -          sigma_Q = adc_lsb/sqrt(12);
4978 -          S_qn = sigma_Q^2/(length(result.S_rn)*delta_f)*ones(size(result.S_rn));
4979 -          result.S_qn = S_qn;
4980 -          result.qn_rms = sqrt(sum(result.S_qn)* delta_f);
4981 -      else
4982 -          result.S_qn=0;
4983 -          result.S_qn_rms = 0;
4984 -          %  result.S_n
4985 -      end
4986 -      result.S_n=result.S_rn+ result.S_tn+ result.S_xn+ result.S_jn+ result.S_qn;
4987 -      result.S_n_rms = sqrt(sum(result.S_n)* delta_f);
```

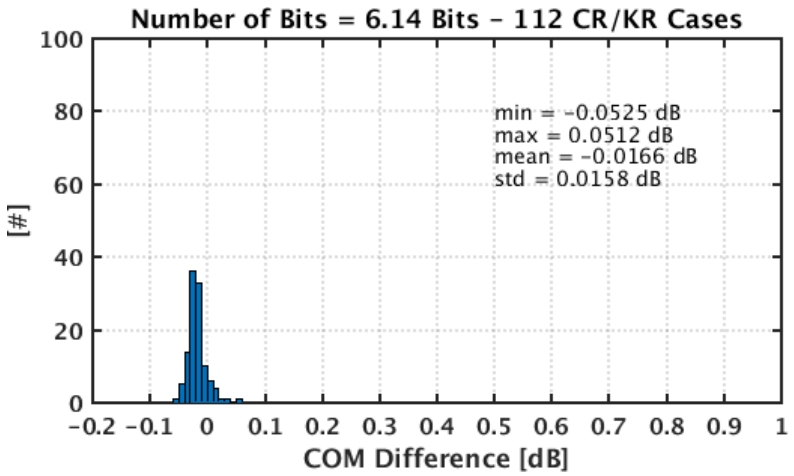
- Also implement the changes in BLUE to cleanup

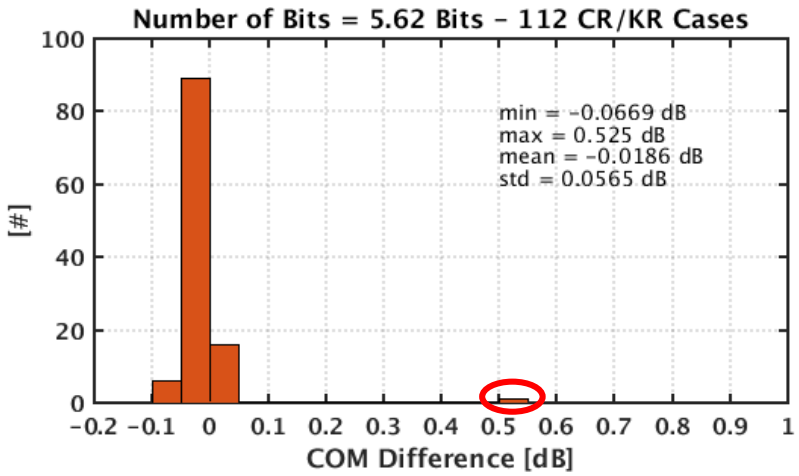
On COM Simulation Run Time – Test Case

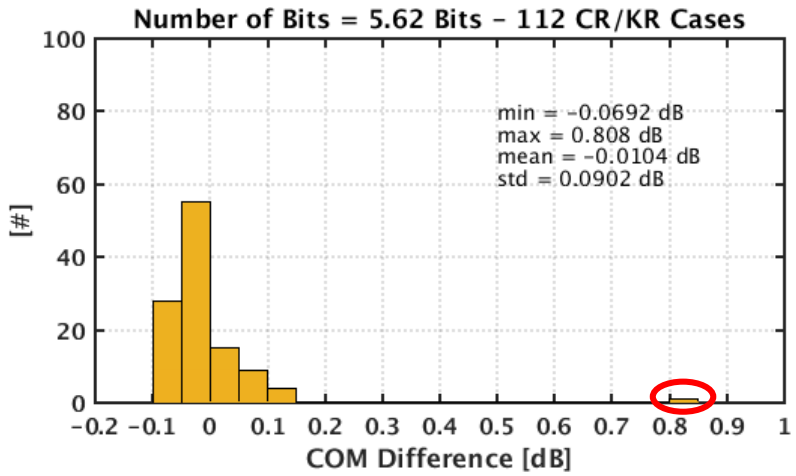
- Run time results with and without quantization noise across 112 test cases and 3 number of quantization bits:

Average Run Time [s] without Quantization Noise	Average Run Time [s] with Quantization Noise (without 4p7_4 #4)	Average Run Time [s] with Quantization Noise (with proper 4p7_4 #4)
195	201 (3% Overhead)	401 (106% Overhead)

- The penalty in COM for the above test cases is less than a fraction of a dB except for two cases







Suggestion

- Options to consider for commit request 4p8_5:
  1) Fix the issue and fully implement change #4 of commit request 4p7_4 and accept 2x increase in the run time
  2) Revert the change (although not implemented properly) and reduce the run time overhead from 106% to only 3%
     - No change to COM results relative to version 480
     - A very small penalty to COM results if the change were implemented properly (see next slide)
  3) Have both options (already implemented in the code) and a switch to select the method
  4) Defer the decision and continue to investigate the impact on COM for more cases

- Open to discussions and decision on options

Thank You ☺

Hossein Shakiba
Huawei Technologies Canada