Commit Request 4p15_2: Adaptive Local Search with Deterministic Zoom-in

Hansel D'Silva and Samuel Kocsis
Amphenol Corporation

IEEE 802.3 Channel Operating Margin (COM) Open Source Project Ad Hoc

History

Revision	Date	Comment
0.5	18-Jun-26	▪ Initial Draft.
1.0	18-Jun-26	▪ Added the commit request I.D in the title slide.
1.5	22-Jun-26	▪ Revised list of supporters and contributors.
2.0	23-Jun-26	▪ Revised a few slides as per feedback from the 802.3 COM ad hoc meeting.

List of Supporters

- Adrien Auge, Qualcomm
- Todd Bermensolo, Independent
- Howard Heck, TE Connectivity
- Noam Kutscher, Marvell Technology
- Adam Gregory, Samtec

List of Contributors

- Adam Gregory, Samtec
- Richard Mellitz, Samtec
- Adee Ran, CISCO

1. Problem Statement

- With TXLE sweep being enabled, Exhaustive Brute Search takes as much as 4 days while Local Search takes as much as 10 hours.
- How can COM runtime be reduced using Local Search while maintaining accuracy and robustness?
  - Local search is not part of the standard; rather, it is used to make runtime more manageable (less than 15 minutes), particularly when handling the 9.227043 Million equalization combinations generated while sweeping the TXLE.

2. Summary

- Adaptive Local Search appears to reduce the run time significantly with nearly negligible loss in accuracy for the value of COM.
  - Compared to the current Local Search, the proposed Adaptive Local Search dynamically adjusts the search radius based on FOM convergence and uses weighted multi-dimensional distance metrics, enabling more aggressive pruning while maintaining focus on the most promising equalization regions.
- In the case of no TXLE, the proposed local search achieves a significant reduction in runtime with a negligible COM degradation of less than 0.05 dB.
- In the case of TXLE, there is work needed in understanding the reason behind increase in FOM leading to a decrease in COM.
- The TXLE equalization is only lightly utilized across the channels.

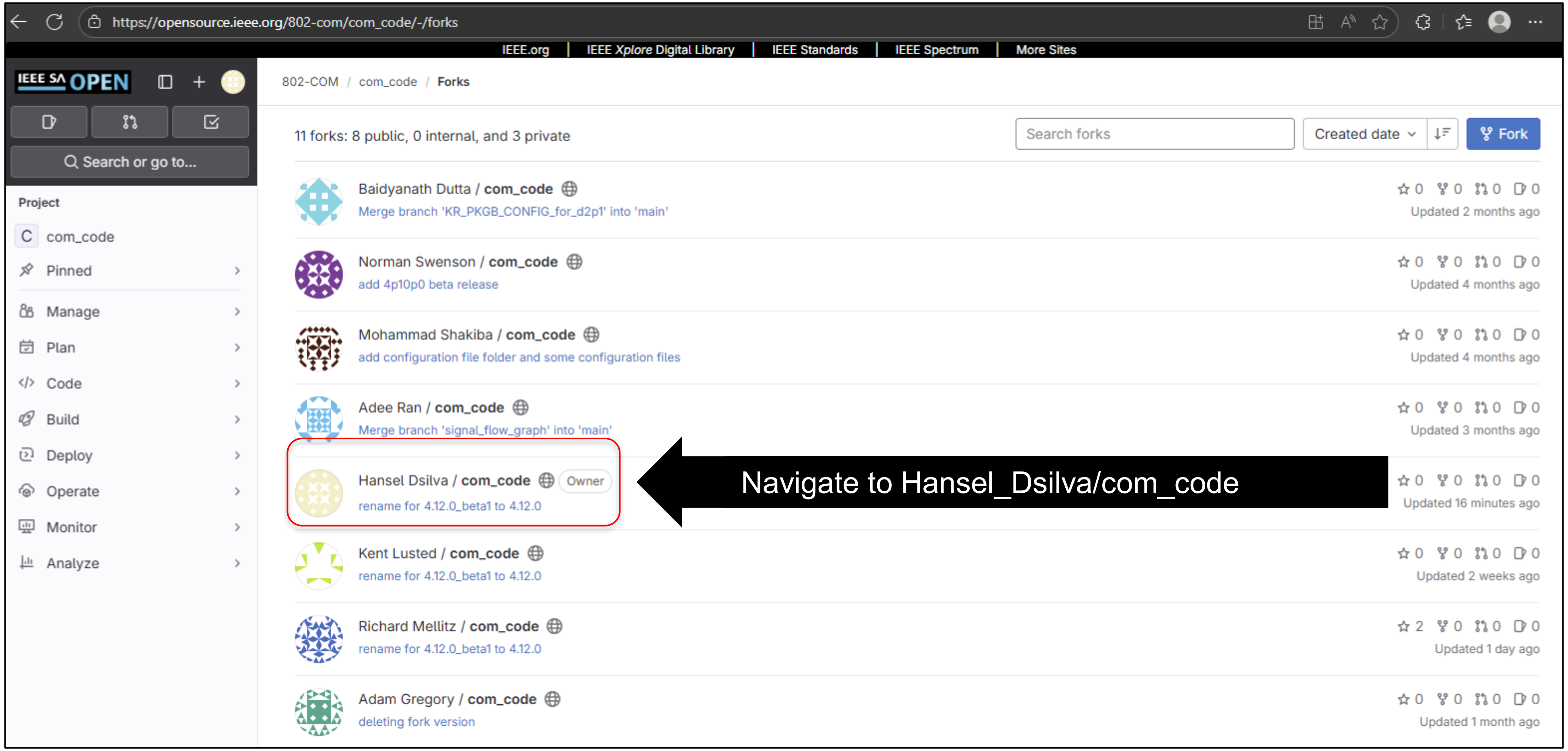
1. Commit Request

A. Purpose for Commit Request

- Commit request related to Local Search.
- Enable a Local Search routine in optimizing run time especially when dealing with TXLE sweep being enabled.
- When TXLE sweep is enabled, adding this feature will help reduce run time hours to minutes.
- Branch: adaptive_local_search. https://opensource.ieee.org/hansel.dsilva/com_code/-/branches
- Git branch file pointer: https://opensource.ieee.org/hansel.dsilva/com_code/-/blob/adaptive_local_search/release/com_ieee8023_4p15p0_adaptive_local_search.m?ref_type=heads

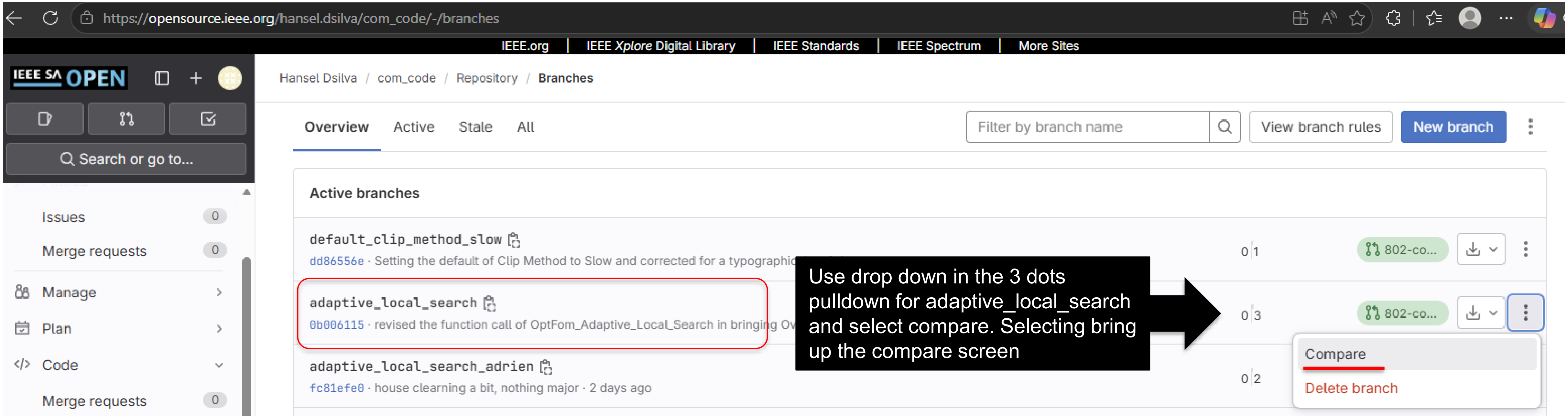
B. Navigate to Hansel_Dsilva/com_code

https://opensource.ieee.org/802-com/com_code/-/forks



C. Checking changes of a branch to the last release

https://opensource.ieee.org/hansel.dsilva/com_code/-/branches



D. Code Updates

- 2 m file changed.
- 3 m files added.
- No additional config csv and xlsx files are included.

Files changed,
src/read_ParamConfigFile.m
src/optimize_fom.m

Files added,
src/OptFom_Adaptive_Local_Search.m
src/append_csv_row.m
src/compute_hard_cap.m

E. New or changed keywords

- Configuration file parameters.

Keywords (not case sensitive)	Default	Units	Comment
Non-zero Local Search Method	0	None	▪ This only comes into play when “Local Search” is greater than zero. ▪ It may take a value of 0 or 1. ▪ If 0 then current local search else 1 then adaptive local search.
Overwrite Minimum Radius	[]	None	▪ It is an optional control parameter for adaptive local search, best to set it as empty ([]). ▪ If empty then min_radius= 1 for TXLE sweep being disabled and min_radius= 2 for TXLE sweep being enabled. ▪ If a value greater than 0 then min_radius is overwritten.

New Outputs

None

2. Introduction

A. List of CR and KR Channels on 802.3dj Public Area

- Below are the 200 Gb/s CR and KR channel data (TP0 to TP5)- with crosstalk.
  1. akinwale_3dj_01_2311: x4
  2. weaver_3dj_02_2311: x12
  3. akinwale_3dj_01_2310: x7
  4. lim_3dj_07_2309: x1
  5. lim_3dj_04_230629: x1
  6. lim_3dj_03_230629: x1
  7. weaver_3dj_elec_01_230622: x8
  8. shanbhag_3dj_01_2305: x6
  9. shanbhag_3dj_02_2305: x4
  10. kocsis_3dj_02_2305: x5
  11. weaver_3dj_02_2305: x36
  12. mellitz_3dj_02_elec_230504: x27
  13. weaver_3dj_02_2303: x5
  14. mellitz_3dj_02_2303: x54

Table 178–14—Device termination and package model parameters

Parameter	Symbol	Value	Units
Device termination model			
Single-ended device capacitance for stage 1	$C_d^{(1)}$	40×10^{-6}	nF
Single-ended device capacitance for stage 2	$C_d^{(2)}$	90×10^{-6}	nF
Single-ended device capacitance for stage 3	$C_d^{(3)}$	110×10^{-6}	nF
Single-ended device series inductance for stage 1	$L_s^{(1)}$	0.13	nH
Single-ended device series inductance for stage 2	$L_s^{(2)}$	0.15	nH
Single-ended device series inductance for stage 3	$L_s^{(3)}$	0.14	nH
Single-ended bump capacitance	C_b	30×10^{-6}	nF
Device package model, class A			
Transmission line parameter γ_0	γ_0	5×10^{-4}	1/mm
Transmission line parameter a_1	a_1	8.9×10^{-4}	$ns^{1/2}$/mm
Transmission line parameter a_2	a_2	2×10^{-4}	ns/mm
Transmission line parameter τ	τ	6.141×10^{-3}	ns/mm
Transmission line 1 length, Test 1	$z_p^{(1)}$	33	mm
Transmission line 1 length, Test 2	$z_p^{(1)}$	12	mm
Transmission line 1 characteristic impedance	$Z_c^{(1)}$	87.5	Ω
Transmission line 2 length	$z_p^{(2)}$	1.8	mm
Transmission line 2 characteristic impedance	$Z_c^{(2)}$	92.5	Ω
Device package model, class B			
Transmission line parameter γ_0	γ_0	5×10^{-4}	1/mm
Transmission line parameter a_1	a_1	6.5×10^{-4}	$ns^{1/2}$/mm
Transmission line parameter a_2	a_2	2.93×10^{-4}	ns/mm
Transmission line parameter τ	τ	6.141×10^{-3}	ns/mm
Transmission line 1 length, Test 1, Tx / Rx	$z_p^{(1)}$	45 / 44	mm
Transmission line 1 length, Test 2, Tx / Rx	$z_p^{(1)}$	30 / 29	mm
Transmission line 1 characteristic impedance	$Z_c^{(1)}$	87.5	Ω
Transmission line 2 length	$z_p^{(2)}$	2	mm
Transmission line 2 characteristic impedance	$Z_c^{(2)}$	95	Ω
Transmission line 3 length	$z_p^{(3)}$	1.3	mm
Transmission line 3 characteristic impedance	$Z_c^{(3)}$	100	Ω
Transmission line 4 length	$z_p^{(4)}$	1.5	mm
Transmission line 4 characteristic impedance	$Z_c^{(4)}$	78	Ω

- Total of 171 channels from the IEEE 802.3dj Public Area are evaluated against the class A and class B package models.
  - ❑ Total cases= 171x4= 684 cases.

B. FOM and COM

93A.1.6 Determination of variable equalizer parameters

COM is a function of the variables $c(-2)$, $c(-1)$, $c(1)$, g_{DC}, and g_{DC2}. The following procedure is used to determine the values of these variables that are used to calculate COM.

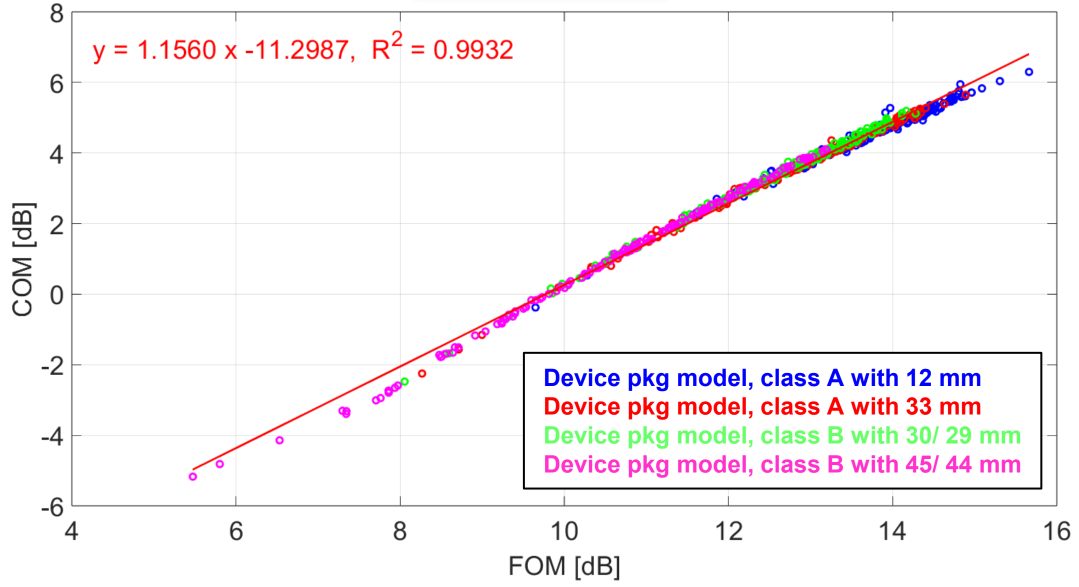
a) Compute the pulse response $h^{(k)}(t)$ of each signal path k for a given $c(-2)$, $c(-1)$, $c(1)$, g_{DC}, and g_{DC2} using the procedure defined in 93A.1.5.

. . .

$$FOM = 10\log_{10}\left(\frac{A_s^2}{\sigma_{TX}^2 + \sigma_{ISI}^2 + \sigma_J^2 + \sigma_{XT}^2 + \sigma_N^2}\right) \quad (93A\text{–}36)$$

The FOM is calculated for each permitted combination of $c(-2)$, $c(-1)$, $c(1)$, g_{DC}, and g_{DC2} values per Table 93A–1, where any parameters not provided by the clause that invokes this method are set to 0. The combination of values that maximizes the FOM, including the corresponding value of t_s, is used for the calculation of the interference and noise amplitude in 93A.1.7 and the calculation of COM in 93A.1.

Without TXLE



- When calculating Channel Operating Margin (COM), there is a callout to Figure Of Merit (FOM) for the determination of the variable equalizer parameters.
- FOM tracks COM reasonably well.
- Below is a summary.
  1] FOM is based on an RMS-type metric, which averages error across the waveform.
  2] COM is based on a CDF/ statistical tail behavior, meaning it is more sensitive to worst-case or tail events rather than the average.

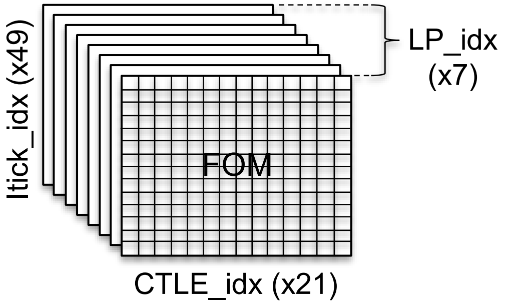
C. Equalization Search Space

Parameter	Definition	Values	Count
c(-2)	TX equalizer, coeff. -2	[0:0.02:0.14]	8
c(-1)	TX equalizer, coeff. -1	[-0.34:0.02:0]	18
c(0)	TX equalizer, minimum coeff. 0	0.54	N.A.
c(1)	TX equalizer, coeff 1	[-0.2:0.02:0]	11
ctle_index	CTLE Gain 1	[-20:1:0]	21
g_LP_index	CTLE Gain 2	[-6:1:0]	7
itickn	Sampling clock offset	[-24:1:24]	49

% Skip combinations with small values of c(0), not guaranteed to be supported by all transmitters.

```
if txffe_cur<param.tx_ffe_c0_min
    continue;
end
```

TXLE combinations= (8*18*11)- 303= 1281



= 49x21x7
= 7203 combinations without TXLE

= 1281x49x21x7
= 9.227043e6 combination with TXLE
= 9.227043 Million combinations with TXLE

- With TXLE sweep being OFF there are **7,203 combinations**.
- With TXLE sweep being ON there are **9.227043 Million combination**.

D. Results on Run Time and Efficiency

IL_db_die_to_die_at_Fnq = 37.10 dB

0] Run Time

TXLE Sweep	COM [dB]	FOM [dB]	TXLE	Run Time		
				Exhaustive (Brute force)	**Existing Local Search= 2**	**Proposed Local Search= 2**
OFF	2.31	11.607	[0 0 1 0]	11.51 minutes	6.92 minutes	0.69 minutes
ON	2.50	11.691	[0 -0.1 0.9 0]	85.04 hours	7.56 hours	7.10 minutes

1] Number of FOM calculations

TXLE Sweep	COM [dB]	FOM [dB]	TXLE	Number of FOM calculations		
				Exhaustive (Brute force)	**Existing Local Search= 2**	**Proposed Local Search= 2**
OFF	2.31	11.607	[0 0 1 0]	7,203	5,243	980
ON	2.50	11.691	[0 -0.1 0.9 0]	9.227043e6	0.854609e6	11,907

- The proposed local search reduces the run time significantly.
- Please refer the presentation titled “Commit Request 4p15_2: Adaptive Local Search with Deterministic Zoom-in” for results involving 684 cases of KR and CR channels from the IEEE 802.3dj Public Area.

E. Advanced Feature of "Overwrite Minimum Radius"

- Setting "Overwrite Minimum Radius" to 1, default is 2 for with TXLE and 1 for without TXLE.

IL_db_die_to_die_at_Fnq = 37.10 dB

0] Run Time

TXLE Sweep	COM [dB]	FOM [dB]	TXLE	Run Time		
				Exhaustive (Brute force)	Existing Local Search= 2	Proposed Local Search= 2
OFF	2.31	11.607	[0 0 1 0]	11.51 minutes	6.92 minutes	0.69 minutes
ON	2.50	11.691	[0 -0.1 0.9 0]	85.04 hours	7.56 hours	~~7.10~~ minutes 3.29

New, Overwrite Minimum Radius= 1; TXLE Sweep= ON; COM [dB]= 2.50; FOM [dB]= 11.690; TXLE= [0 -0.06 0.94 0]; Run Time= 3.29 minutes; Number of FOM calculations= 2,597

1] Number of FOM calculations

TXLE Sweep	COM [dB]	FOM [dB]	TXLE	Number of FOM calculations		
				Exhaustive (Brute force)	Existing Local Search= 2	Proposed Local Search= 2
OFF	2.31	11.607	[0 0 1 0]	7,203	5,243	980
ON	2.50	11.691	[0 -0.1 0.9 0]	9.227043e6	0.854609e6	~~11,907~~ 2,597

- An advanced feature, Overwrite Minimum Radius, enables the search radius to shrink progressively with each iteration.
- When the **TXLE sweep** option is enabled, *Overwrite Minimum Radius* can be used to prioritize runtime over accuracy (risk!) by allowing the search to terminate with a smaller minimum search radius.
- In this case, the value of COM turned out to be nearly the same with significant decrease in run time.

3. Local Search

A. Equalization Search Space Pruning

```
for ctle_index = 1:length(param.ctle_gdc_values)
  %% CTLE Gain
  THIS.ctle_index = ctle_index;
  THIS.g_dc = param.ctle_gdc_values(ctle_index);

  for g_LP_index = 1:length(param.g_DC_HP_values)
    %% Apply CTLE to impulse response
    THIS.g_DC_low = param.g_DC_HP_values(g_LP_index);
    THIS.g_LP_index = g_LP_index;

    % Apply CTLE
    [chdata, THIS.H_ctf, H_low_xc, H_ctf2] = ...
      OptFom_Compute_CTLE(chdata, ctle_gain, THIS, SETTINGS.f_xc, param, OP);

    for TK = 1: size(txffe_matrix,1)
      % Skip combinations with small values of c(0)
      % not guaranteed to be supported by all transmitters.
      txffe_cur = txffe_cursor_vector(TK);
      if txffe_cur < param.tx_ffe_c0_min
        continue;
      end

      THIS.tx_index_vector = FULL_tx_index_vector(TK, :);

      if param.LOCAL_SEARCH > 0 && ~isinf(BEST.FOM)
        skip_it = OptFom_Local_Search(param.LOCAL_SEARCH, BEST, THIS, txffe_sweep_indices);
        if skip_it
          continue;
        end
      end
```

Pruning (skip logic)

```
      %% TXFFE
      % fetch txffe for this iteration
      THIS.txffe = txffe_matrix(TK, :);
      [sbr, chdata, pulse_struc] = .OptFom_Compute_TXFFE(chdata, pulse_struc, THIS.txffe, ...
                ctle_response_updated, param, OP);

      for itickn = 1:length(full_sample_range)

        THIS.itick = full_sample_range(itickn);


        % Calculate FOM
        % (your FOM calculation logic here)

        if (THIS.FOM > BEST.FOM)
          BEST.txffe_index = THIS.tx_index_vector;
          BEST.ctle      = THIS.ctle_index;
          BEST.gdc       = THIS.g_dc;
          BEST.G_high_pass = THIS.g_LP_index;
          BEST.FOM       = THIS.FOM;
        end


      end % itickn
    end % TK
  end % g_LP_index
end % ctle_index
```

Calculate FOM

Tracking BEST versus THIS

- The equalization optimization performs a nested search across CTLE Gain 1, CTLE Gain 2, TXFFE, and sampling phase (itick).
- Local search prunes the equalization space by skipping CTLE and TXFFE configurations that are farther than a user-defined distance from the current best equalization setting.
- Sampling phase adjustment (itick) is evaluated through an exhaustive sweep, whereas RxFFE coefficients are determined using MMSE-based optimization when MMSE optimization is enabled.

B. Use of Indices for TXLE, CTLE Gain 1 and CTLE Gain 2

```
param.tx_ffe_c0_min= 0.54
param.tx_ffe_cm1_values= [-0.34:0.02:0.00] % [1x18]
param.tx_ffe_cm2_values= [0.00:0.02:0.14] % [1x8]
param.tx_ffe_cm3_values= 0
param.tx_ffe_cm4_values= 0
param.tx_ffe_cp1_values= [-0.20:0.02:0.00] % [1x 11]

param.ctle_gdc_values= [-20:1:0]
param.g_DC_HP_values= [-6:+1:0]

full_sample_range= [-24:1:24]

BEST.FOM = -inf;
```

Parameters to be initialized

```
%% Build txffe values dynamically
[txffe_matrix, cur, txffe_sweep_indices, FULL_tx_index_vector, txffe_cursor_vector]
= OptFom_Build_TXFFE(param);
num_txffe_runs = size(txffe_matrix,1);

%% if LOCAL_SEARCH> 0
if param.LOCAL_SEARCH> 0
   FOM_history = [];
   iter_count = 0;
end
```

1. for TK = 1:size(txffe_matrix,1)

FULL_tx_index_vector=

1584x5 double

	1 (cm4)	2 (cm3)	3 (cm2)	4 (cm1)	5 (cp1)
1	1	1	1	1	1
2	1	1	1	1	2
3	1	1	1	1	3
. . .					
1583	1	1	8	18	10
1584	1	1	8	18	11

2. for ctle_index =1:length(param.ctle_gdc_values)

3. for g_LP_index = 1:length(param.g_DC_HP_values)

- The Local Search uses indices for the TXLE, CTLE Gain 1 and CTLE Gain 2.
- It is important that the matrix columns are ordered as: C-4, C-3, C-2, C-1, C+1, C+2, with the main cursor (C0) intentionally excluded.

C. Current Local Search in the COM tool

```
function skip_it = OptFom_Local_Search(LocalSearch_Value, BEST, THIS, txffe_sweep_indices)

best_txffe_index = BEST.txffe_index;
best_G_high_pass = BEST.G_high_pass;
tx_index_vector = THIS.tx_index_vector;
ctle_index = THIS.ctle_index;
g_LP_index = THIS.g_LP_index;
num_txffe_sweep_indices = length(txffe_sweep_indices);

skip_it=0;

%instead of looping across all taps, only loop across those with length>1 (txffe_sweep_indices)
%It saves time since this block is encountered so often
for kj=1:num_txffe_sweep_indices
    kv=txffe_sweep_indices(kj);
    if kv==1
        previous_loop_val=g_LP_index;
    else
        previous_loop_val=tx_index_vector(kv-1);
    end
    if previous_loop_val>1
        best_index_this_tap=best_txffe_index(kv);
        if abs(tx_index_vector(kv)-best_index_this_tap)>LocalSearch_Value
            skip_it=1;
            break;
        end
    end
end

if ~skip_it && ctle_index>1 && abs(g_LP_index-best_G_high_pass)>LocalSearch_Value
    skip_it=1;
end
```

- For example,
  tx_index_vector = [5 4 3 2 1 ...]
  best_txffe_index = [5 5 3 2 1 ...]
  Hence, distance= abs(current_index - best_index).

- Do not allow LP/CTLE to drift too far from best.
  if abs(g_LP_index - best_G_high_pass) > LocalSearch_Value
  skip_it = 1;

- Authored by Adee Ran and improved by Adam Gregory in making it modular for n-tap TXFFE.
- For each TXFFE tap and CTLE Gain 1 & CTLE Gain 2 index, the algorithm compares the current candidate index to the best-known index. If the difference exceeds a predefined threshold (LocalSearch_Value, let us say 2) in any dimension, the candidate is skipped without evaluation.

D. Proposed Adaptive Local Search

```
%% --------------------------------------------------------
%  Extract tap vectors
%% --------------------------------------------------------
best_taps = BEST.txffe_index(:);
curr_taps = THIS.tx_index_vector(:);

ctle_index = THIS.ctle_index;
lp_curr    = THIS.g_LP_index;
lp_best    = BEST.G_high_pass;

%% --------------------------------------------------------
%  Build weighted vectors
%% --------------------------------------------------------
best_vec = [best_taps; lp_best];
this_vec = [curr_taps; lp_curr];

num_taps = numel(curr_taps);
w_taps = ones(num_taps,1) * edge_weight;

% LP weight (patched)
if THIS.ctle_index > 1
    w_lp = lp_weight * (1 + 0.5 * (THIS.ctle_index - 1));
else
    w_lp = lp_weight;
end
weights = [w_taps; w_lp];
```

```
%% --------------------------------------------------------
%  Compute distances
%% --------------------------------------------------------
diff_vec      = this_vec - best_vec;
weighted_diff = weights .* diff_vec;

L1_w = sum(abs(weighted_diff));
L2_w = sqrt(sum(weighted_diff.^2));

raw_L1_TX = sum(abs(diff_vec(1:num_taps)));
```

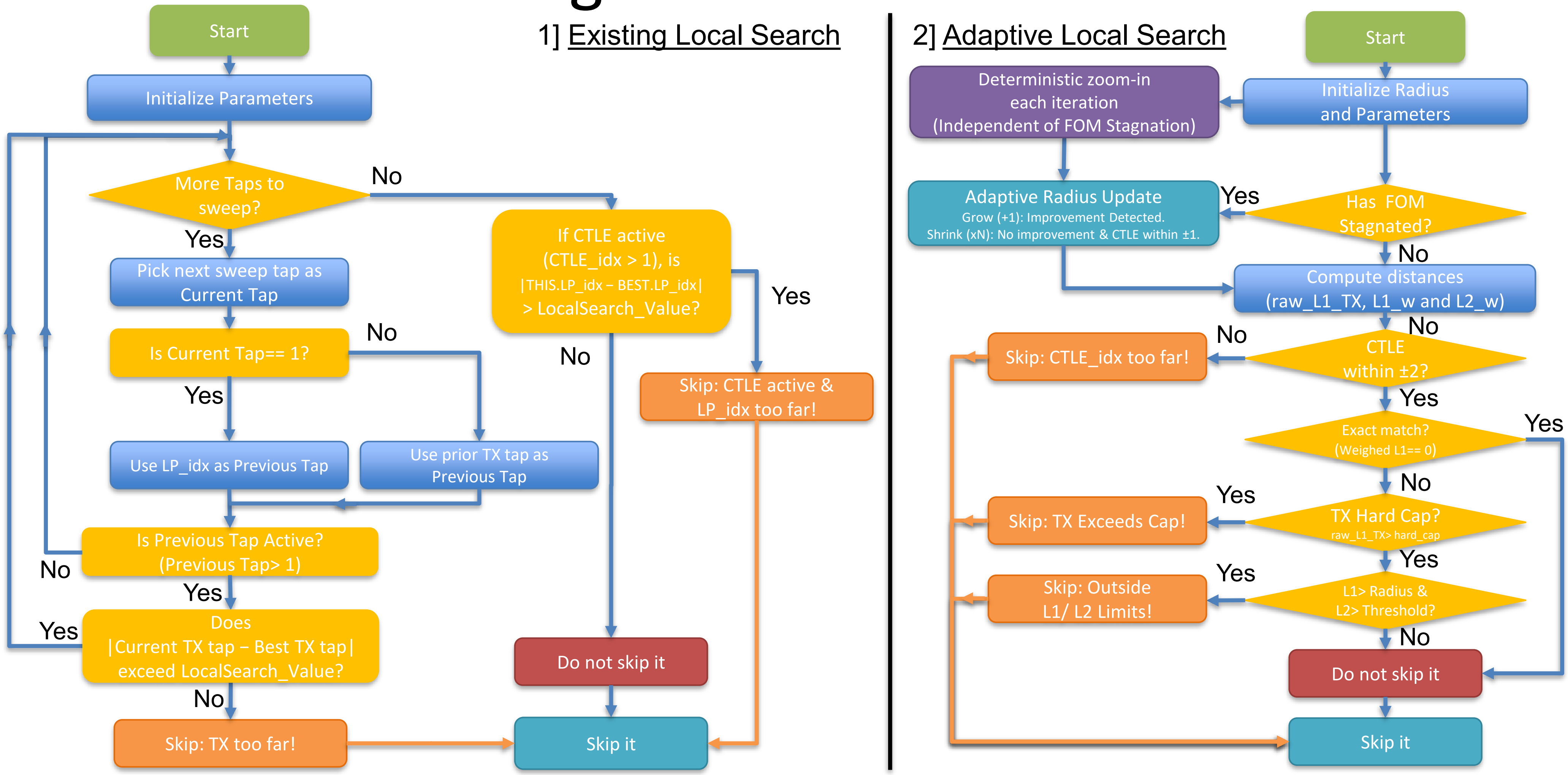
Definitions,
raw_L1_TX: Unweighted Manhattan distance between the current and best TXFFE tap-index vectors.

L1_w: Weighted Manhattan distance between the current equalization setting and the current best equalization setting, including TXFFE tap indices and CTLE Gain 2.

L2_w: Weighted Euclidean distance between the current equalization setting and the current best equalization setting, providing a geometric measure of proximity in the equalization search space.

- Instead of checking each parameter independently, the adaptive local search computes global weighted L1 and L2 distances between the current candidate and the best-known solution.
- It maintains an adaptive search radius that shrinks when improvement stalls and expands when progress is observed.
- If the candidate exceeds this radius, violates a hard cap on total deviation, or fails additional constraints (e.g., CTLE proximity), it is skipped without evaluation.

E. Rough Flowchart of Local Search



Definitions,
raw_L1_TX: Unweighted Manhattan distance between the current and best TXFFE tap-index vectors.

L1_w: Weighted Manhattan distance between the current equalization setting and the current best equalization setting, including TXFFE tap indices and CTLE Gain 2.

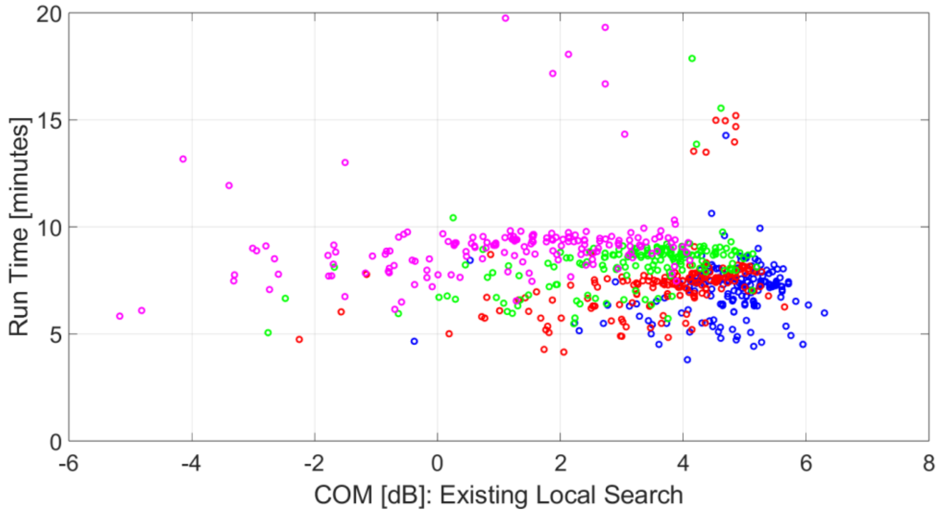
L2_w: Weighted Euclidean distance between the current equalization setting and the current best equalization setting, providing a geometric measure of proximity in the equalization search space.

- Compared to the current Local Search, the proposed Adaptive Local Search dynamically adjusts the search radius based on FOM convergence and uses weighted multi-dimensional distance metrics, enabling more aggressive pruning while maintaining focus on the most promising equalization regions.

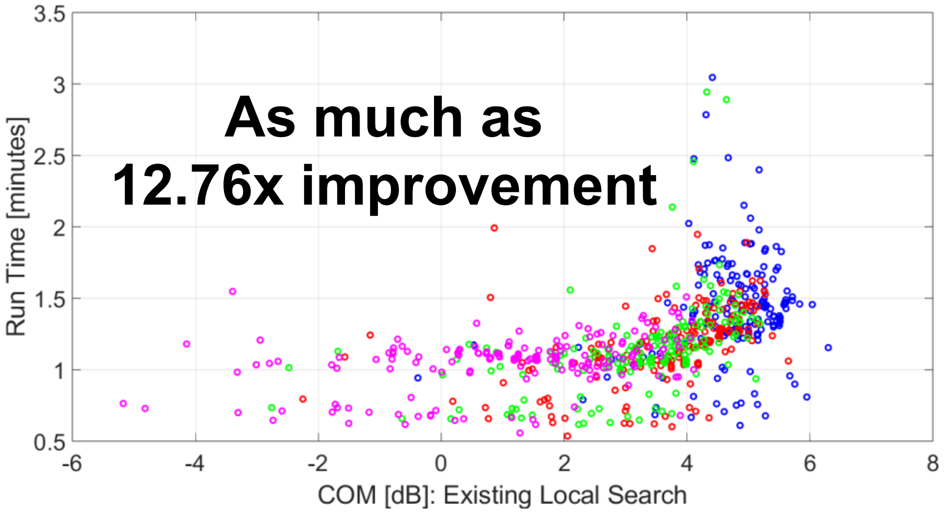
4. Results

A. Without TXLE: Results on Run Time

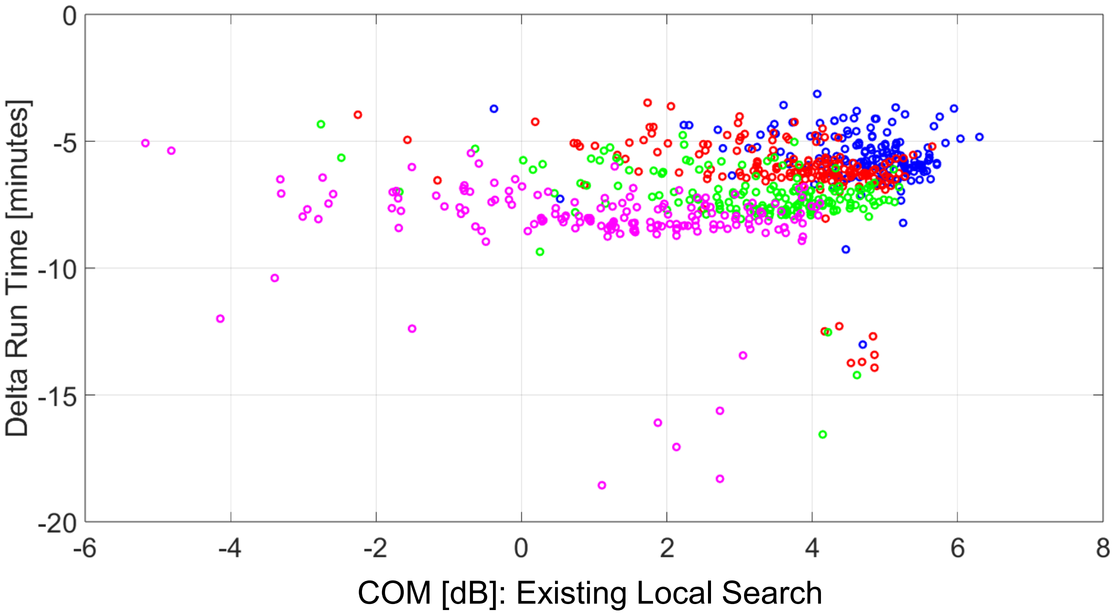
1] **Existing Local Search**



2] **Proposed Local Search**



3] **Delta= Proposed Local Search- Existing Local Search**



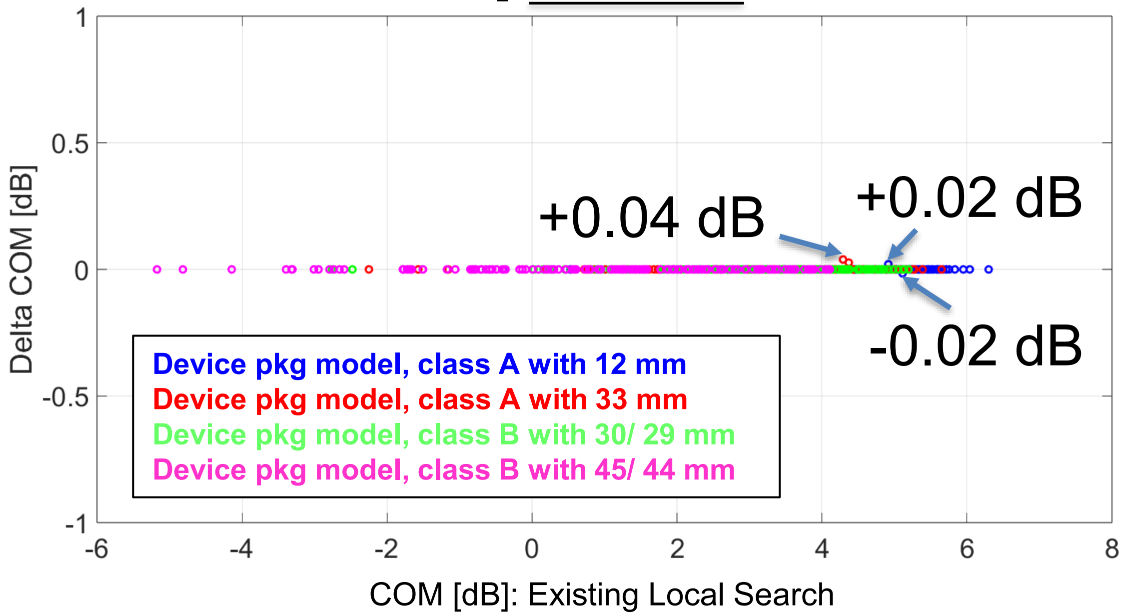
Device pkg model, class A with 12 mm
Device pkg model, class A with 33 mm
Device pkg model, class B with 30/ 29 mm
Device pkg model, class B with 45/ 44 mm

- The proposed local search delivers as much as 12.76x runtime improvement.

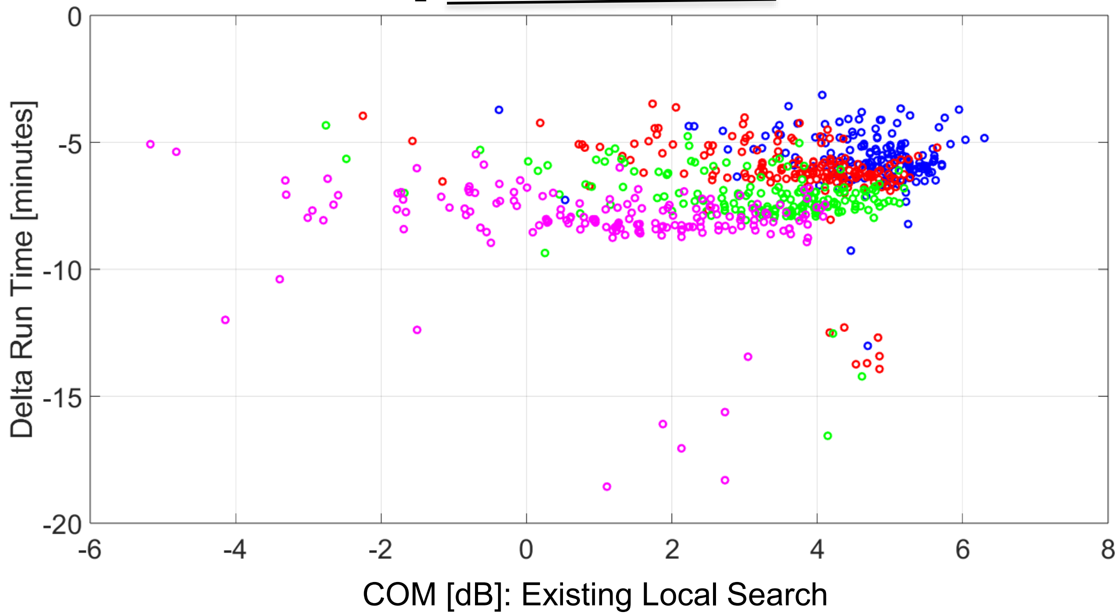
B. Without TXLE: Results on COM and Run Time

Delta= Proposed Local Search- Existing Local Search

1] **Delta COM**



2] **Delta Run Time**

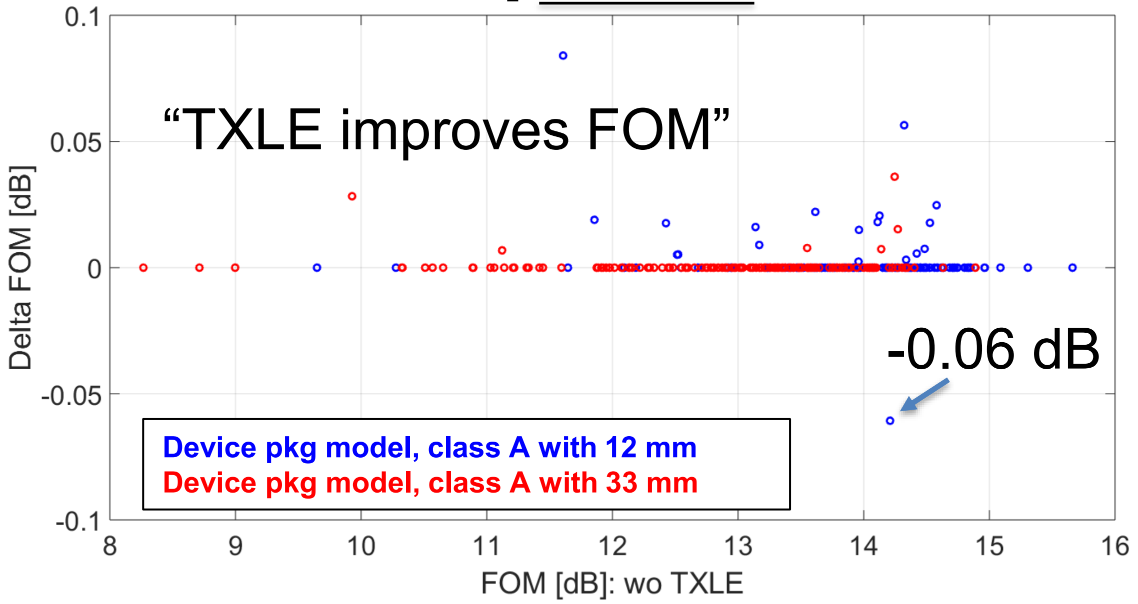


- The proposed local search achieves a significant reduction in runtime with a negligible COM degradation of less than 0.05 dB.

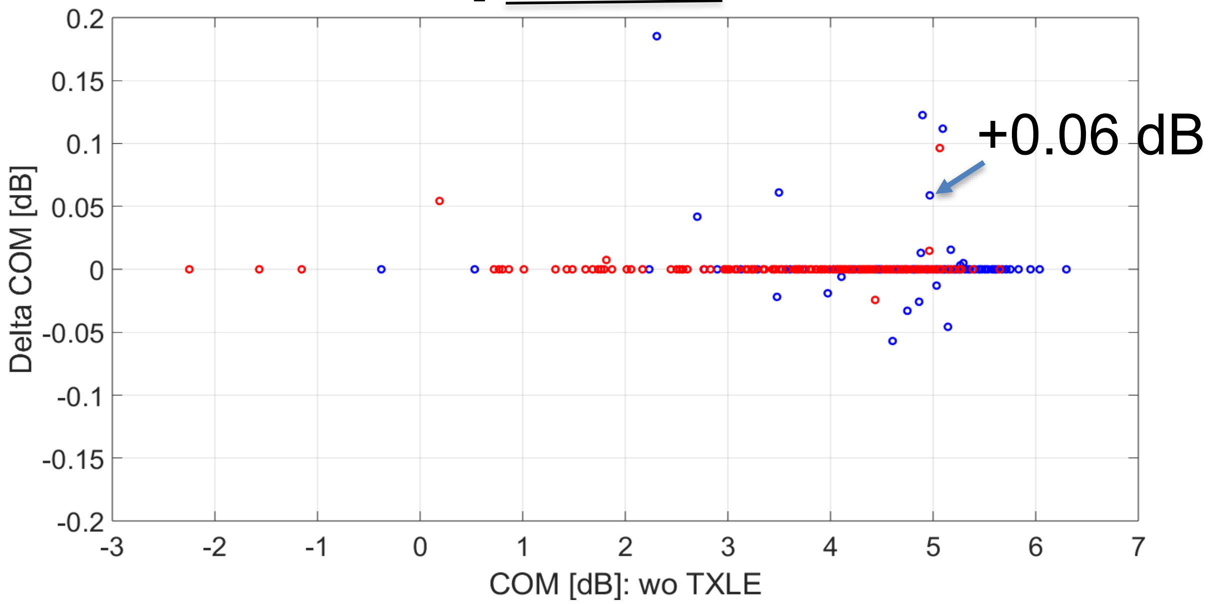
C. Without versus With TXLE: Results on FOM and COM

Delta= Proposed Local Search- Existing Local Search

1] **Delta FOM**



2] **Delta COM**

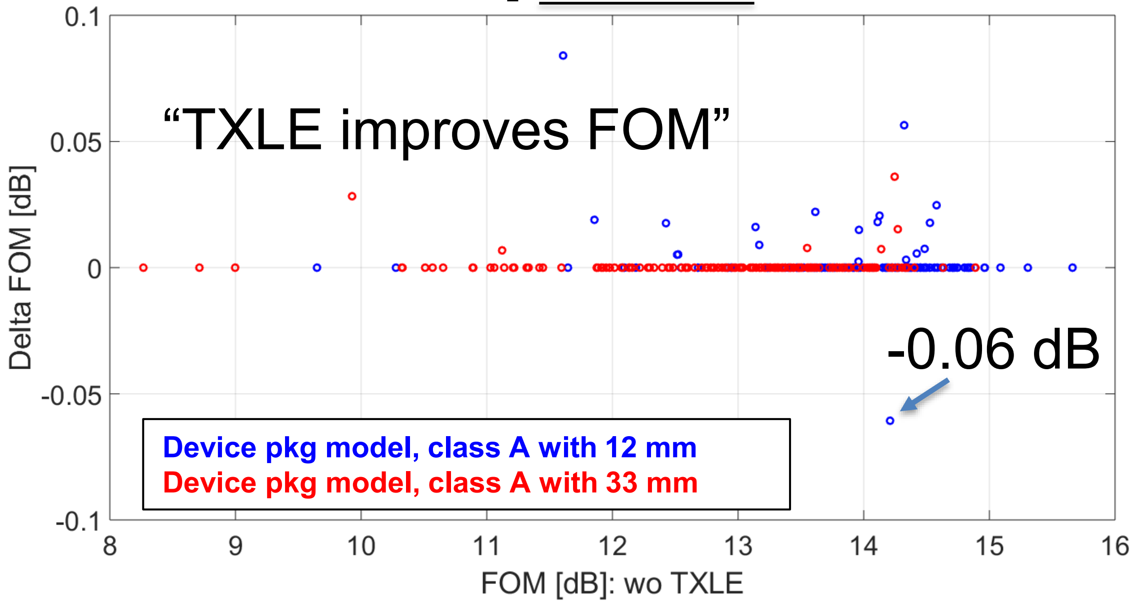


- The proposed local search enables TXLE sweep though the increase in margin is minimal.
- An action is needed in understanding the increase in FOM leading to a decrease in COM.

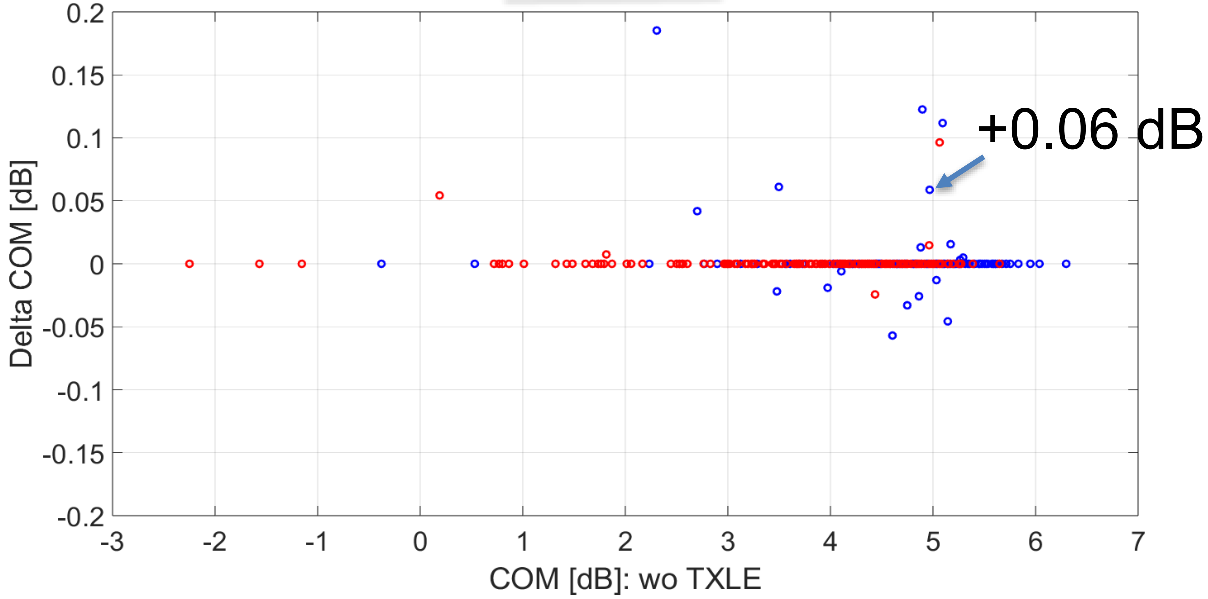
D. Without versus With TXLE: Results on FOM and COM

Delta= Proposed Local Search- Existing Local Search

1] **Delta FOM**



2] **Delta COM**



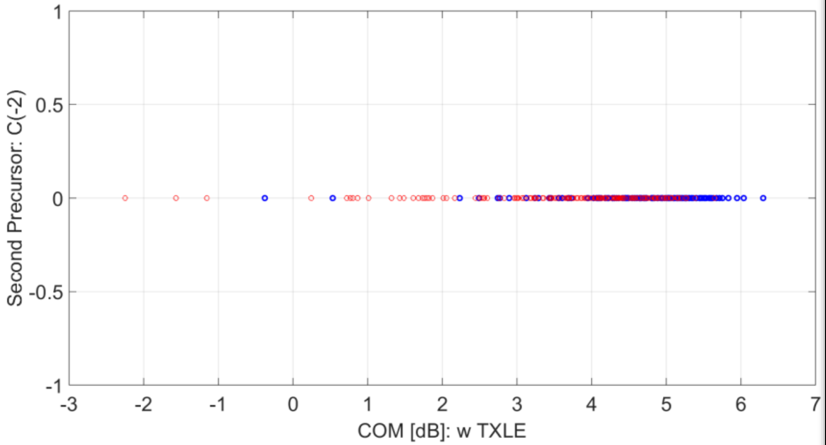
Outlier in delta FOM,

Parameter	wo TXLE	w TXLE	Delta= w TXLE- wo TXLE	TXLE chosen
FOM [dB]	14.21	14.15	-0.06	[0 -0.12 0.88 0]
COM [dB]	4.97	5.03	+0.06	

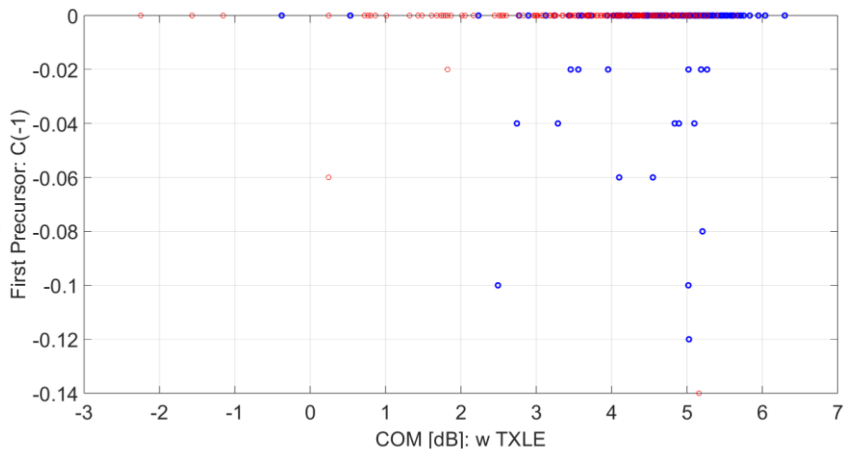
- An action is needed in understanding the increase in FOM leading to a decrease in COM.

E. Results on TXLE taps

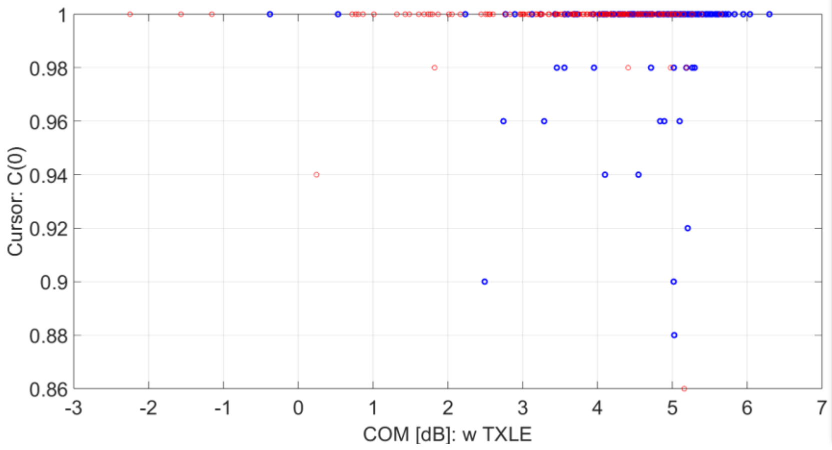
1] **Second Precursor**



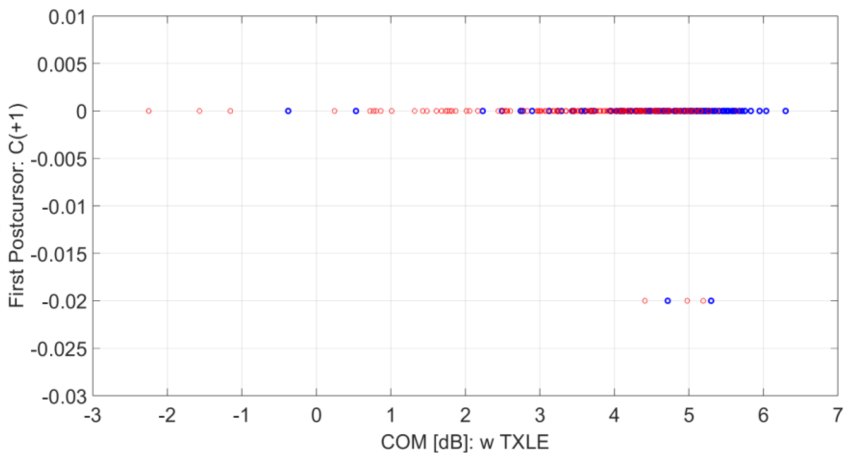
1] **First Precursor**



3] **Cursor**



4] **First Postcursor**



- The TXLE equalization is only lightly utilized across the channels.

Thank you

COM Spreadsheet for Package Class A

data rate, die load, ref impedance			
Parameter	**Setting**	**Units**	**Information**
f_b	106.25	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[0.4e-4 0.9e-4 1.1e-4 ;0.4e-4 0.9e-4 1.1e-4]	nF	[TX RX]
L_s	[0.13 0.15 0.14; 0.13 0.15 0.14]	nH	[TX RX]
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]
R_0	46.25	Ohm	
PKG_NAME	**PKG_LowR_CLASSA PKG_LowR_CLASSA**		TX RX
z_p select	[1 2]		
L	4		
M	32		
filter and Eq			
f_r	0.55	*fb	
c(0)	0.55		min
c(-1)	0	[-0.34:.02:0]	[min:step:max]
c(-2)	0	[0.14:.02:0]	[min:step:max]
c(-3)	0		[min:step:max]
c(-4)	0		[min:step:max]
c(1)	0	[-0.2:.02:0]	[min:step:max]
N_b	1	UI	
b_max(1)	0.85		As/dffe1
b_max(2..N_b)	0		not used
b_min(1)	0		As/dffe1
b_min(2..N_b)	0	S	not used
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	42.50	GHz	
f_p1	42.50	GHz	
f_p2	106.25	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	1.328125	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	0	logical
RESULT_DIR	.\results\CAKR_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	KR_pkgA_	
COM_CONTRIBUTION	0	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	ns
TR_TDR	0.005	
N	7000	logical
TDR_Butterworth	1	
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	UI
N_bx	16	??
fixture delay time	[0 0]	
Tukey_Window	1	
Z_t	46.25	
Noise, jitter		UI
sigma_RJ	0.01	UI
A_DD	0.02	V^2/GHz
eta_0	7.50E-09	dB
SNR_TX	33.5	
R_LM	0.95	
N_qb	6	
P_qc	1.00E-07	

Operational			
ERL Pass threshold	11	dB	
COM Pass threshold	3	db	
DER_0	2.00E-04		
T_r	0.00400	ns	
FORCE_TR	1	logical	for legacy but required
PMD_type	C2C	for MMSE use C2C only	
EW	1		
MLSE	1	logical	
ts_anchor	1		
sample_adjustment	[-24 24]		
Local Search	2		
flim	6.70E+10	Hz	
zero_pad	1	logical	
Filter: Rx FFE			
ffe_pre_tap_len	**6**	UI	d_w
ffe_post_tap_len	8	UI	N_fix-d_w
ffe_pre_tap1_max	0.7	(normalized)	w_max(d_w) and -w_min(d_w)
ffe_post_tap1_max	0.7	(normalized)	w_max(d_w+2) and -w_min(d_w+2)
ffe_tapn_max	0.7	(normalized)	all other fixed w_max and w_min
num_ui_RXFF_noise	4096		
Floating Tap Control			
N_bg	**2**	0 1 2 or 3 groups	N_wg
N_bf	4	taps per group	N_wf
N_f	80	UI span for floating taps	Nmax-d_w-1
bmaxg	0.05	max FFE value for floating taps	all floating w_max and w_min
N_tail_start	9	(UI) start of tail taps limit	not supposed to be used but untested
TS_SRCH_MODE	full-sweep		
Clip Method	Slow		
Non-zero Local Search Methoc	0		

SAVE_CONFIG2MAT	0	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
ICN parameters		
T_t	6.000	ps
f_v	0.371	39.42
T_ft	4.250	ps
T_nt	4.250	ps
f_f	0.524	55.65
f_n	0.524	55.65
f_1	0.010	GHz
f_2	67.000	GHz
A_ft	0.600	V
A_nt	0.600	V

Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 5.95e-4 2.6e-05]*	1.4 db/in @ 53.125G
board_tl_tau	*5.790E-03*	ns/mm
board_Z_c	92.5	Ohm
z_bp (TX)	*9*	mm
z_bp (NEXT)	*9*	mm
z_bp (FEXT)	*9*	mm
z_bp (RX)	*9*	mm
C_0	[0 0]	nF
C_1	[0 0]	nF
Include PCB	**0**	**logical**

<u>Note</u>.
Set Clip Method to “slow”
Set TS_SRCH_MODE to “full-sweep”
Set sample_adjustment to “[-24 24]”
Toggle “Non-zero Local Search Method” to 0 or 1.

.START	PKG_LowR_CLASSA		
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[0.0005 0.00089 0.0002]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	[87.5 87.5 ; 95 95 ; 100 100; 100 100]	Ohm	
R_d	[46.25 46.25]	Ohm	[TX RX]
z_p (TX)	[12 33 33 33 ; 1.8 1.8 1.8 1.8 ; 0 0 0 0 ; 0 0 0 0]	mm	[test cases]
z_p (NEXT)	[12 33 33 33 ; 1.8 1.8 1.8 1.8 ; 0 0 0 0 ; 0 0 0 0]	mm	[test cases]
z_p (FEXT)	[12 33 33 33 ; 1.8 1.8 1.8 1.8 ; 0 0 0 0 ; 0 0 0 0]	mm	[test cases]
z_p (RX)	[12 33 33 33 ; 1.8 1.8 1.8 1.8 ; 0 0 0 0 ; 0 0 0 0]	mm	[test cases]
C_p	[0.4e-4 0.4e-4]	nF	[TX RX]
A_v	0.385	V	Vf=0.400
A_fe	0.385	V	Vf=0.399
A_ne	0.481	V	Vf=0.400
.END			

COM Spreadsheet for Package Class B

data rate, die load, ref impedance			
Parameter	Setting	Units	Information
f_b	106.25	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[0.4e-4 0.9e-4 1.1e-4 ;0.4e-4 0.9e-4 1.1e-4]	nF	[TX RX]
L_s	[0.13 0.15 0.14; 0.13 0.15 0.14]	nH	[TX RX]
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]
R_0	46.25	Ohm	
PKG_NAME	PKG_HiR_CLASSB PKG_HiR_CLASSB		TX RX
z_p select	[3 4]		
L	4		
M	32		
filter and Eq			
f_r	0.55	*fb	
c(0)	0.55		min
c(-1)	0	[-0.34:.02:0]	[min:step:max]
c(-2)	0	[0.14:.02:0]	[min:step:max]
c(-3)	0		[min:step:max]
c(-4)	0		[min:step:max]
c(1)	0	[-0.2:.02:0]	[min:step:max]
N_b	1	UI	
b_max(1)	0.85		As/dffe1
b_max(2..N_b)	0		not used
b_min(1)	0		As/dffe1
b_min(2..N_b)	0	S	not used
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	42.50	GHz	
f_p1	42.50	GHz	
f_p2	106.25	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	1.328125	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\CAKR_{date}\	
SAVE_FIGURES	1	logical
Port Order	[1 3 2 4]	
RUNTAG	KR_pkgB_	
COM_CONTRIBUTION	0	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	ns
TR_TDR	0.005	
N	7000	logical
TDR_Butterworth	1	
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	UI
N_bx	15	??
fixture delay time	[0 0]	
Tukey_Window	1	
Z_t	46.25	
Noise, jitter		UI
sigma_RJ	0.01	UI
A_DD	0.02	V^2/GHz
eta_0	7.50E-09	dB
SNR_TX	33.5	
R_LM	0.95	
N_qb	6	
P_qc	1.00E-07	

Operational			
ERL Pass threshold	11	dB	
COM Pass threshold	3	db	
DER_0	2.00E-04		
T_r	0.00400	ns	
FORCE_TR	1	logical	
PMD_type	C2C		
EW	1		
MLSE	1	logical	
ts_anchor	1		
sample_adjustment	[-24 24]		
Local Search	2		
flim	6.70E+10	Hz	
zero_pad	1	logical	
Filter: Rx FFE			
ffe_pre_tap_len	**6**	UI	d_w
ffe_post_tap_len	8	UI	N_fix-d_w
ffe_pre_tap1_max	0.7	(normalized)	w_max(d_w) and -w_min(d_w)
ffe_post_tap1_max	0.7	(normalized)	w_max(d_w+2) and -w_min(d_w+2)
ffe_tapn_max	0.7	(normalized)	all other fixed w_max and w_min
num_ui_RXFF_noise	4096		
Floating Tap Control			
N_bg	**2**	0 1 2 or 3 groups	N_wg
N_bf	4	taps per group	N_wf
N_f	80	UI span for floating taps	Nmax-d_w-1
bmaxg	0.05	max FFE value for floating taps	all floating w_max and w_min
N_tail_start	9	(UI) start of tail taps limit	not supposed to be used but untested
TS_SRCH_MODE	full-sweep		
Clip Method	Slow		
Non-zero Local Search Method	0		

SAVE_CONFIG2MAT	0	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
ICN parameters		
T_t	6.000	ps
f_v	0.371	39.42
T_ft	4.250	ps
T_nt	4.250	ps
f_f	0.524	55.65
f_n	0.524	55.65
f_1	0.010	GHz
f_2	67.000	GHz
A_ft	0.600	V
A_nt	0.600	V

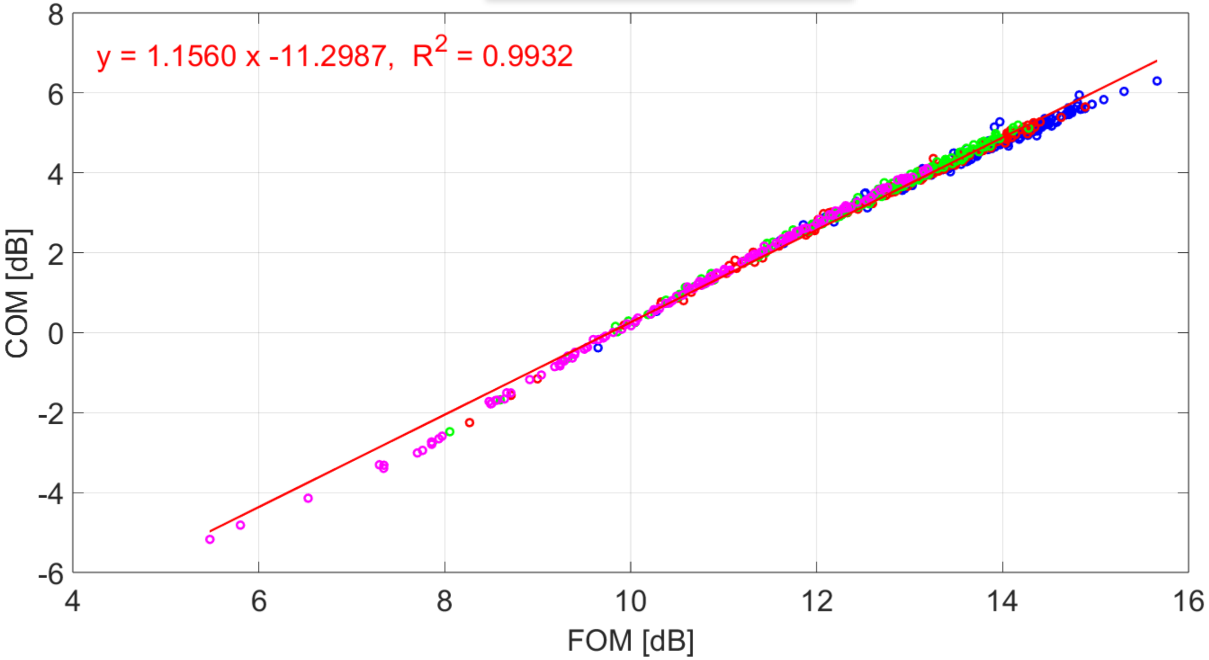
Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 5.95e-4 2.6e-05]*	1.4 db/in @ 53.125G
board_tl_tau	*5.790E-03*	ns/mm
board_Z_c	92.5	Ohm
z_bp (TX)	*60*	mm
z_bp (NEXT)	*60*	mm
z_bp (FEXT)	*60*	mm
z_bp (RX)	*60*	mm
C_0	[0 0]	nF
C_1	[0 0]	nF
Include PCB	**0**	**logical**

<u>Note</u>.
Set Clip Method to "slow"
Set TS_SRCH_MODE to "full-sweep"
Set sample_adjustment to "[-24 24]"
Toggle "Non-zero Local Search Method" to 0 or 1.

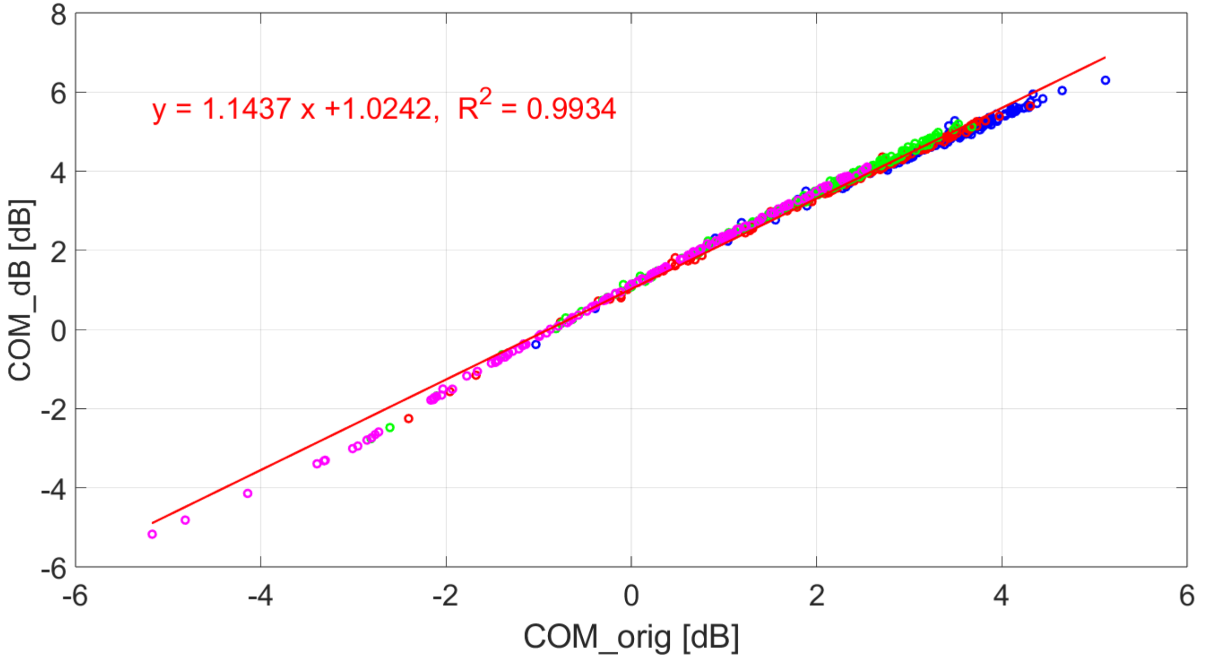
.START	PKG_HiR_CLASSB		
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[0.0005 0.00065 0.000293]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	[87.5 87.5 ; 95 95 ; 100 100; 78 78]	Ohm	
R_d	[46.25 46.25]	Ohm	[TX RX]
z_p (TX)	[8 24 30 45 ; 2 2 2 2; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (NEXT)	[8 24 29 44 ; 2 2 2 2; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (FEXT)	[8 24 30 45 ; 2 2 2 2; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (RX)	[8 24 29 44 ; 2 2 2 2; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
C_p	[0.4e-4 0.4e-4]	nF	[TX RX]
A_v	0.385	V	Vf=0.400
A_fe	0.385	V	Vf=0.399
A_ne	0.481	V	Vf=0.400
.END			

COM_dB, COM_orig and FOM

1] **COM versus FOM**



2] **COM versus COM_orig**



Knobs of Adaptive Local Search

- **min_improvement_threshold= 0.002**
  - Purpose: Distinguish real improvements from noise.
  - If too low: We widen on noise. If too high: we miss real progress.
  - Rule of thumb: Set ≈ 1-2x the short-term FOM noise.

- **adpatation_window= 2**
  - Purpose: How many recent points to judge progress.
  - If smaller: fast reaction, jittery. If larger: stable, slower to adapt.
  - Rule of thumb: 2-5 depending on how noisy FOM is.

- **radius_shrink_factor= 0.60**
  - Purpose: How aggressively we shrink on stalls.
  - If smaller: very aggressive, skips good neighbors. If larger: gentle, may waste time
  - Rule of thumb: 0.5-0.8.

- **deterministic_shrink_factor = 0.15**
  - Purpose: Guarantees endgame tightening over time.
  - Rule of thumb: Choose rate r such that after N iterations
  - LocalSearch_Value/ (1+r*N)≈ min_radius.
  - Example, If LSV= 3, min= 1 and N=30 then r ≈ (3/1- 1)/30≈ 0.067.

- **min_radius= 1**
  - Purpose: Ensured we always do a minimal local check.
  - If >1: Might miss exact/ near matches. If 0: Not meaningful.
- **edge_weight= 1.0**
  - Purpose: Importance of street (tap) differences.

- **lp_weight= 0.25**
  - Purpose: Garden Importance (LP).

- **l2_to_l1_ratio= 0.55**
  - Purpose: Safety rule: skip only if far in both L1 and L2.
  - Rule of thumb: For d dimensions, L2≈ L1/ (d^0.5) on random offsets. 0.4-0.7 works well.

- **use_hard_cap= true, hard_cap_multiplier= 1.2**
  - Purpose: Instant reject if raw L1 is way beyond the starting radius.
  - Rule of thumb: 1.0-1.5. Lower= stricter; higher= more exploratory.