Comparison of different options to account for
- ADC Quantization Noise and
- MLSE Implementation Penalty

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Overview

- Different options were presented so far in 802.3 dj in Electrical track to account for impact from ADC quantization noise and MLSE implementation penally

  ADC Quantization Noise consideration
  - Adjust Input reference noise ETA_0 parameter in COM
  - Include a separate parameter like ENOB in COM
  - See presentation(s)
    - Budgeting for receiver noise in Channel Operating Margin (COM)
    - Significance of including Quantization Noise in COM Evaluation

  MLSE Implementation Penalty Consideration
  - Arbitrary limit on MLSE benefit like 1dB max
  - MLSE sequence truncation as a way to account for Implementation penalty
  - Account for incomplete receiver impairments in COM_{DFE} and adjust ΔCOM
  - See presentation(s)
    - MLSE Sequence Truncation Implementation Penalty
    - Modification to the calculation of COM for an MLSD reference receiver
- Include and/or Compare these options in CR/KR channel analysis

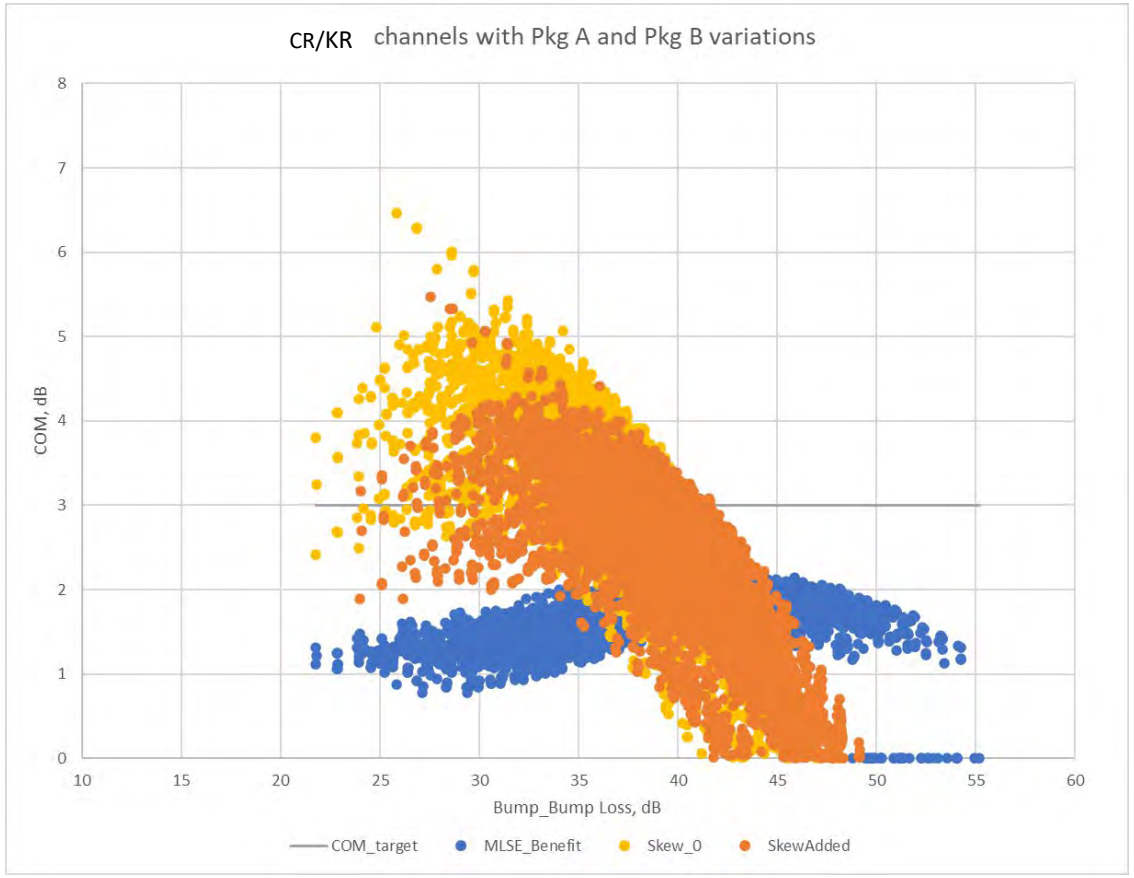
Compare ADC Quantization Noise Options

ADC Quantization Noise – Option1: Adjust ETA_0

Config: 5 from kareti_3dj_01_2407 **phase 2 settings**
Package Combination: **BB**
Eta_0 is set to 1e-8 v²/GHz
g_DC is set to 0.
COM version: 4.6 beta 4
Receiver

- Num of RX FFE pre-cursors : 6
- Num of RX FFE fixed post cursors : 8
- Number of banks of floating up to 100 UI: 3

**Max Tolerable Skew cases included but separated the stats.*



1 tap DFE (No MLSE)

Loss Range /number of COM failures -- Loss Range: 21.7672 : 55.1644					
<=24	6	**24-32**	157	**32-40**	2651
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	5	108	49	1447	1204

>40	3887
Skew_Added	Skew_0
2438	1449

MLSE - No Limit Placed

Loss Range /number of COM failures -- Loss Range: 21.7672 : 55.1644					
<=24	0	**24-32**	0	**32-40**	66
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
0	0	0	0	32	34

>40	1753
Skew_Added	Skew_0
1055	698

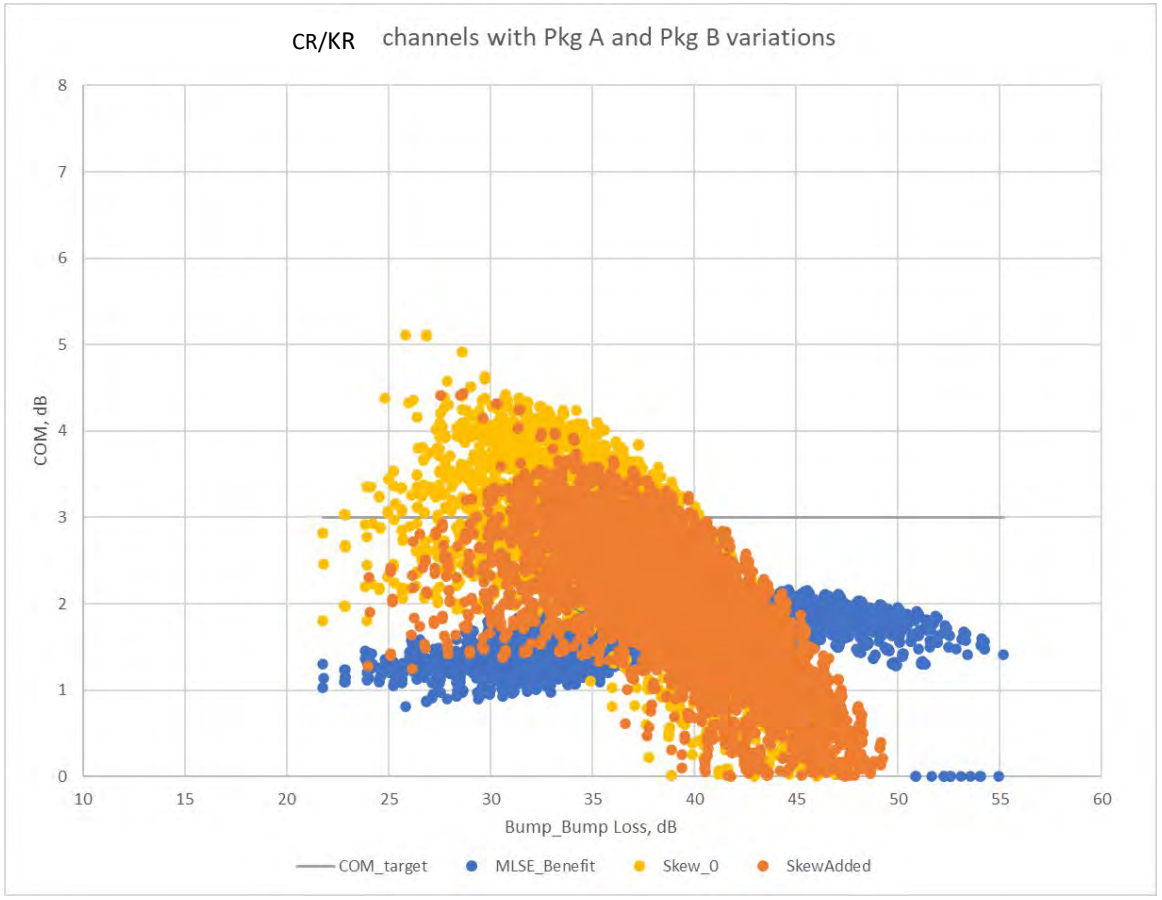
MLSE with max benefit limited to 1 dB

Loss Range /number of COM failures -- Loss Range: 21.7672 : 55.1644					
<=24	1	**24-32**	2	**32-40**	428
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	0	2	0	247	181

>40	3056
Skew_Added	Skew_0
1894	1162

Total#cases	10678	8832	1846	1630	9048
Cases <40 dB	6735	Cabled Host	PCB Host	CR	KR

ADC Quantization Noise – Option2: Add a separate Parameter (ENOB)



Config: 5 from kareti_3dj_01_2407 phase 2 settings
Package Combination: **BB**
Eta_0 is set to 4.1e-9 v²/GHz
g_DC is set to adapt (max limited to -20 dB).
COM version: 4.6 beta 4 with code update from Hossein Shakiba with a parameter ENOB added and set to 6
Receiver

- Num of RX FFE pre-cursors : 6
- Num of RX FFE fixed post cursors : 8
- Number of banks of floating up to 100 UI: 3

**Max Tolerable Skew cases included but separated the stats.*

1 tap DFE (No MLSE)

Loss Range /number of COM failures -- Loss Range: 21.7672 : 55.1644					
<=24	13	**24-32**	510	**32-40**	4098
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	12	240	270	2176	1922

>40	3936
Skew_Added	Skew_0
2472	1464

MLSE - No Limit Placed

Loss Range /number of COM failures -- Loss Range: 21.7672 : 55.1644					
<=24	1	**24-32**	23	**32-40**	186
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	0	23	0	112	74

>40	1886
Skew_Added	Skew_0
1167	719

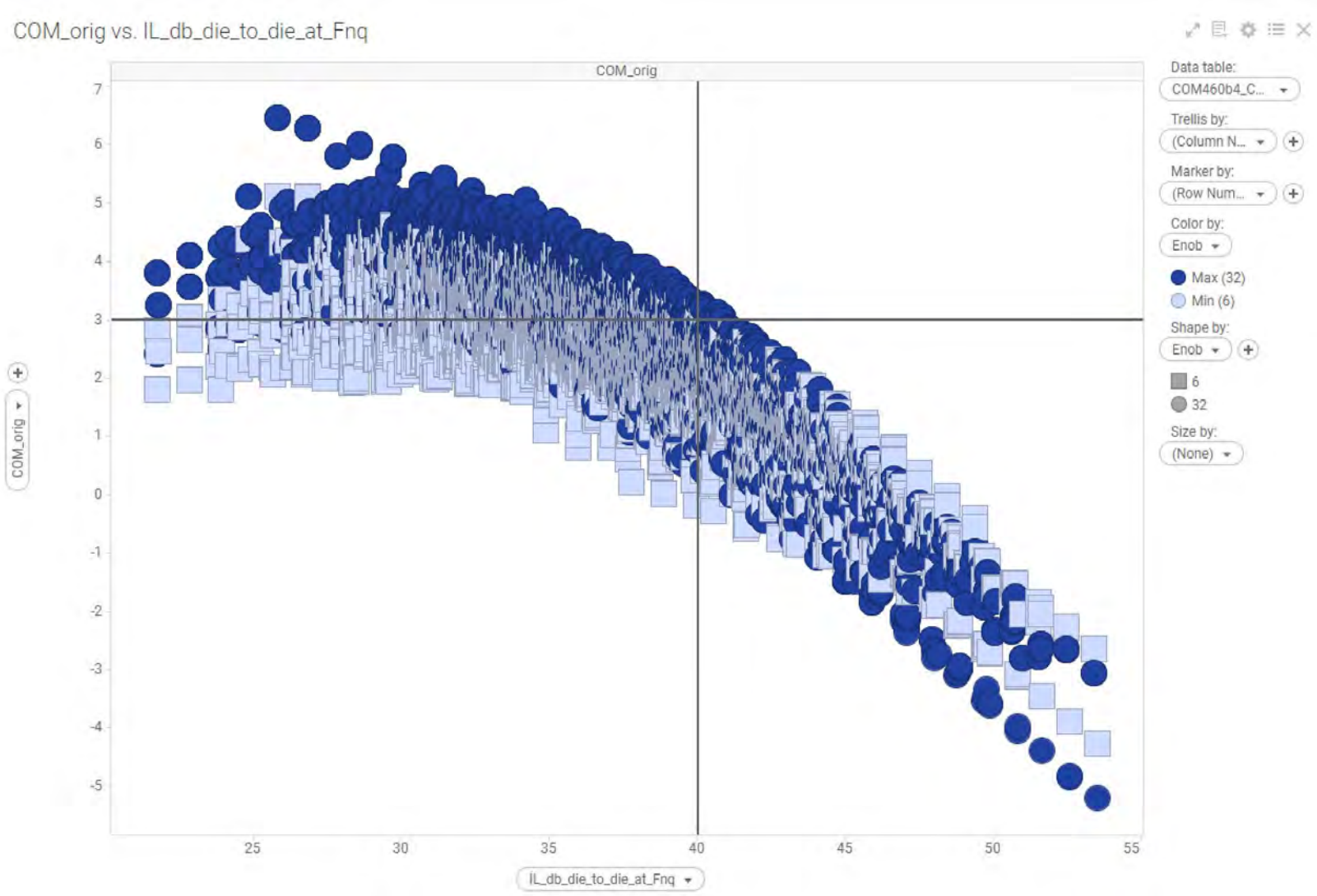
MLSE with max benefit limited to 1 dB

Loss Range /number of COM failures -- Loss Range: 21.7672 : 55.1644					
<=24	5	**24-32**	80	**32-40**	1105
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	4	71	9	712	393

>40	3309
Skew_Added	Skew_0
2086	1223

Total#cases	10678	8832	1846	1630	9048
Cases <40 dB	6735	Cabled Host	PCB Host	CR	KR

ADC Quantization Noise – Comparison of Option1 and Option2: COM_DFE (No MLSE)



ADC Quantization Noise – Comparison of Option1 and Option2: COM_DFE (No MLSE)

COM_orig per COM_orig and Enob, IL_db_die_to_die_at_Fnq

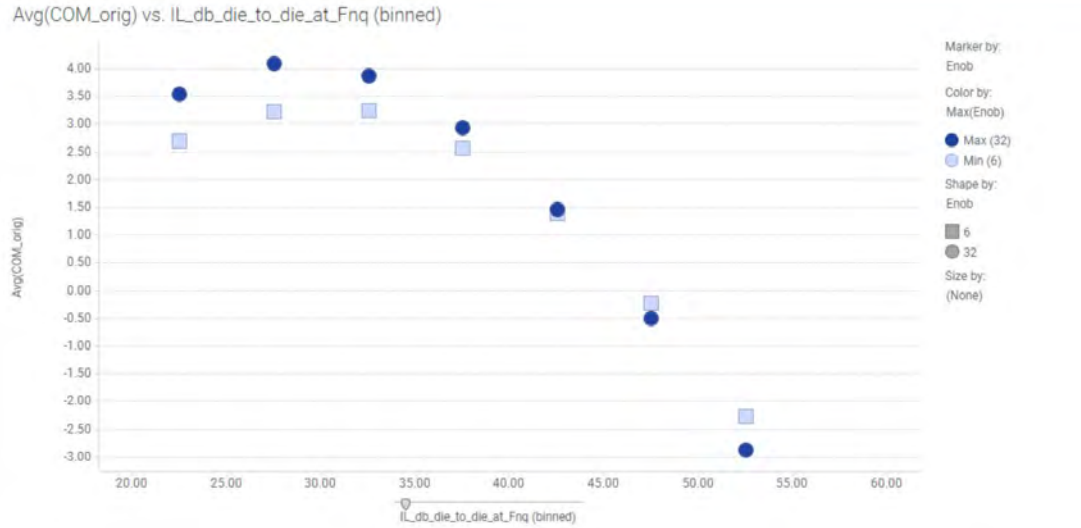
Enob | IL_db_die_to_die_at_Fnq (binned)

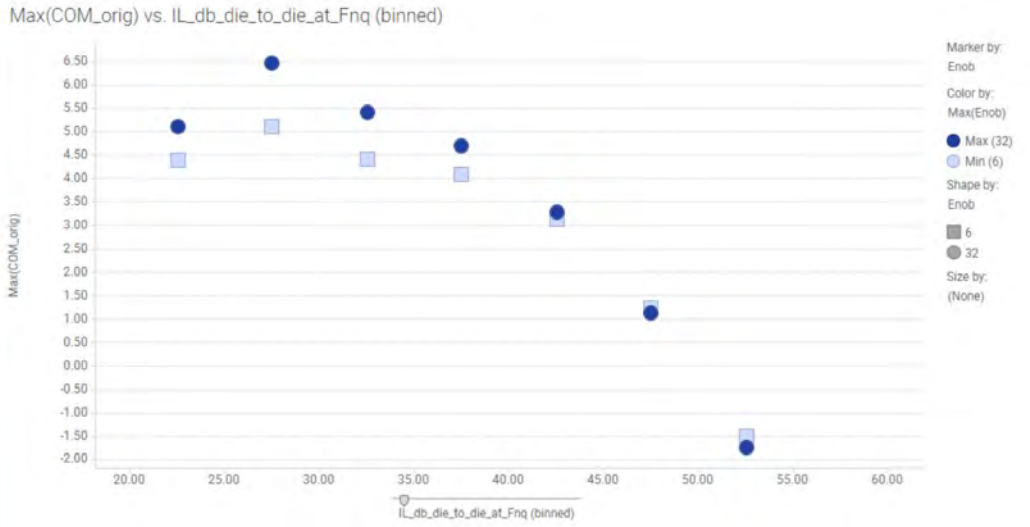
COM_orig (binned)	6		32		Grand total
	20.00 ≤ x < 40...	40.00 ≤ x < 60...	20.00 ≤ x < 40...	40.00 ≤ x < 60...	
-6.00 ≤ x < -4.00	-	1	-	5	6
-4.00 ≤ x < -2.00	-	20	-	38	58
-2.00 ≤ x < 0.00	1	226	-	225	452
0.00 ≤ x < 2.00	405	976	181	894	2456
2.00 ≤ x < 4.00	3284	248	2704	309	6545
4.00 ≤ x < 6.00	178	-	979	-	1157
6.00 ≤ x < 8.00	-	-	4	-	4
Grand total	3868	1471	3868	1471	10678

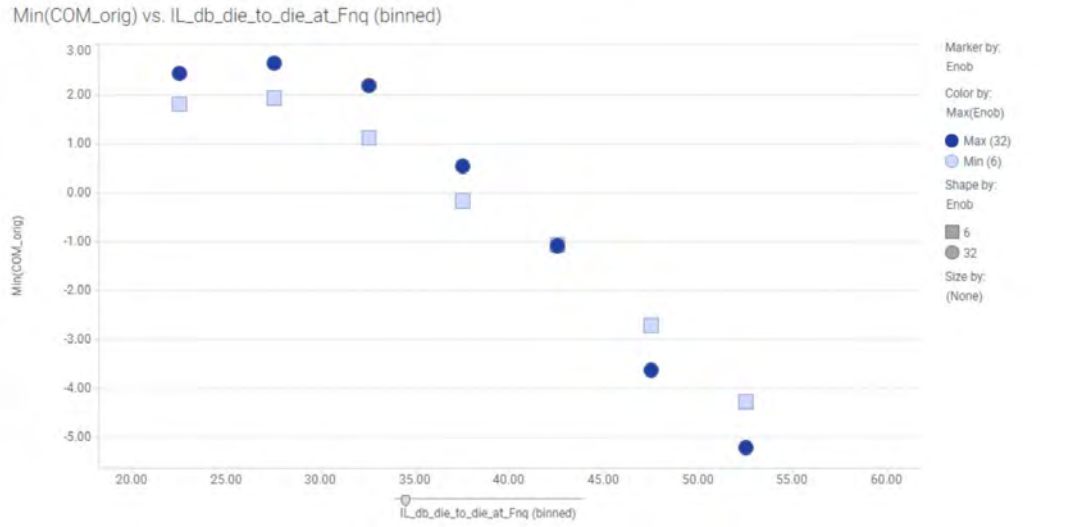
COM_orig (binned)

Count(COM_orig)

Colors: All values







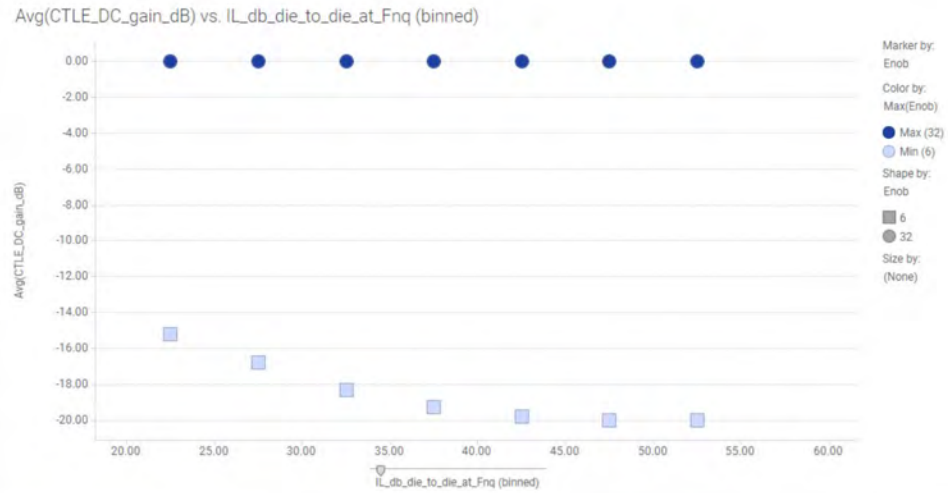
ADC Quantization Noise – Comparison of Option1 and Option2: g_DC

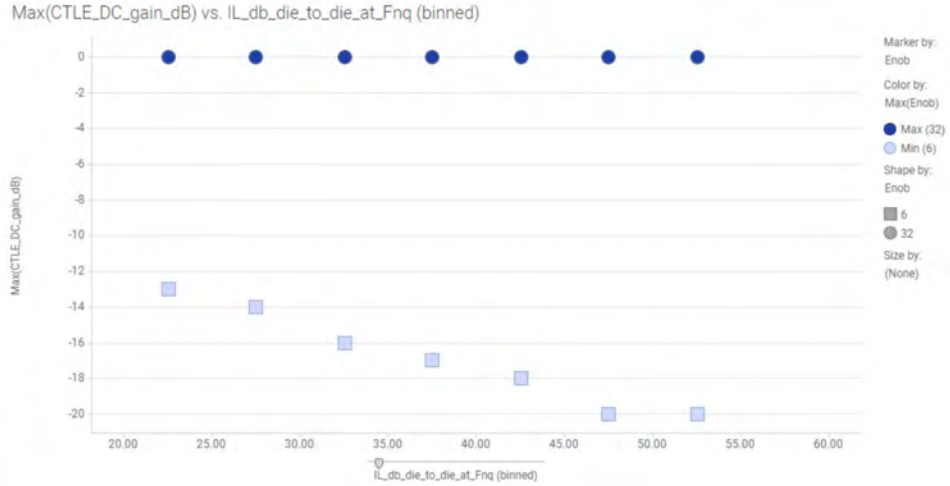
COM_orig per CTLE_DC_gain_dB and Enob, IL_db_die_to_die_at_Fnq

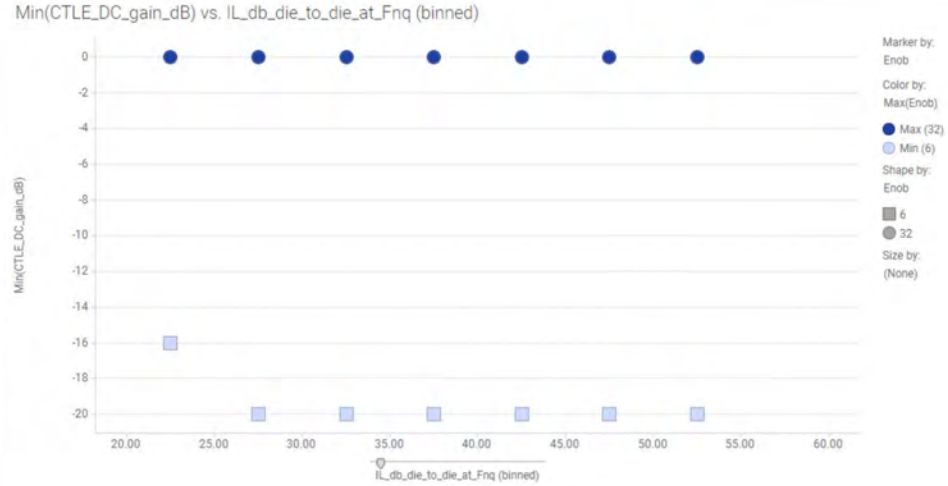
Enob | IL_db_die_to_die_at_Fnq (binned)

	6		32		
CTLE_DC_gain_dB	20.00 ≤ x < 40...	40.00 ≤ x < 60...	20.00 ≤ x < 40...	40.00 ≤ x < 60...	Grand total
-20	950	1204	-	-	2154
-19	1554	261	-	-	1815
-18	800	6	-	-	806
-17	384	-	-	-	384
-16	120	-	-	-	120
-15	51	-	-	-	51
-14	8	-	-	-	8
-13	1	-	-	-	1
0	-	-	3868	1471	5339
Grand total	3868	1471	3868	1471	10678

Count(COM_orig)







ADC Quantization Noise Options Summary

- Comparison shows COM may have some deviation at low loss cases and aligns around 40 dB loss and slight deviation >40 dB loss cases
- While using g_DC max range is limited to -20 dB. Extending this range may close the gap a little.
- Simulation time : Option 2 which needs exhaustive search in optimization takes about 20 times more time per channel compared to simulation time for Option 1(for computational advantage g_DC is set to 0 as RXFFE takes the burden which results in the same COM value.)
  - Option1 : 0.9 min – 38 min (average 20 min)
  - Option2 : 25 min – 17 hrs. (average 10 hours)
- **Option1: using ETA_0 is a reasonable compromise than using Option 2: introducing a separate parameter to account for ADC quantization noise**

Include MLSE Implementation Penalty Considerations

MLSE Implementation Penalty- Options: Arbitrary limit vs Seq. truncation

MLSE - No Limit Placed ; trunc: 128

Loss Range /number of COM failures -- Loss Range: 21.7672 : 55.1644							
<=24	0	**24-32**	0	**32-40**	66	**>40**	1753
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
0	0	0	0	32	34	1055	698

MLSE with max benefit limited to 1 dB; trunc: 128

Loss Range /number of COM failures -- Loss Range: 21.7672 : 55.1644							
<=24	1	**24-32**	2	**32-40**	428	**>40**	3056
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	0	2	0	247	181	1894	1162

MLSE - No Limit Placed; trunc:15

Loss Range /number of COM failures -- Loss Range: 21.7672 : 54.244							
<=24	0	**24-32**	0	**32-40**	91	**>40**	1995
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
0	0	0	0	51	40	1235	760

MLSE - No Limit Placed; trunc: 12

Loss Range /number of COM failures -- Loss Range: 21.7672 : 54.244							
<=24	0	**24-32**	0	**32-40**	151	**>40**	2463
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
0	0	0	0	90	61	1557	906

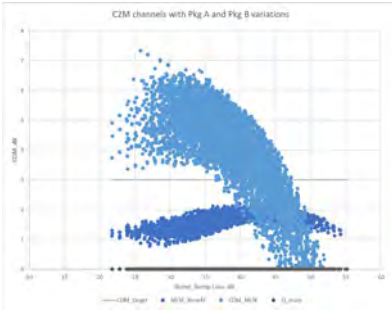
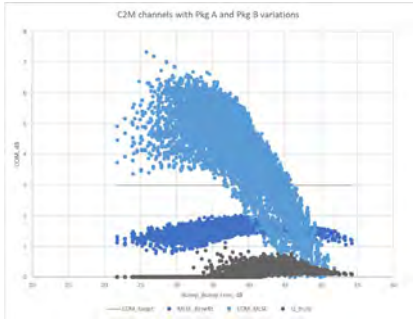
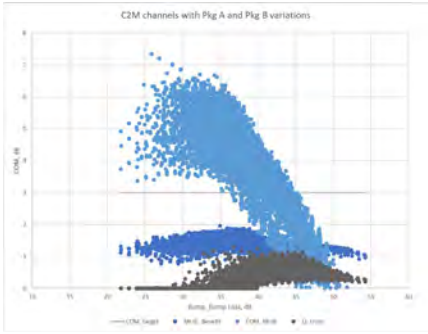
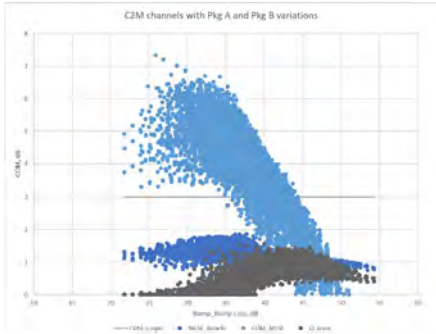
MLSE - No Limit Placed; trunc:10

Loss Range /number of COM failures -- Loss Range: 21.7672 : 54.244							
<=24	0	**24-32**	0	**32-40**	281	**>40**	2932
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
0	0	0	0	169	112	1846	1086

Config: 5 from kareti_3dj_01_2407 phase 2 settings
Package Combination: **BB**
Eta_0 is set to 1e-8 v^2/GHz
g_DC is set to 0.
COM version: 4.6 beta 4 with a code update from Hossein Shakiba with a parameter "trunc" added and is set a values 10,12 or 15 (a value of 128 represent no sequence truncation)
Receiver

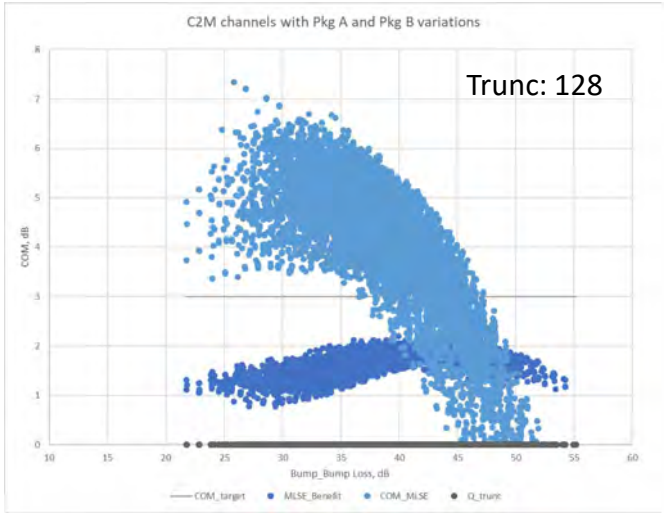
- Num of RX FFE pre-cursors : 6
- Num of RX FFE fixed post cursors : 8
- Number of banks of floating up to 100 UI: 3

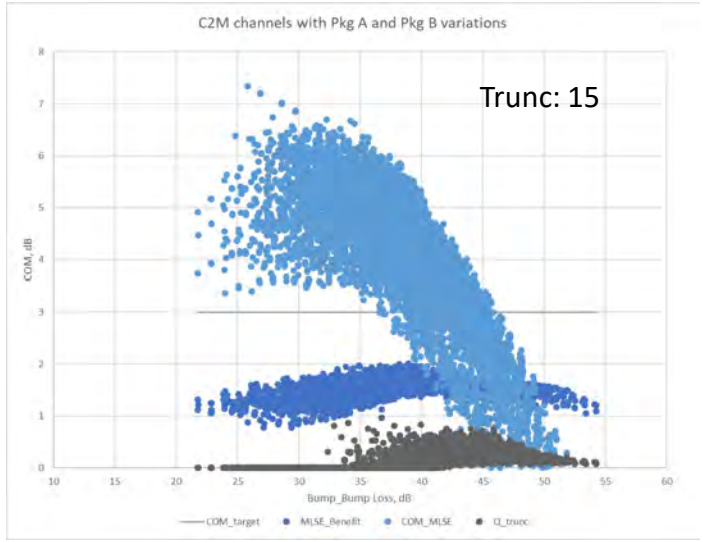
**Max Tolerable Skew cases included but separated the stats.*

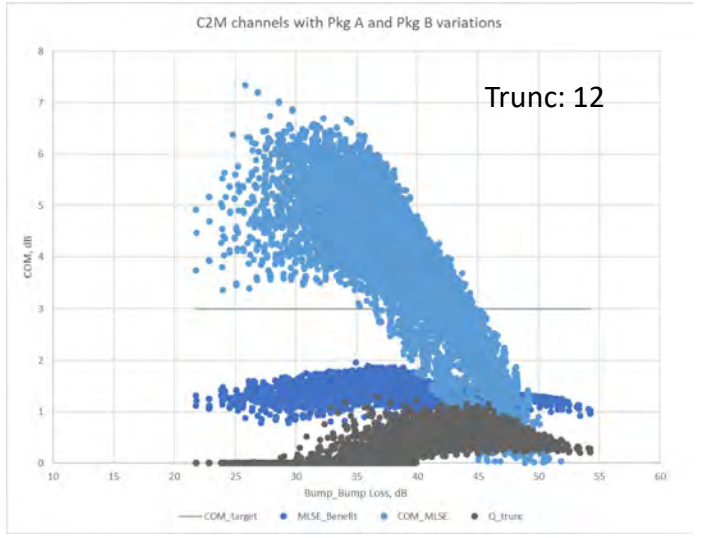





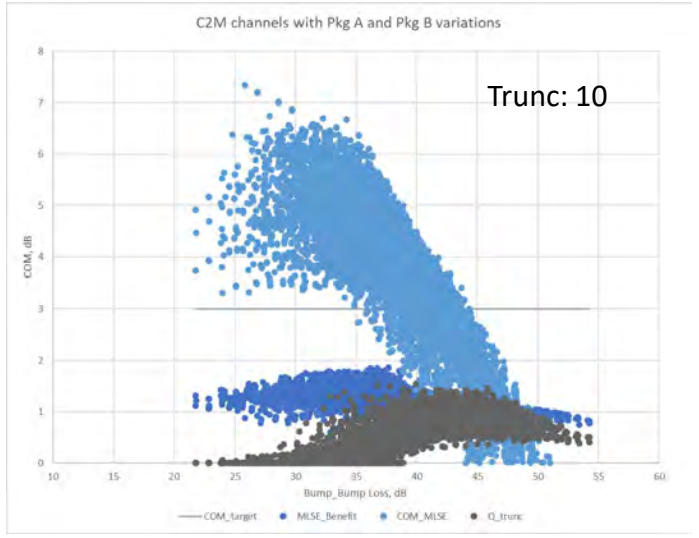
MLSE Implementation Penalty-Options: Arbitrary limit vs Seq. truncation

- Most implementations concerned about complexity and latency of MLSE implementation limit Sequence processing and trace back length to minimum of 15 symbols
- Using trunc = 15 for this analysis and compared with other trunc options 10 , 12 and limiting MLSE benefit to 1 dB
- Q_trunc in the plot shows the penalty compared to No implementation penalty case (trunc = 128)





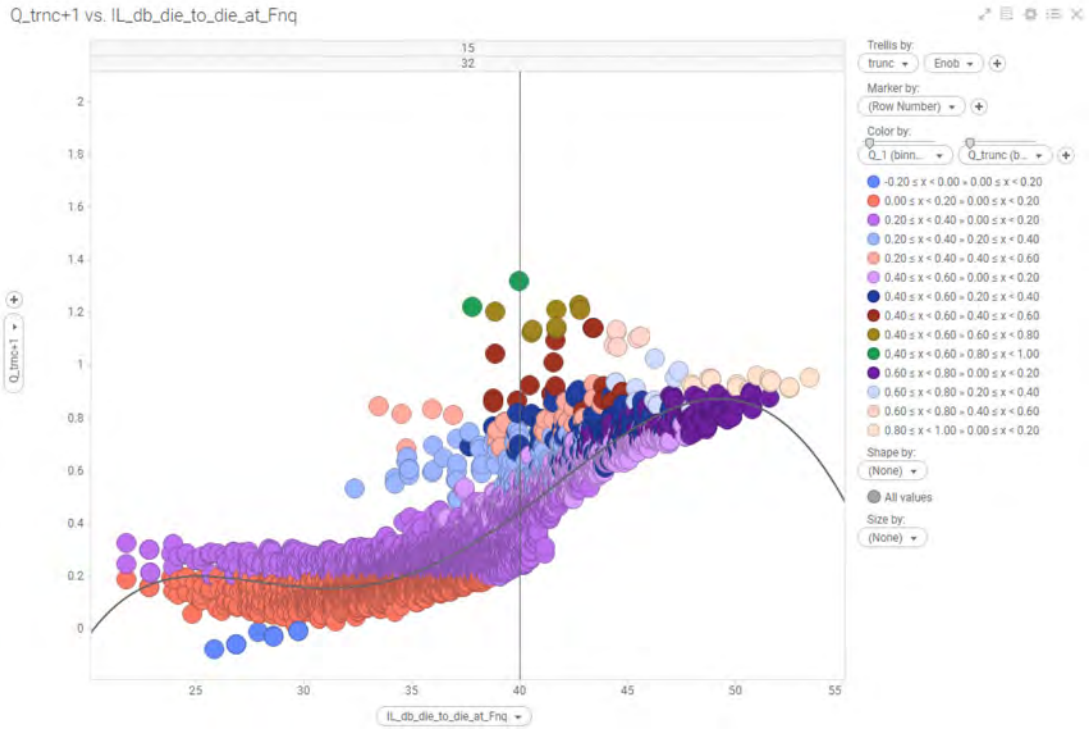




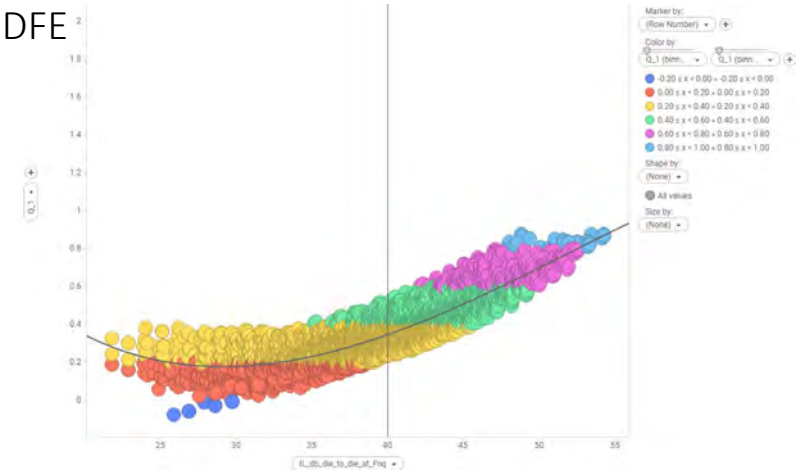
MLSE Implementation Penalty – Adjustments to ΔCOM

-Consideration of Incomplete receiver impairments in COM_{DFE}

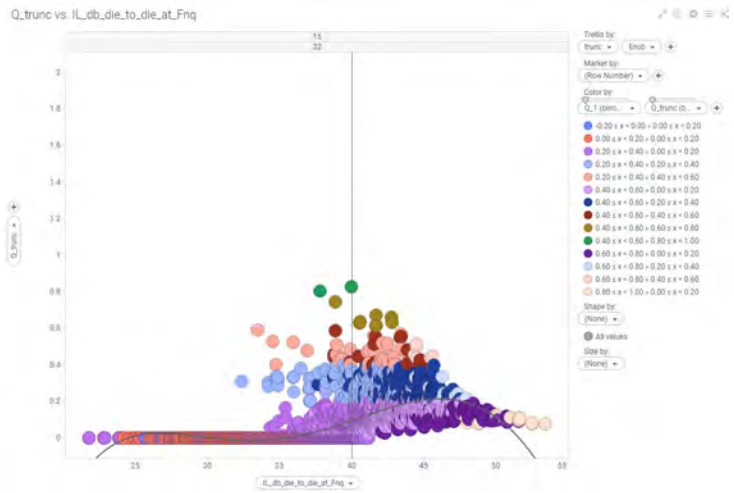
- Three different ways of introducing noise terms presented in Modification to the calculation of COM for an MLSD reference receiver and their respective trends are identified in slide 6. All these trends are evaluated but sharing analysis from the most conservative results approach



Penalties from both seq. truncation with trunc=15 and Incomplete Receiver impairment adjustments

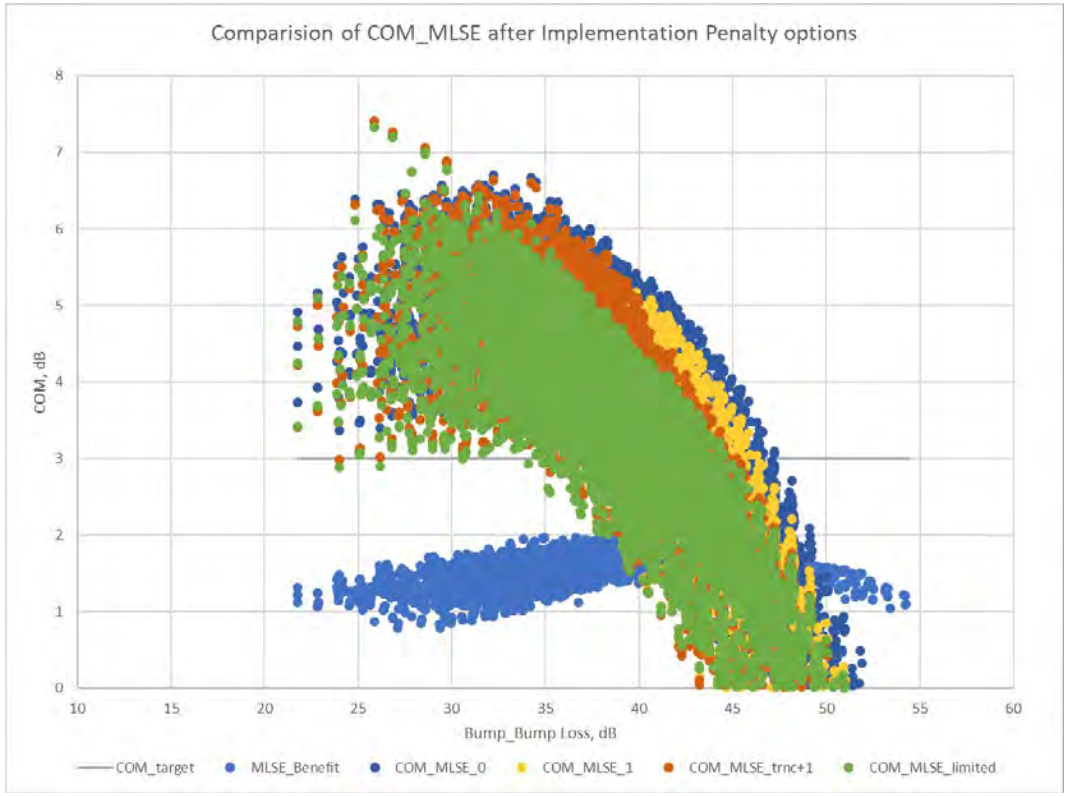


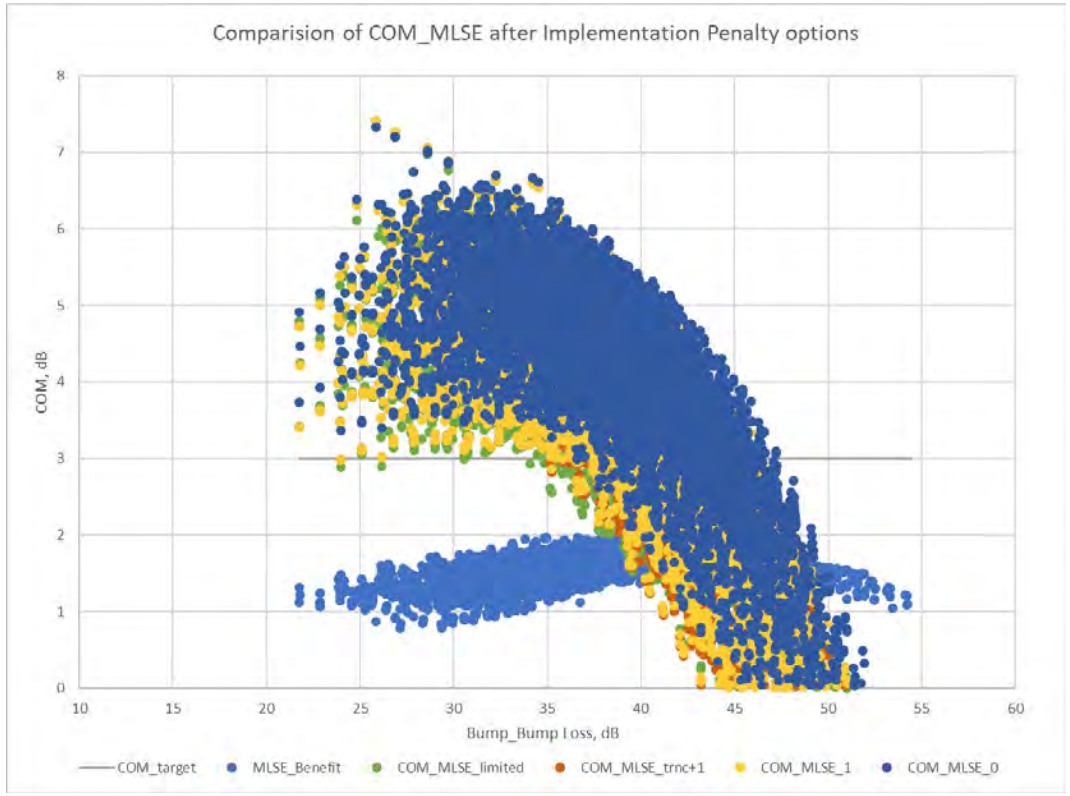
Penalty from Incomplete Receiver impairment adjustment



Penalties from seq. truncation with trunc=15

MLSE Implementation Penalty –comparison of impact on CR/KR channels





MLSE Implementation Penalty –comparison of impact on CR/KR channels

1 tap DFE (No MLSE)

Loss Range /number of COM failures -- Loss Range: 21.7672 : 54.244							
<=24	6	**24-32**	157	**32-40**	2651	**>40**	3832
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	5	108	49	1447	1204	2403	1429

MLSE - No Limit Placed

Loss Range /number of COM failures -- Loss Range: 21.7672 : 54.244							
<=24	0	**24-32**	0	**32-40**	91	**>40**	1995
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
0	0	0	0	51	40	1235	760

Number unique channels (No skew added) failed COM 3 dB with loss <=40dB : 8

MLSE with max benefit limited to 1 dB

Loss Range /number of COM failures -- Loss Range: 21.7672 : 54.244							
<=24	1	**24-32**	2	**32-40**	428	**>40**	3001
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	0	2	0	247	181	1859	1142

Number unique channels (No skew added) failed COM 3 dB with loss <=40dB : 38

MLSE - with Implentation panalties(both)

Loss Range /number of COM failures -- Loss Range: 21.7672 : 54.244							
<=24	1	**24-32**	0	**32-40**	231	**>40**	2608
Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0	Skew_Added	Skew_0
1	0	0	0	134	97	1634	974

Number unique channels (No skew added) failed COM 3 dB with loss <=40dB : 20

MLSE Implementation Penalty Options Summary

- Arbitrary limit to MLSE benefit is not a reasonable option as shown in analysis
- Increase in COM computation time per case is almost negligible when Seq. truncation code is added to COM code.
- Using sequence truncation method and seq. truncation of 15 PAM4 symbols since most implementations concerned about complexity and latency use it as a minimum and **recommend this option to include for MLSE Implementation Penalty**
- **Analysis is shared to include MLSE Implementation penalties both from Seq. truncation and Adjustments to incomplete accounting of receiver impairments**